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STRATIGRAPHY AND COAL RESOURCE POTENTIAL OF THE UPPER CRETACEOUS TO TERTIARY STRATA OF NORTHWESTERN ALBERTA

F.M. Dawson, W.D. Kalkreuth and A.R. Sweet

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PREFACE

Western Canada contains vast resources of coal, much of which has not been studied in any detail. This bulletin is part of an ongoing project, the aims of which are to delineate these coal-bearing strata and to quantify their economic potential.

The study area is situated in northwest Alberta, immediately adjacent to the deformed belt of the Alberta foothills. Potentially economic coals outcrop along the valleys of the Wapiti, Cutbank, Kakwa, Smoky, and Simonette rivers. Three distinct coal measures have been defined, each containing up to 12 coal zones.

Regional mapping and analyses indicate that coal seams of potentially mineable thickness occur at shallow depths. The region should be considered as a source of thermal coal for future development.

E.A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

PRÉFACE

L'Ouest canadien renferme de vastes ressources en charbon, dont la plupart n'ont pas été étudiées dans le détail. Le présent bulletin s'incrit dans un projet permanent dont les buts sont de délimiter ces couches houillères et de quantifier leur potentiel économique.

La zone d'étude se trouve dans le nord-ouest de l'Alberta, tout près de la ceinture déformée des Foothills. Du charbon qui pourrait avoir une valeur économique affleure le long des vallées des rivières Wapiti, Cutbank, Kakwa, Smoky et Simonette. Trois couches à charbon distinctes ont été définies, renfermant chacune jusqu'à 12 zones houillères.

La cartographie et les analyses régionales indiquent la présence, à une faible profondeur, de filons de charbon dont l'épaisseur pourrait justifier l'exploitation. La région devrait être considérée comme une source éventuelle de charbon de chaudière.

E.A. Babcock
Sous-Ministre adjount
Commission géologique du Canada

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The following changes should be made to Figure 3 (in pocket).

1. Under "Legend" make the following change:

   *Areas of **Cutbank** coal measures*
   suitable for open pit mining . . . .

2. Section line B-B′ and its borehole numbers have been reversed on the map. B-B′ should be changed to B′-B and the boreholes should be changed as follows:

Now reads	Change to
80-4	85-8
81-26	85-11
85-24	85-15
85-21	77-46
77-46	85-21
85-15	85-24
85-11	81-26
85-8	80-4

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STRATIGRAPHY AND COAL RESOURCE POTENTIAL OF THE UPPER CRETACEOUS TO TERTIARY STRATA OF NORTHWESTERN ALBERTA

Abstract

The Late Campanian to Paleocene strata of northwest Alberta and northeast British Columbia consist of up to 1700 m of continentally derived sediments deposited in an eastward-thinning wedge. This thick sequence is contained within the Wapiti, Coalspur and Paskapoo formations. Lithologies consist of interbedded sandstone, siltstone and mudstone with minor coal, and appear to have been deposited in a predominantly fluvial environment. Three distinctive coal horizons - Red Willow, Cutbank and Kakwa - contain coal zones up to 8 m thick of subituminous to high-volatile A bituminous rank. These coals commonly contain numerous thin partings that may affect the mineability of the seams. Areas of exploration and development potential are highlighted for each of the coal measures.

Résumé

Les couches du Campanien tardif au Paléocène du nord-ouest de l'Alberta et du nord-est de la Colombie-Britannique se composent de jusqu'à 1 700 m de sédiments d'origine continentale déposés dans un coin qui s'amincit vers l'est. Cette séquence épaisse se trouve dans les formations de Wapiti, de Coalspur et de Paskapoo. Les lithologies renferment du grès, du siltstone et du mudstone interstratifiés avec un peu de charbon, et semblent s'être déposées dans un milieu surtout fluviatile. Trois horizons houillers distincts - Red Willow, Cutbank et Kakwa - contiennent des zones atteignant 8 m d'épaisseur de charbon de rang sub-bitumineux à bitumineux A très volatil. Ces charbons contiennent en général de nombreuses petites passées stériles qui pourraient compliquer l'exploitation des filons. Les zones d'exploration et de mise en valeur potentielles sont mises en évidence pour chacune des couches à charbon.

INTRODUCTION

Potentially economic coals of late Campanian to Paleocene age lie within the Wapiti study area in northwestern Alberta. Coal seams outcrop along the valleys of the Wapiti, Cutbank, Kakwa, Smoky and Simonette rivers and are grouped into three, distinct, stratigraphic horizons: the Red Willow, Cutbank, and Kakwa coal measures. Individual coal seams within the measures are widely variable in thickness and lateral continuity.

The study area is situated immediately adjacent to the deformed belt of the Alberta foothills. Strata on the western edge have moderate dips, while those farther to the east are essentially flat lying. River valleys cutting the region from west to east have produced a series of topographic ridges that influence the distribution and potential mineability of the coal resources.

Within the Wapiti area, coal seams up to 3 m in thickness have been observed in outcrop. Commonly, the individual seams coalesce to form thick coal zone intervals containing numerous, thin coal seams separated by thick to thin partings. The coals range in rank from a reflectance of 0.46 per cent (lignite) in the northeast to 0.74 per cent (high-volatile A bituminous) in the west, and are generally vitrinite rich.

This paper presents a regional stratigraphic framework for the late Campanian to Paleocene strata, provides a detailed assessment of coal distribution and characterization, and highlights regions of potentially economic shallow coal resources.

STUDY AREA

The Wapiti project area (Fig. 1), encompasses approximately 600 km^2 in northwestern Alberta, extending from the Smoky River (Twp. 58) in the south to north of Grande Prairie (Twp. 72). The eastern limits are defined by Range 25, west of the 5th Meridian and the area extends westward to the edge of the disturbed belt of the Rocky Mountains (the presence of Lower Cretaceous strata in outcrop).

The area is incised from southwest to northeast by major rivers such as the Smoky, Kakwa and Wapiti. Numerous smaller drainage systems such as the Cutbank and Simonette rivers and Prairie and Bolton creeks flow into the larger waterways. In general, north-south-trending tributaries flow into east-west-trending rivers. This bidirectional drainage pattern produces a series of east-west topographic

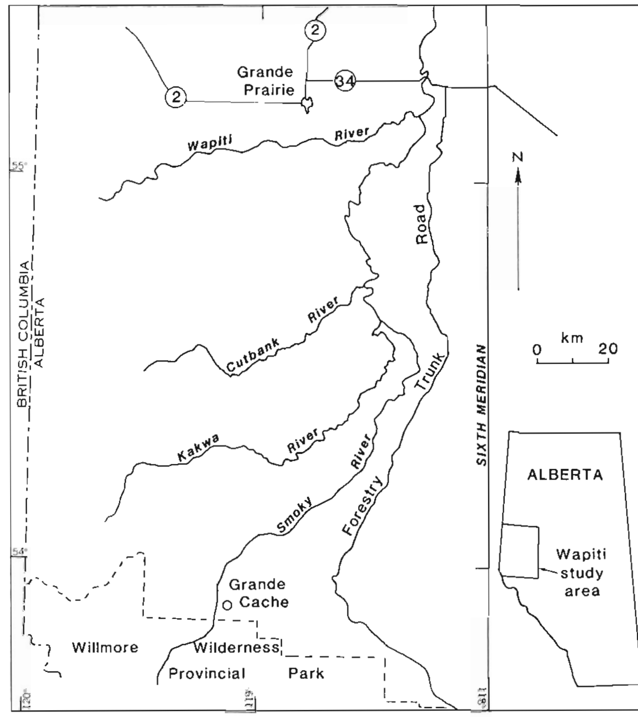


***Figure 1.** Wapiti project location map.*

divides with north-south-trending escarpments oriented toward the major river valleys.

Along the western edge of the study area, structural folding of resistant strata has produced an elongated ridge escarpment (consisting of Morley Hill and Nose Mountain), extending from the Smoky River in the south to the Wapiti River in the north. This topographic lineament reflects the edge of the tectonic belt of the Rocky Mountains to the west.

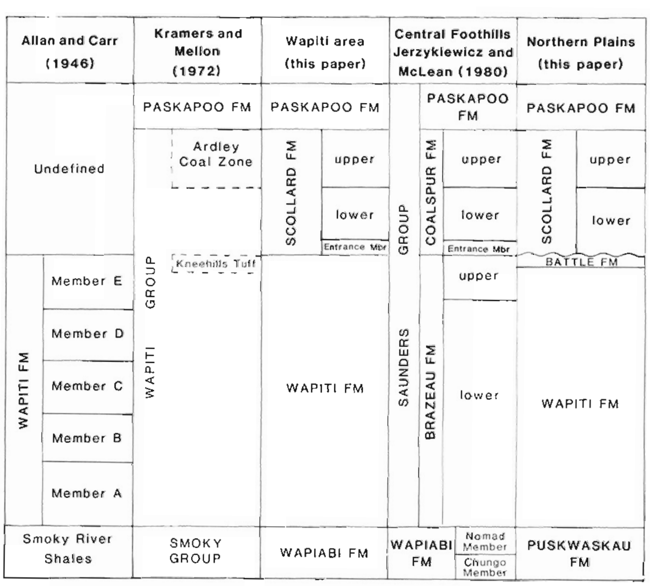
Within the limits of the study area, the elevation varies from greater than 1585 m (5200 ft.) above sea level on the ridges, to less than 610 m (2000 ft.) above sea level in the river valleys. Outcrops are limited to river bank exposures and roadcuts. Most of the access roads, developed for the extensive logging and oil and gas exploration activities, follow along the ridge crests between the Wapiti and Cutbank rivers and the Cutbank and Kakwa rivers. Access west of Nose Mountain and between the Smoky and Kakwa rivers is much more restricted.

PREVIOUS WORK

Clastic nonmarine strata of Upper Cretaceous to Tertiary age overlying the dark grey marine shales of the Smoky Group were first recognized in outcrop along the Smoky River by Dawson (1881). These strata were defined as the Wapiti Group, the base of which was thought to be correlative with the base of the Foremost Formation of southern Alberta (McLearn, 1919). Allan and Rutherford (1934) defined the Wapiti Group so that it was correlative with the Belly River, Bearpaw and Edmonton formations of southern and central Alberta.

Detailed coal exploration work conducted by Allan and Carr (1946) resulted in the definition of the Wapiti as a formation with five informal members (A-E) in the region of the Cutbank and Kakwa rivers. Stott (1961) recognized correlative Wapiti Formation strata farther west in northeast British Columbia, south of the town of Dawson Creek. Kramers and Mellon (1972) presented an assessment of the coal potential of the region and elevated the Wapiti Formation back to group status, based upon a comparison with the established nomenclature for the Upper Cretaceous and Tertiary of the Alberta Plains. The stratigraphy for the same aged succession has been refined by Jerzykiewicz and McLean (1980), in the central Alberta foothills and the northern plains of Alberta by Baofang and Dawson (1988). No emphasis, however, was placed on the Wapiti region until this project was initiated.

Studies by the Geological Survey of Canada have resulted in a new stratigraphic nomenclature based upon regional subsurface correlation of coal zones (Dawson and Kalkreuth, 1989). Figure 2 illustrates the previously defined stratigraphic nomenclature, and that proposed in this paper.



*Note: In the Wapiti study area, west of the axis of the Alberta Syncline, the nomenclature of the Central Foothills applies.

Figure 2. Stratigraphic nomenclature for the Wapiti region.

DATA SOURCES

Field studies of the Wapiti area consisted of three summer mapping programs undertaken from 1987 to 1989. Helicopter and vehicle reconnaissance coupled with surface mapping and trenching of coal seams, were carried out. Most of the outcrops are restricted to roadcuts and river valleys, and a total of 42 coal localities were excavated and sampled (Appendix 1). Other coal occurrences were mapped but were not suitable for sampling. These coal outcrop locations, together with those mapped by Esso Resources Canada Limited during the early 1980s, are presented in Figure 3 (in pocket). In addition to coal occurrences, Figure 3 also illustrates the numerous outcrop localities of the Entrance Member (a thick resistant sandstone at the base of the Coalspur Formation).

The geology of the western edge of the map area encompassing the rocks within the disturbed belt, was studied by M. McMechan of the Geological Survey of Canada (McMechan and Dawson, 1990).

Subsurface data consist of the results from 300 petroleum wells and 400 coal exploration holes, including all boreholes with complete geophysical logs. Table 1 summarizes the data sources utilized for the geological interpretation in this report.

TABLE 1

Wapiti project data sources

Coal exploration boreholes	400
Petroleum exploration boreholes	300
Coal trenches	40
Stratigraphic section localities	10
Palynological sample sets	102

METHODOLOGY

The initial goals of the Wapiti project were to determine the amount of outcrop exposure and the lateral continuity of the major coal-bearing sequences. Upon completion of this initial assessment, a stratigraphic framework was developed into which more detailed geological observations could be placed. Interpretation of subsurface exploration data was undertaken to develop a stratigraphic model and to assist in the determination of formation boundaries and distribution of coal zones. Structure contour maps were then generated and overlain onto topographic maps to delineate the subcrops of the formation boundaries. Subsequent mapping in 1990 verified the locations of the projected subcrops. Where necessary, adjustments were then made to the geological maps.

In addition to the primary geology map (Fig. 3), detailed cross-sections were created to illustrate the variability of the coal seams within the Kakwa and Cutbank coal zones (Figs. 4, 5). Areas of greatest surface minable coal potential have been highlighted on Figure 3 (in pocket) for the Wapiti region.

STRATIGRAPHY

Age and correlation

Terrestrial strata that conformably overlie the marine sediments of the Puskwaskau Formation (Wapiabi Formation equivalent (Stott, 1961) subcrop within the Wapiti area of northwest Alberta and northeast British Columbia and are of late Campanian to Paleocene age (Sweet, unpub. data, 1990). The sediments are correlative with the Brazeau and Coalspur formations to the south and to the Belly River and Bearpaw formations and the Edmonton Group to the east (Dawson et al., 1989). Palynological samples, summarized in Appendix 2, have yielded floral assemblages that have been correlated to similar-aged samples in the Coalspur region to the south and the Ardley and Judy Creek regions of the Alberta plains. Detailed palynological studies conducted by Sweet (pers. comm., 1990) indicated that the two major correlative coal measures, Cutbank and Kakwa, are equivalent in age to the Upper Brazeau and Coalspur coal zones of the central Alberta foothills and the Carbon/Thompson and Ardley coal zones of the Alberta plains. The Cretaceous/Tertiary boundary is believed to lie at the base of the first laterally persistent coal seam within the Kakwa coal measures.

Palynological dating of samples from location WA88008 indicates that a 40 m thick succession of sandstone, siltstone and minor coal, normally absent at the top of, or correlative with the Battle Formation in other parts of the Alberta Basin (Appendix 2) is present. Unlike the major part of the plains, which comprises lacastrine and paleosol facies (Binda, 1991), in the Wapiti area, during Battle Formation deposition, environments were suitable for the formation and preservation of coal.

Outcrops of coal along the Simonette River (WA89006) display a P3 palynological assemblage, indicative of a lower Paskapoo Formation age (Sweet, unpub. data, 1990). This coal zone, which lies approximately 60 m above the main Kakwa coal zone, is younger than the Upper Ardley or Pipestone coal that is developed in the Pigeon Lake area of central Alberta (Sweet, unpub. data, 1990).

Biostratigraphy

The Cutpick Hill section provides a reference locality for the lower part of the Wapiti Formation. It contains a late Campanian assemblage that falls within the *Aquilapollenites trialatus* Zone of Sweet et al. (1989) of the Little Bear Formation, Brackett Basin, Northwest Territories. Representative species of this assemblage are illustrated in Plate 1, figures 1 to 21 and include *Aquilapollenites clarireticulatus, A. drumhellerensis, A. mirabilis, A.* sp. cf. *A. quadrilobus, A. rigidus* (illustrated in Plate 2, fig. 7) *A. stelckii, A. trialatus* var. *variabilis, A. turbidus, A.* sp. cf. *A. hirsuta, A. recta, A. sufflata, Fibulapollis scabratus*, *Mancicorpus anchoriforme, Pulcheripollenites krempii,* and *Umbosporites callosus*. This palynoflora assemblage is allied with the "early and late loranthaceous suites" of Norris et al. (1975), which are of early late Campanian age (Nichols and Sweet, in press), and has some species in common with the assemblage illustrated by Eberth et al. (1990) from the Judith River Formation. A closely similar assemblage occurs in the lower part of the Brazeau Formation in the central Alberta foothills (Braman and Sweet, 1988, 1989; Wall and Sweet, 1982). This confirms a correlation between the lower parts of the Wapiti and Brazeau formations and hence a more or less contemporaneous initiation of continental sedimentation throughout the central and north-central foothills of Alberta.

The upper part of the Wapiti Formation exposed at Cutpick Hill contains a palynofloral assemblage (Pl. 2, figs. 1–23; Pl. 3, figs. 1–7) with affinity to the *Cranwellia* suite of Norris et al. (1975) and the *Triprojectus unicus* Zone of Sweet et al. (1989). This latest Campanian assemblage is identified by the combined presence of *Anacolsoidites* sp., *Aquilapollenites funkhouseri*, *A. quadrilobus*, *A. rectus* (not illustrated), *Cranwellia rumseyensis*, *Erdtmanipollis procumbentiformis*, *Expressipollis* sp. cf. *E. barbatus*, *Liliacidites mirus*, *Mancicorpus calvus*, *M. tripodiformis*, *Orbiculapollis* sp. cf. *O. globosus* and *Senipites drumhellerensis*.

The assemblage from the upper part of the Cutpick Hill section occurs elsewhere in the Wapiti area in association with the Red Willow coal zone (WA88019). Additional taxa sometimes found in association with Red Willow coals include *Mancicorpus albertensis* and *Trudopollis meekeri* as well as *Kurtzipites andersonii*, an index species for the early Maastrichtian (McIver et al., 1991). As samples from the Red Willow coal zone contain both species typical of the latest Campanian (*Aquilapollenites clarireticulatus*, *A. trialatus*, *Mancicorpus calvus* and *Trudopollis meekeri*) and *Kurtzipites andersonii*, the Campanian/ Maastrichtian boundary probably occurs within or immediately contiguous to this interval. Similar assemblages occur in cyclothems Ib and IIa of the Brazeau Formation in the Blackstone River section and in the basal beds of the St. Mary River Formation (Jerzykiewicz and Sweet, 1988), and from the upper part of the Judith River Formation (Eberth et al., 1990). These associations suggest a correlation between the upper part of the Wapiti Formation exposed at Cutpick Hill and the Red Willow coal zone with the middle part of the Brazeau Formation in the central Alberta foothills and the Bearpaw Formation and contiguous strata in central and southern Alberta.

The early Maastrichtian interval between the Red Willow and the stratigraphically higher Cutbank coal measures has yet to be analyzed in detail. *Kurtzipites* spp. occurs very abundantly in many early Maastrichtian assemblages from the foothills of central Alberta (McIver et al., 1991). A comparable assemblage has yet to be identified in the Wapiti Formation.

The Cutbank coal measures yield a distinctive palynological assemblage (Pl. 3, figs. 8–19) characterized by the zonal index species *Scollardia trapaformis* in association with an abundance of specimens of the longer ranging species *Aquilapollenites augustus*, *A. delicatus* var. *delicatus*, *A. quadrilobus*, *Liliacidites complexus*, *Mancicorpus gibbus* and *Orbiculapollis lucidus*. This assemblage is allied with the *Scollardia trapaformis* Zone of Srivastava (1970) and the *Mancicorpus gibbus/ Scollardia trapaformis* Zone of Sweet et al. (1989). The middle Maastrichtian *Scollardia trapaformis* Zone VI of Srivastava (1970) occurs in association with the Thompson coal in the upper part of the Horseshoe Canyon Formation and is contiguous in the central Alberta Plains (Srivastava, 1970). This same assemblage occurs within the coal-bearing beds in the upper part of the Brazeau Formation (Jerzykiewicz and Sweet, 1988) and therefore provides the means of correlating the Cutbank coal measures to both the uppermost part of the Brazeau and Horseshoe Canyon formations.

Although the lower part of the section at Nose Mountain contains an assemblage that includes *Scollardia trapaformis*, its uppermost part includes the typically late Maastrichtian taxa, *Wodehouseia spinata* in association with *Aquilapollenites bertillonites*. Other common taxa in the assemblage, such as *Aquilapollenites augustus*, *A. delicatus* var. *delicatus*, *A. quadrilobus*, *Liliacidites complexus*, *Mancicorpus gibbus*, *M. rostratus* and *Orbiculapollis lucidus*, also occur in the underlying *Scollardia trapaformis* Zone. This assemblage is allied to the *Porosiportis porosus* Zone of Sweet et al. (1989). A similar assemblage (Sweet, 1980; section 77-TJ-6; unpublished data) also occurs in the tuffaceous unit described by Jerzykiewicz and McLean (1977) from the Luscar Sterco mine and in a laminated unit at the base of the Battle Formation in the Scollard Canyon (Srivastava, 1970; unpublished data). Hence, this early late Maastrichtian assemblage (Pl. 4, figs. 1–4) represents strata coeval with the uppermost part of the Brazeau Formation and the Battle Formation.

The late late Maastrichtian is poorly represented in the currently available samples. A short Smoky River outcrop section (DB90055) situated some tens of metres below the projected base of the Paleocene was found to yield a palynoflora typical of the *Wodehouseia spinata* zone of Srivastava (1970) (Pl. 4, figs. 5–9). This assemblage includes an abundance of *Aquilapollenites delicatus* var. *collaris*, *Myrtipites scabratus*, and *Tricolpites microreticulatus,* and common *Aquilapollenites reductus*, *A. reticulatus*, *Tricolpites parvistriatus* and *Wodehouseia spinata*. It is closely comparable to that found in the lower part of the Coalspur and Scollard formations (Jerzykiewicz and Sweet, 1986; Srivastava, 1970) and to that of the *Myrtipites scubratus/Aquilapollenites delicatus* var. *collaris* Zone of Sweet et al. (1989).

The overlying Kakwa coal measures are of Early Paleocene (P1 and P2) age. They contain a low-diversity assemblage (Pl. 4, figs. 10–15) dominated by gymnosperm pollen of the Taxodiaceae–Cupressaceae complex and *Laevigatosporties*. Specimens of *Paraalnipollenites alterniporus*, *Azolla schopfii* Dijkstra (1961) and more uncommonly *Wodehouseia fimbriata* are also present. The coal in the Deep Valley Creek outcrop section (WA89012) along the Simonette River is also of Early Paleocene age and hence correlative to the Kakwa coal measures based on the presence of *Alnipollenites trina*, *Paraalnipollenites alterniporus*, *Retitrescolpites anguloluminosus* and the otherwise overall low diversity of the palynoflora. *Hazaria*, a fern spore, is often abundant in the Deep Valley Creek coal and in other Kakwa coal measure coals, whereas it is scarce in the coal discussed below from Simonette River and in samples from the vicinity of the Smoky fire tower (SCA90015, SCA90017). Based on their palynology, the Kakwa coal measures are correlative with the Ardley coal zone of the central Alberta plains Scollard Formation and the upper

A

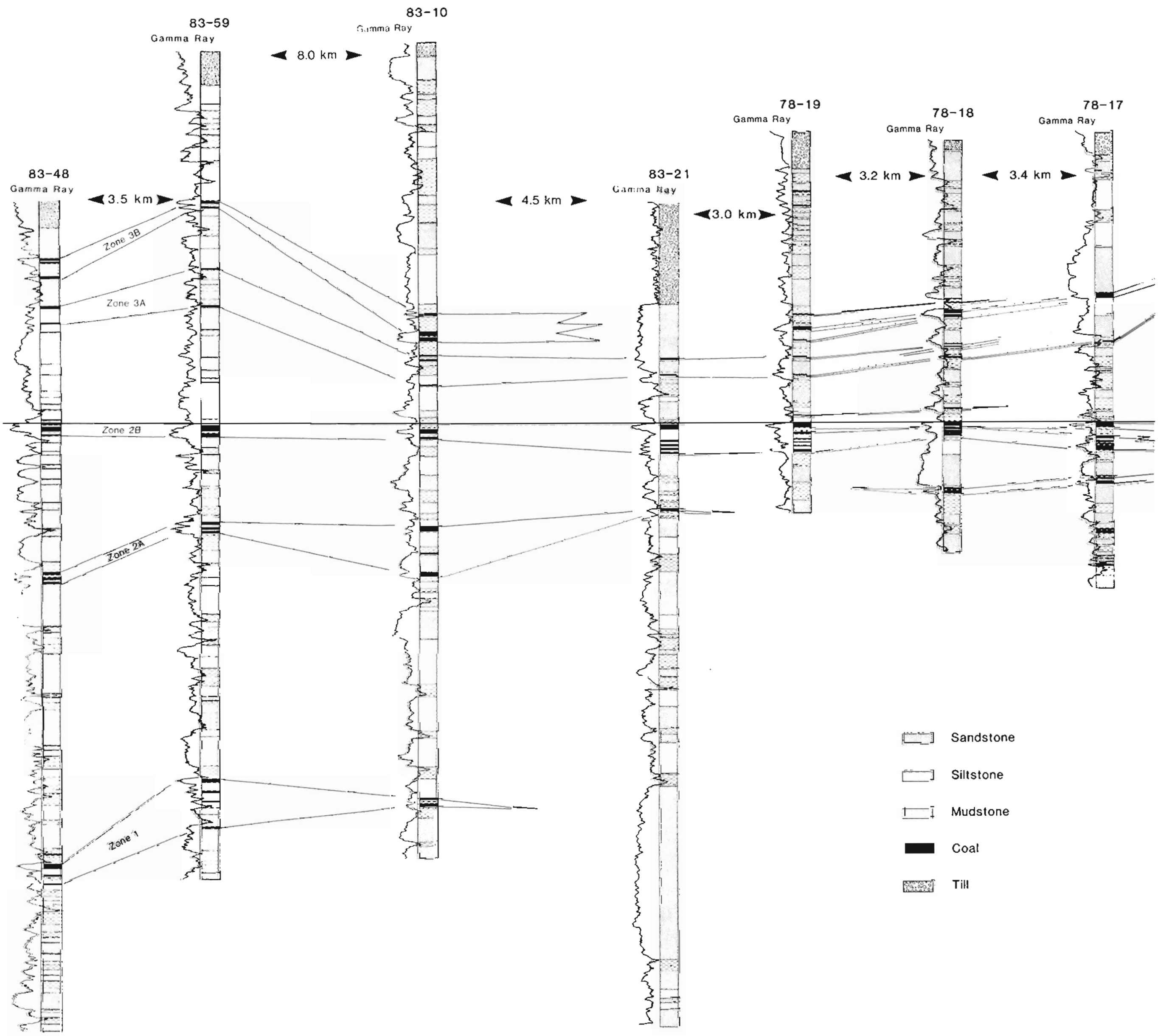


Figure 4. Stratigraphic correlation of the Kakwa coal measures. For location of cross-section A–A' see Figure 3.

coal-bearing part of the Coalspur Formation of the central Alberta foothills.

Christophel (1976, p. 3) concluded a Paleocene (or Early Paleocene) age for the Smoky fire tower plant locality (SLA90015) based on the radiometic ages of 61.5 to 62.5 Ma determined for a plant-bearing tuff horizon. The radiometric dates are equally supportive of the middle Paleocene age indicated palynologically by the combined presence of *Alnipollenites trina*, *A. verus*, *Aquilapollenites spinulosus*, *Caryapollenites imparalis*, *Ericaceoipollenites rallus*, *Momipites ventifluminis*, *M. waltmanensis*, *M. wyomingensis*, *Tilia danei* and *Ulmipollenites undulosus* in associated mudstones and coals. The flora of the Smoky Tower plant locality has an affinity with the upper part of zone P3 of Nichols and Ott (1978), the *Aquilapollenites spinulosus* Zone of Demchuk (1990) and the *Aquilapollenites spinulosus/Wodehouseia capillata* Zone of Sweet et al. (1989) and the enclosing strata are

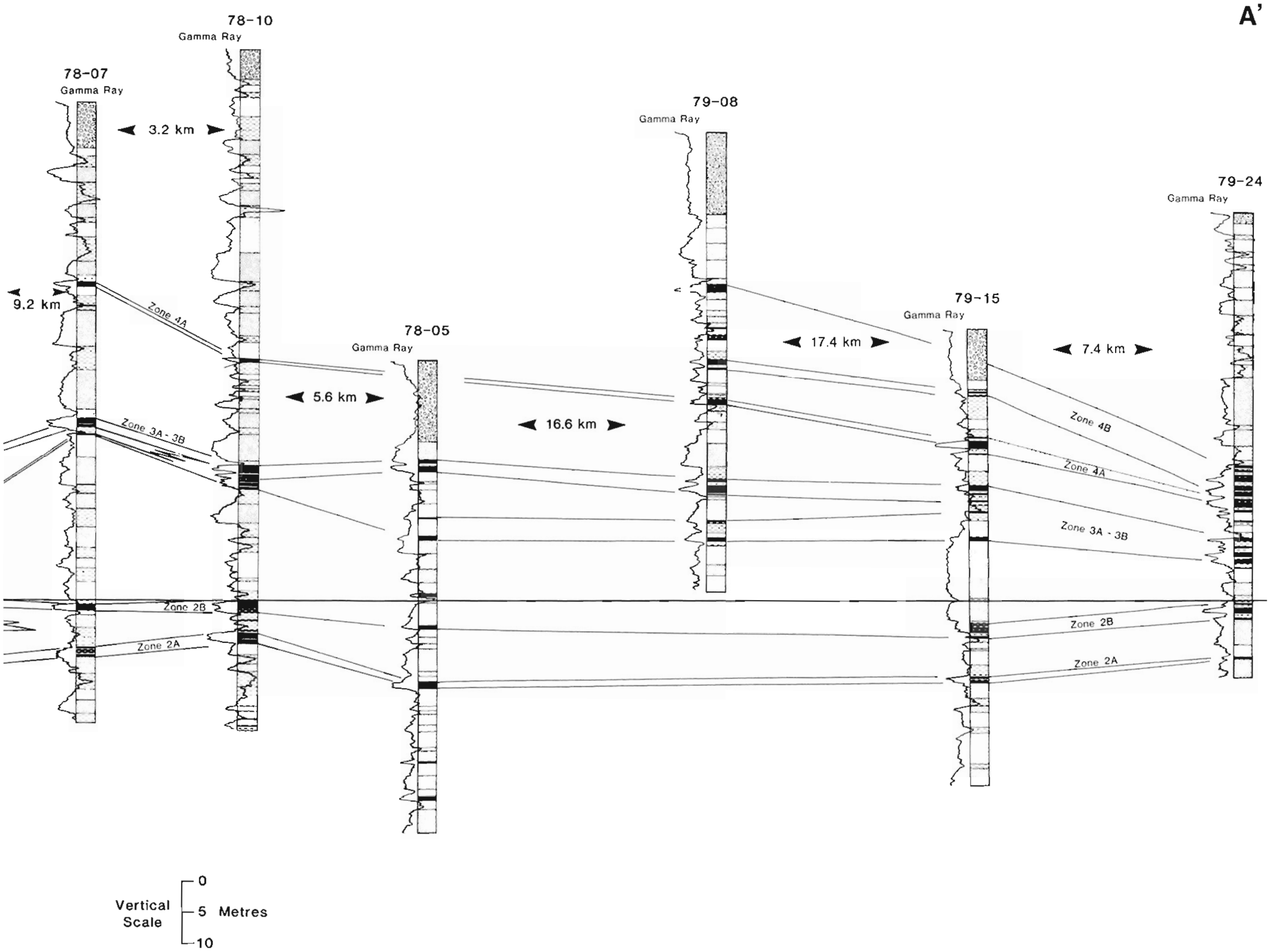


***Figure** 4 (cont'd.)*

correlative with the Paskapoo Formation. There is no comparison between this flora and that of the primarily late Maastrichtian *Wodehouseia spinata* Zone as suggested by Srivastava in Christophel (1976, p. 32).

Samples collected from roadcuts near the Smoky fire tower (SLA90015 and SLA90017) and along the Simonette River (WA89006) were found to also contain a flora (Pl. 4, figs. 16–29) of middle Paleocene age. *Alnipollenites trina*, *A. verus*, *Aquilapollenites spinulosus*, *Caryapollenites imparalis*, *Ericaceoipollenites rallus*, *Insulapollenites rugulatus*, *Momipites leffingwellii*, *M. ventifluminis*, *M. waltmanensis*, *M. wyomingensis*, *Tilia danei* and *Ulmipollenites undulosus* occur in the vicinity of the Smoky fire tower. These species in addition to *Brevicolporites colpella*, *Cranwellia subtilis*, *Momipites triorbicularis*, *Paraalnipollenites alterniporus* and *Retitrescolpites anguloluminosus* occur in the coals and mudstones of the Simonette River (WA89006) locality. This assemblage is indicative of the P3 zone of Nichols and Ott (1978), the *Aquilapollenites spinulosus/ Wodehouseia capillata* Zone of Sweet et al. (1989) and the *Aquilapollenites spinulosus* zone of Demchuk (1990). Therefore, both the exposures on the highland areas immediately east of the Smoky River in the vicinity of the Smoky fire tower and the Simonette River coal exposure are correlative to the Paskapoo Formation of central Alberta. As thin coals occur in sections in the vicinity of the Smoky fire tower (Christophel, 1976) that are more or less correlative with the Simonette River coal exposure, a laterally extensive, middle Paleocene interval of coal-bearing strata must occur in the lower part of the Paskapoo Formation east of the Smoky River.

Definition of nomenclature

Campanian to Paleocene terrestrial rocks of northwestern Alberta have been traditionally defined

B

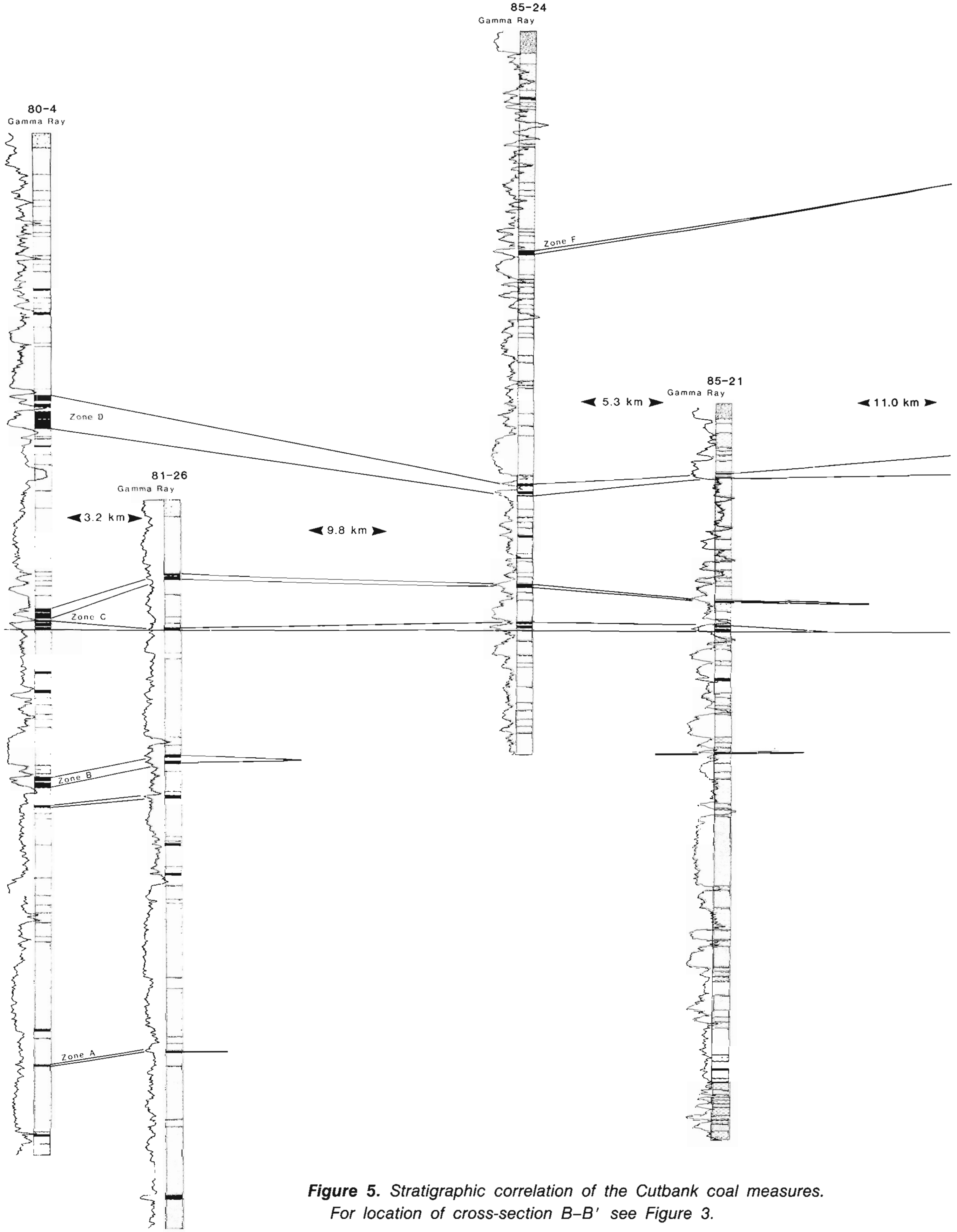


Figure 5. *Stratigraphic correlation of the Cutbank coal measures. For location of cross-section B–B′ see Figure 3.*

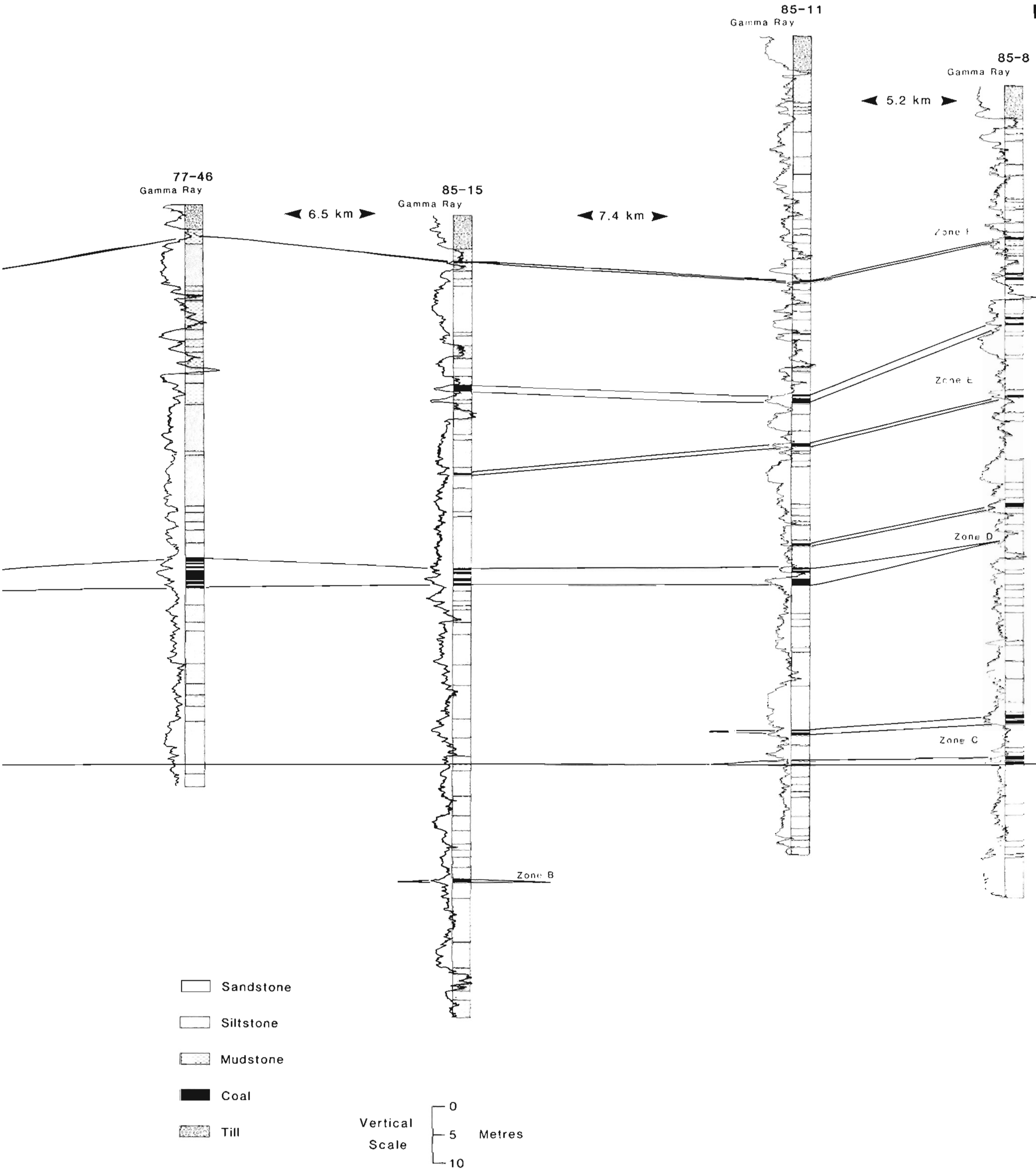


Figure 5 *(cont'd.)*

as those of the Wapiti Group. This stratigraphic interval encompasses all rocks younger than the underlying marine Puskwaskau Formation and older than the buff coloured sandstones of the Paskapoo Formation (Allan and Rutherford, 1934). Allan and Carr (1946) subdivided the Wapiti Formation into five members based upon the outcrops of thick coal seams between the Wapiti and Kakwa rivers. This stratigraphic framework was reasonable at the time, but did not include the entire Wapiti Formation as defined by Allan and Rutherford. Kramers and Mellon (1972) outlined a stratigraphic framework that elevated the Wapiti Formation to group status, but did not however, develop any formal designation of formations. The stratigraphic position and age of units within the Wapiti Group were poorly defined, and correlation with the strata of the Alberta Plains to the east and the Alberta foothills to the south was highly speculative.

The correlation of both outcrop and subsurface data as presented in this paper, in conjunction with accurate palynological dating, have enabled recognition of formations and formation boundaries that can be directly correlated with rocks in the central Alberta foothills and the Alberta Plains. In attempting to link the stratigraphy for these geographic regions the use of the term Wapiti Group as presently defined is not practical. In this paper, the Wapiti Group status is eliminated and the term Wapiti Formation is restricted to the specific stratigraphic interval lying above the marine sediments of the Puswaskau Formation and below the resistant massive sandstone (Entrance Member) at the base of the Coalspur/Scollard Formation. A continuation of the formation names that have been applied to adjoining regions is proposed for younger strata.

Local geographic features and the structural axis of the Alberta Syncline have been used to define the regional boundary between foothills and plains stratigraphic nomenclature in the Wapiti area. The main study area, to which central Alberta foothills nomenclature (Brazeau and Coalspur formations) is applied, lies west of the axis of the Alberta Syncline and south of the Wapiti River. East of the Alberta Syncline axis, and north of the Wapiti River, the plains terminology of the Wapiti and Scollard formations is used. This nomenclatural configuration facilitates the correlation of Wapiti rocks to both the south and the east, where the stratigraphy is already well defined. Figure 6 illustrates the proposed nomenclature for the Wapiti study area and the correlation with the equivalent-age rocks.

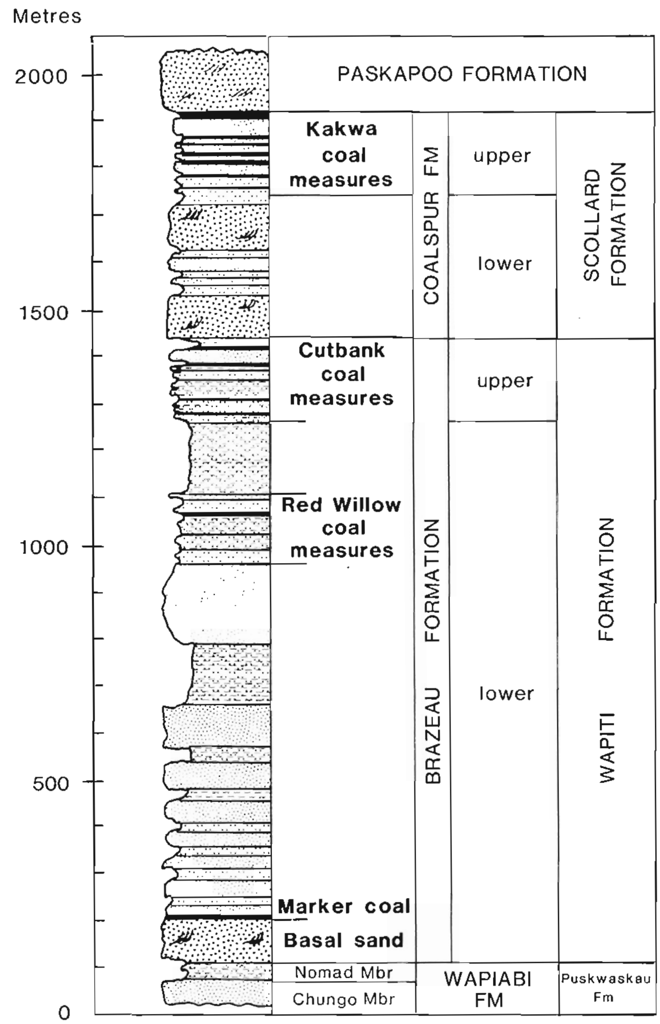


Figure 6. *Proposed nomenclature, Wapiti project.*

Lower Brazeau Formation (lower Wapiti Formation)

The lower Brazeau Formation consists of approximately 1000 m of clastic sediments lying stratigraphically above the Puskwaskau Formation. North of the Wapiti River and east of the Alberta Syncline, the equivalent-age rocks are defined (in this paper), as part of the Wapiti Formation. Rocks generally consist of fine to medium grained, light grey to brown sandstones, light grey-green siltstone and dark grey shale. Individual lithological units vary from thin to thick (greater than 5 m), with some very thick (greater than 30 m) channel deposits of fining-upward sandstone. Fine grained facies commonly contain carbonaceous beds and abundant plant rootlets. Claystone beds up to 1 m thick are present, usually associated with thin, discontinuous coal seams.

The basal 30 m of the lower Brazeau Formation (lower Wapiti Formation) consist of a thick, resistant, coarse grained sandstone, capped by a thin coaly horizon, as observed on the Smoky River (sample location WA880014, Fig. 7).

This medium to coarse grained unit is correlative with the "Basal Belly River Sand" of the Belly River Formation of the Alberta Plains. Toward the western edge of the project area (sample location WA88007, Fig. 8), the same stratigraphic interval becomes more coarse grained, consisting of conglomeratic beds, up to

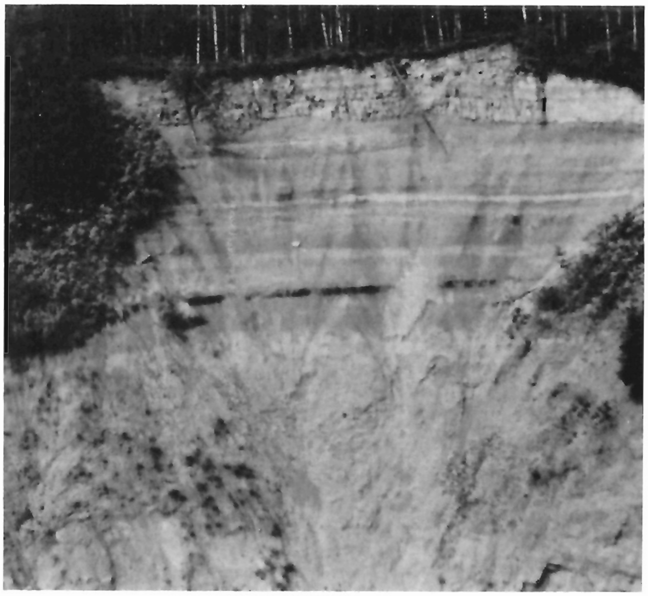


Figure 7. Basal sandstone strata at base of Wapiti Formation, location WA88014, Smoky River. ISPG photo 3733-4.

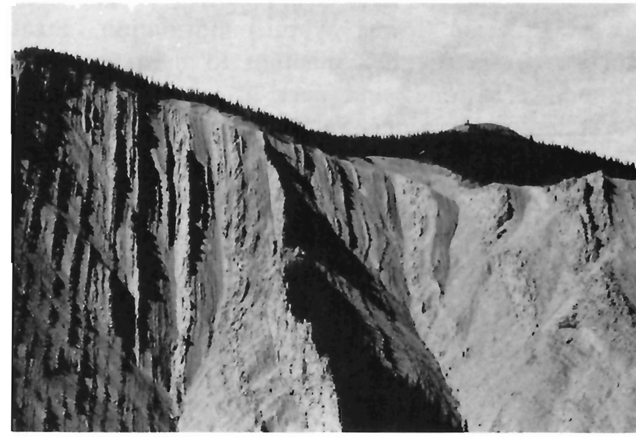


Figure 8. Base of the Brazeau Formation, location WA88007, Cutpick Hill. ISPG photo 3733-6.

Figure 9. Outcrop of Red Willow coal measures, location WA88003, Pinto Creek. ISPG photo 3733-3.

5 m in thickness, separated by light to dark grey siltstone units. The underlying sediments are fine grained siltstones and shales of the Nomad Member of the Wapiabi Formation (Stott, 1984).

The regressive marginal marine sandstones are commonly downcut by thick, fluvial sandstones that are generally medium to coarse grained and up to 35 m thick. These fluvial sandstones are commonly prolific hydrocarbon pools in the subsurface in west-central Alberta (Rosenthal et al., 1984).

The lower Brazeau Formation and equivalents appear to have been deposited in a series of cyclothemic sequences, consisting of 5 to 15 m cycles of sandstone and siltstone customarily capped by a 1 to 5 m thick carbonaceous zone containing 1 or more thin coal seams. Locally the formation contains thick intervals of fine grained sediments, probably indicative of local lacustrine depositional settings.

Approximately 100 m below the top of the lower Brazeau Formation (lower Wapiti Formation) is a laterally persistent zone of coal and carbonaceous beds defined as the Red Willow coal measures. This zone ranges from 10 to 30 m in thickness and contains up to 8 coal seams. The coals are locally discontinuous and may be up to 4 m thick. Outcrop localities WA88003 (Fig. 9), and WA89011 represent surface exposures of several coal seams within these coal measures.

Upper Brazeau Formation (upper Wapiti Formation)

Lying stratigraphically above the interbedded arenaceous sediments of the lower Brazeau Formation are the coal-bearing strata defined as the upper Brazeau (upper Wapiti) Formation. This portion of the Brazeau Formation ranges from 125 to 175 m in thickness and contains up to 12 coal seams of varying thickness. The contact with the underlying beds is gradational and is defined by the presence of the first laterally persistent coal seam lying above the predominantly barren zone of the top 100 m of the lower Brazeau (lower Wapiti) Formation. Strata consist of interbedded medium to light grey, fine grained sandstones and dark grey mudstones with carbonaceous horizons. Sandstone units range from 1 to 15 m in thickness, are generally fining upward and are commonly capped by a coal zone. Coals near the base of the upper Brazeau Formation are usually less than 2 m thick and are laterally discontinuous. Near the top of the formation, several thicker (greater than 3 m) seams are developed. The upper Brazeau (upper Wapiti) Formation tends to thin from west to east, and grain size decreases in the same direction.

Palynological dating of numerous samples indicates that the lower coals of the upper Brazeau (upper Wapiti), are equivalent in age to the laterally persistent Thompson coal zone of the Alberta Plains (see Appendix 1). At Nose Mountain (WA880008, Fig. 10), it appears that the upper coals are equivalent in age to the Battle Formation of the Plains. The presence of coal of this age is in contrast to the predominantly barren lacustrine and paleosol facies of the Battle Formation in most of Alberta and southern Saskatchewan, suggesting a different depositional regime or climatic condition for the northwest corner of Alberta. Further work is required to determine the paleogeographic implications the presence of "Battle" equivalent coals may have on our current understanding of the Alberta Basin.

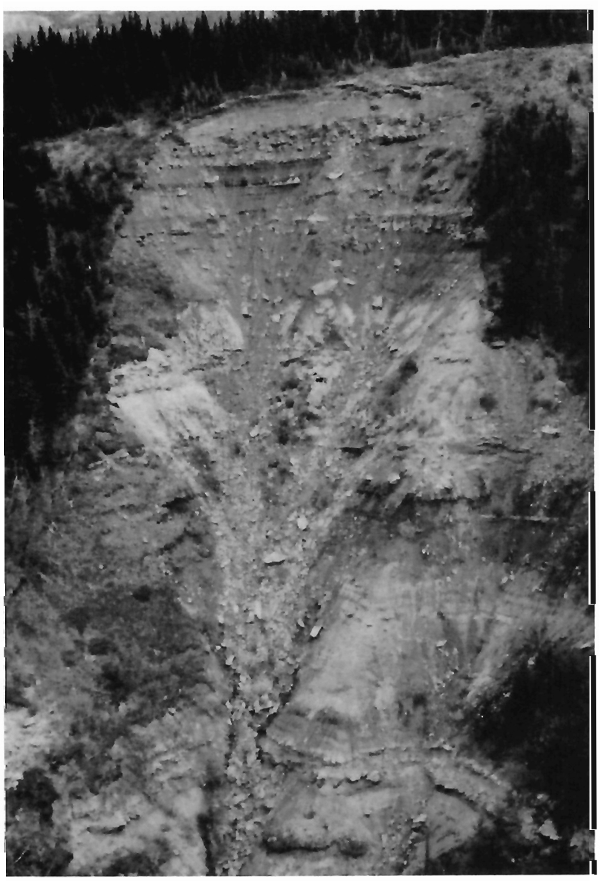


Figure 10. Outcrop of Cutbank coal measures, location WA88008, Nose Mountain. ISPG photo 3733-10.

Lower Coalspur Formation (lower Scollard Formation)

The lower Coalspur Formation encompasses a stratigraphic interval separating the Maastrichtian coals of the upper Brazeau Formation from the overlying Paleocene coals of the upper Coalspur Formation. The interval varies in thickness from greater than 300 m in the west to approximately 175 m in the east. Farther to the east, in the Judy Creek coalfield, equivalent strata are less than 50 m thick (Baofang and Dawson, 1988).

The lower Coalspur Formation (lower Scollard) primarily comprises thin, fining-upward cycles of fine grained, buff coloured sandstones overlain by medium to dark grey mudstone and greenish grey siltstone. The cycles vary in thickness from 5 to 15 m with a prominent cliff-forming sandstone at the base. The lower Coalspur Formation is essentially barren of coal, containing only rare, thin, carbonaceous shaly zones. Locality WA88011 (Fig. 11), illustrates the interbedded nature of the strata.

Figure 11. Outcrop of lower Coalspur Formation, location WA880011, Kakwa River area. ISPG photo 3733-2.

The contact of the lower Coalspur Formation and the underlying upper Brazeau Formation is commonly abrupt and easy to recognize in outcrop. It usually consists of predominantly fine grained, coal-bearing strata overlain by a massive, resistant, medium to coarse grained, buff to light grey sandstone unit defined as the Entrance Member. The thickness of the Entrance Member is variable, ranging from 5 to 20 m. In the western half of the study area, the Entrance Member contains thin, conglomeratic layers and forms resistant cliffs, especially in the region of Nose Mountain and Morley Hill. Other exposures of the Entrance Member are found along road outcrops within the Kakwa, Cutbank and Smoky river valleys (Fig. 12). The resistant nature of the Entrance Member was used as a guideline for surface mapping of the underlying Cutbank coal measures throughout the western part of the Wapiti study area.

Detailed sedimentological analyses by Jerzykiewicz (pers. comm., 1990) indicate that the Entrance Member, as defined in the Wapiti project area, is equivalent to the Entrance conglomerate outcropping farther to the south in the Alberta foothills near Hinton (McLean and Jerzykiewicz, 1980; Mack and Jerzykiewicz, 1989).

In the eastern half of the Wapiti project area, the Entrance Member is less resistant, possibly due to a finer grain size or poorer lithification. Outcrops are limited and the impact on topographic expression is less definite. Several outcrops have been observed along roadcuts and the Cutbank River. These locations, coupled with detailed subsurface analyses, have allowed the subcrop line of the Entrance Member as well as the underlying coals to be mapped in this part of the map area.

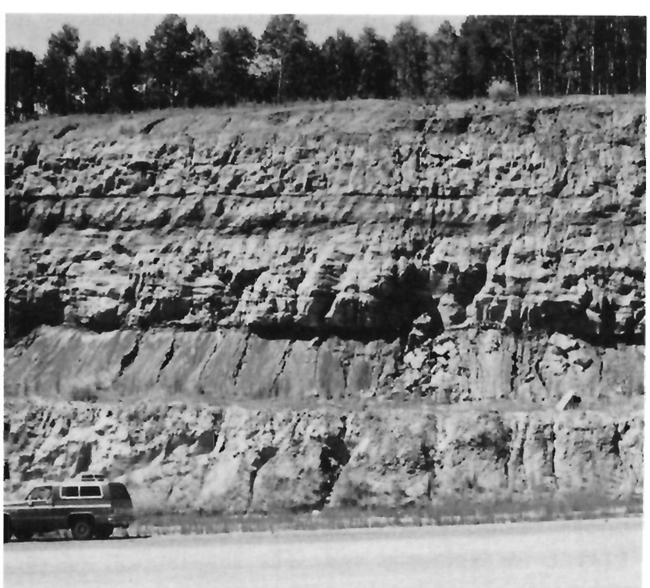


Figure 12. Outcrop of Entrance Member of the lower Coalspur Formation, Highway 40, Smoky River valley. ISPG photo 3180-1.

The regional correlation of subsurface coal exploration data between the eastern edge of the Wapiti project area and the Fox Creek coalfield 50 km to the east indicates that the Entrance Member of the lower Coalspur Formation may be correlative with the resistant sand unit at the base of the lower Scollard Formation, below the Ardley coal zone and immediately above the Battle Formation (Dawson and Richardson, unpublished data). East of the Wapiti study area, the Battle Formation has been recognized in the subsurface, whereas in the Wapiti area it is difficult to recognize and may not be present. This may be due to either the Battle Formation having undergone a facies change or the overlying Entrance Member erosionally downcutting and removing the Battle Formation. Figure 13 illustrates a typical geophysical log response for the Entrance Member and the lower Coalspur/upper Brazeau formations boundary.

The upper contact of the lower Coalspur Formation is defined as the presence of the first laterally persistent coal seam above the barren zone. It is believed that this seam (observed at locality WA88006) is correlative with the Nevis seam in the plains region of central Alberta, and the X seam in the Judy Creek coalfield (Baofang and Dawson, 1988).

In the Wapiti region, the lowest seam usually is in association with the Cretaceous/Tertiary boundaries as it is in other regions of Alberta (Lerbekmo et al., 1987; Sweet and Braman, 1992). Palynological dating has been undertaken for numerous coal seams within the interval and it has been determined that most of the coals are of Paleocene age and that the K/T boundary is found at or near the base of the coal measures. In the Wapiti region, the exact placement of the contact has not been determined.

Upper Coalspur Formation (upper Scollard Formation)

Lying conformably above the barren strata of the lower Coalspur (lower Scollard) Formation are the coal-bearing strata of the upper Coalspur (upper Scollard) Formation. This stratigraphic interval ranges from greater than 175 m in thickness in the west to less

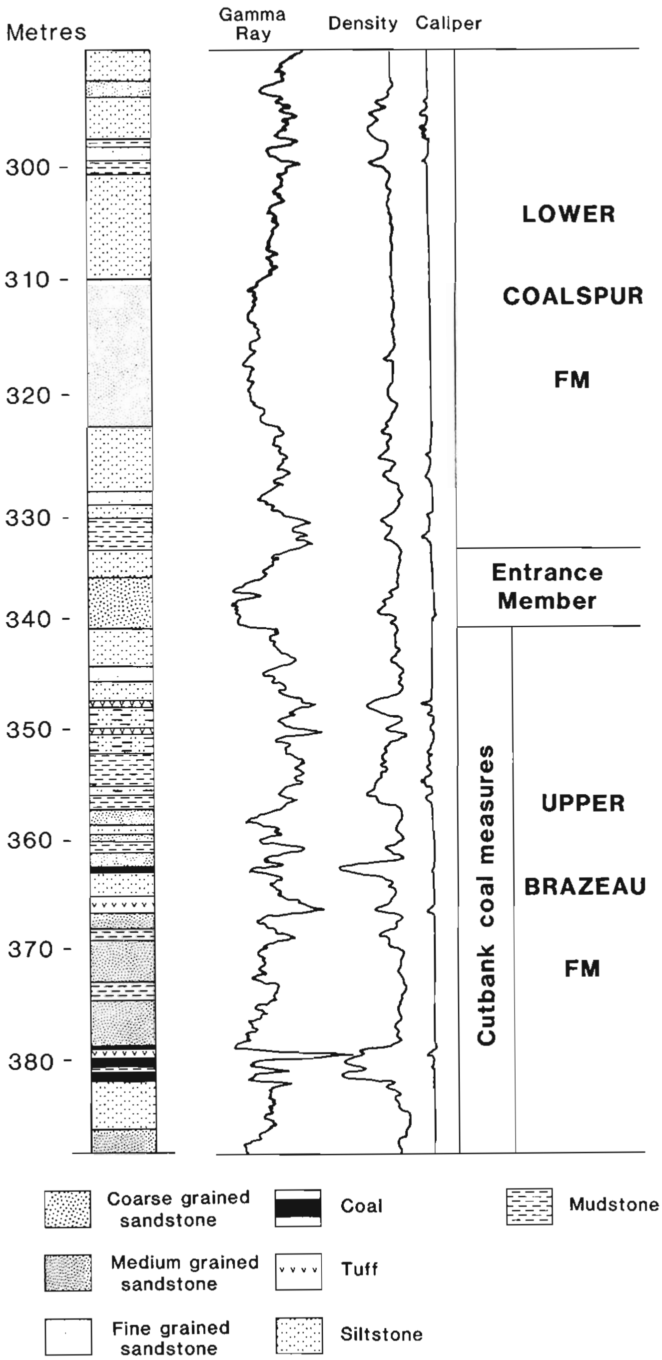


Figure 13. Typical geophysical log response for the lower Coalspur/upper Brazeau Formation contact, illustrating the prominent sandstone beds of the Entrance Member.

than 120 m in the east. To the south, in the foothills, the correlative upper Coalspur Formation increases in thickness to greater than 250 m, while in the plains the correlative upper Scollard Formation thins to less than 50 m at outcrop near Edmonton.

The clastic rocks are similar to those of the underlying formation, consisting of fine to medium grained, buff coloured sandstone and green to grey siltstone and mudstone. The primary difference between the two is the extensive development of coal. In the upper Coalspur Formation numerous coal zones (up to 10) have been observed. The entire coal-bearing interval is defined as the Kakwa coal measures. This interval is correlative with the Coalspur coal zone in the foothills to the south and the Ardley coal zone in the plains to the east.

Within the Kakwa coal measures, individual coal zones appear to be regionally extensive, but the seams are laterally discontinuous and highly variable in thickness. A correlation of subsurface data for the Kakwa coal measures indicates that 5 major coal zones can be recognized. Individual coal seams within each zone commonly split and coalesce with other seams to form thick accumulations of coal with minor rock partings; for example, in the northeast corner of the study area, where 4 zones coalesce to form a coal horizon greater than 6 m thick. Commonly the thick coal intervals contain thin rock partings that may be representative of the interseam strata.

Paskapoo Formation

The upper Coalspur Formation is overlain by the resistant sandstone cliffs of the Paskapoo Formation. Structure contour projections from subsurface data suggest that the Paskapoo strata may subcrop on the higher topographic surfaces between the Kakwa and Smoky rivers. Here and there, outcrops of buff coloured, resistant sandstone occur in roadcuts on Highway 40. Trenches WA88001, WA89001, WA89002 and WA89003 exposed coals of Paleocene age and lie topographically below a resistant escarpment on the south side of the Smoky River valley. Although no outcrops were observed, this topographic expression probably reflects the thick, resistant sandstone beds at the base of the Paskapoo Formation.

Post-Paskapoo Tertiary age strata

Lying unconformably above the Paskapoo-age strata within the Wapiti study area are remnant gravels and poorly indurated conglomerates and sandstones of Eocene to Holocene age. The distribution of these sediments is very localized and restricted to the higher, more prominent topographic features such as Morley Hill and Nose Mountain in the west and the Smoky Tower escarpment in the south.

STRUCTURAL GEOLOGY

The Upper Cretaceous (post-Wapiabi) strata of the Wapiti area are generally shallow dipping on either side of the Alberta Syncline. Immediately to the east of the Nose Mountain/Morley Hill lineation the rocks appear to be gently folded (less than 10°) into a anticlinal and synclinal pair. To the west of the Nose Mountain trend the dip of the strata increases to near vertical or overturned, signifying the surface trace of the first major overthrust fault. The surface trace of this fault zone appears to be east dipping and may represent the eastern edge of a triangle zone, similar to that recognized in the foothills farther to the south (McMechan, pers. comm., 1990).

East of these structural elements, strata dip gently to the east to form the western limb of the Alberta Syncline, a broad structure that trends northwest, parallel to the Rocky Mountains and plunges to the south. The axis of the syncline extends from Township 58, Range 1, W6M, northwest toward Township 64, Range 6, W6M. Strata on the eastern side dip gently (less than 5°) to the west. The shallow dips at outcrop make delineation of the axis difficult, but detailed correlation of coal beds from subsurface data provides some indication of its location. It appears that the axis migrates to the east. This is typically interpreted as the foreland basin down-warping in response to increased sediment supply into the basin proximal to the emergent Rocky Mountains to the west. A structure contour map of the base of the Wapiti Formation (Fig. 14) illustrates the axis of the Alberta Syncline, and the rapid increase in dip along the edge of the disturbed belt to the west and southwest.

Figure 15 illustrates the structure contours for the base of the lower Coalspur Formation and highlights the "migrating" axis of the Alberta Syncline.

COAL GEOLOGY AND DISTRIBUTION

In this paper, coal characterization and resource appraisal are restricted to the three main coal measures - Red Willow, Cutbank and Kakwa - lying approximately 1000 m, 1250 m and 1500 m, respectively, above the base of the Wapiti Formation. All of these coal-bearing sequences appear to have been deposited in a predominantly fluvial environment, resulting in a wide variability in seam thickness and continuity. In general, the topography increases in elevation toward the south, resulting in rocks of younger age outcropping farther south than those lower in the succession. The Red Willow is more exposed in the northern part of the study area, the Cutbank in the middle and the Kakwa coal measures in the southern part. Trenches and detailed sampling were completed for many of the coal zones within the three main coal measures. The stratigraphic position of the sample localities are illustrated in Figure 16.

Red Willow coal measures

The Red Willow coal measures encompass a 50 to 75 m thick sequence of coal-bearing rocks that lie near the top of the lower Brazeau Formation. Four distinct zones have been recognized from subsurface data. When projected to surface, these horizons appear to outcrop along the Wapiti, Red Willow and Narraway rivers in the north and west and the Smoky River in the northeast. Outcrops WA88003, WA880019, WA88020, WA88021, WA89007 and WA89011 represent trench localities from within this zone. Continuous exposure of several of the coal seams on the Red Willow River (downstream from WA88019) indicate that the seams tend to pinch out over short distances and are commonly replaced by dark grey carbonaceous shales. Thick lenticular sandstone bodies, believed to represent fluvial channel sediments, have downcut and removed the coal-bearing strata in numerous localities. Seam thicknesses up to 1.9 m (WA88019) have been measured in outcrop (Fig. 17). The seams are commonly split by partings of light grey, kaolinitic mudstone or medium to dark grey siltstone. The floors of the seams are generally well rooted and commonly show carbonaceous mudstone gradational contacts. Where well developed, the coal seams are blocky and resistant to erosion.

The Red Willow coal measures contain coal zones up to 4 m thick (in the subsurface); however, the lateral continuity of these thick coal accumulations may generally be limited. However, correlation of subsurface data has defined a regionally persistent coal, defined as the M seam, in the central region of the Wapiti study area. This coal bed ranges in thickness from less than 0.5 m to greater than 2 m. The M seam represents the uppermost coal seam developed in the Red Willow coal measures, and is overlain by a thick (approximately 100 m), fine grained sequence of siltstone and mudstone that is essentially barren of coal.

Cutbank coal measures

The upper Brazeau Formation consists of a coal-bearing sequence approximately 120 to 150 m thick defined as the Cutbank coal measures. Up to 12 seams have been observed in both outcrop and from

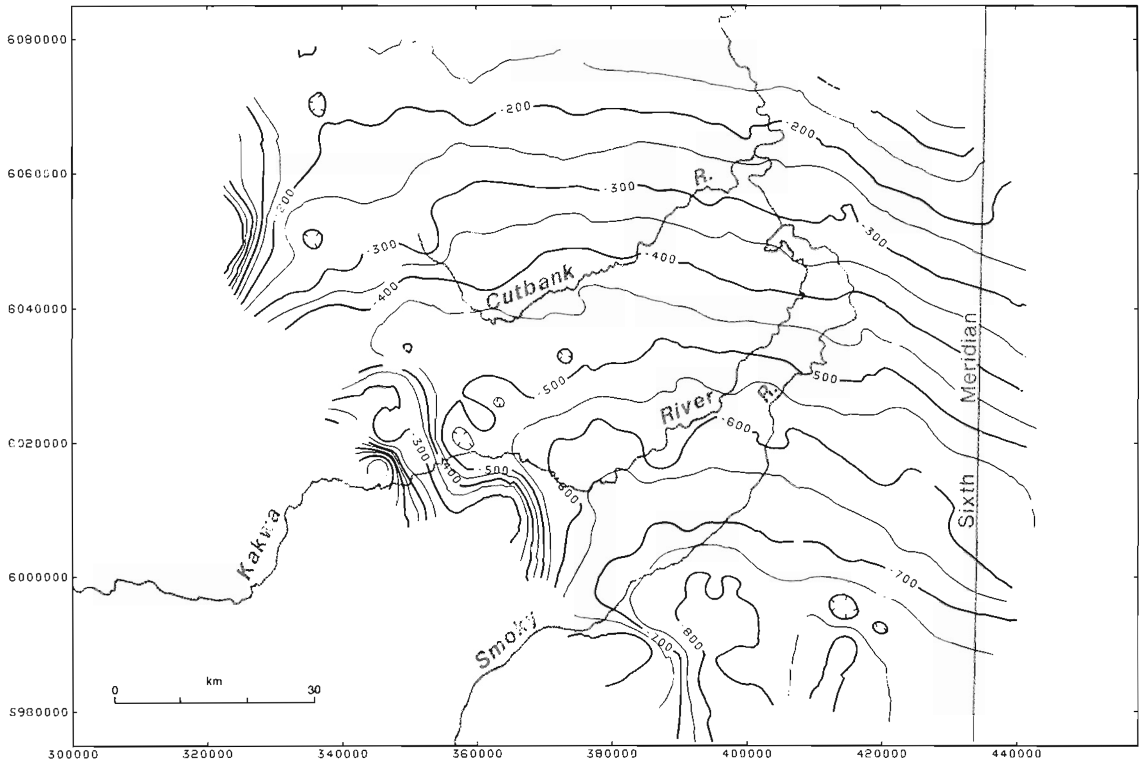


__Figure 14.__ Structure contour map of the base of the Wapiti Formation (contour interval 50 m). Geographic grid based upon UTM system.

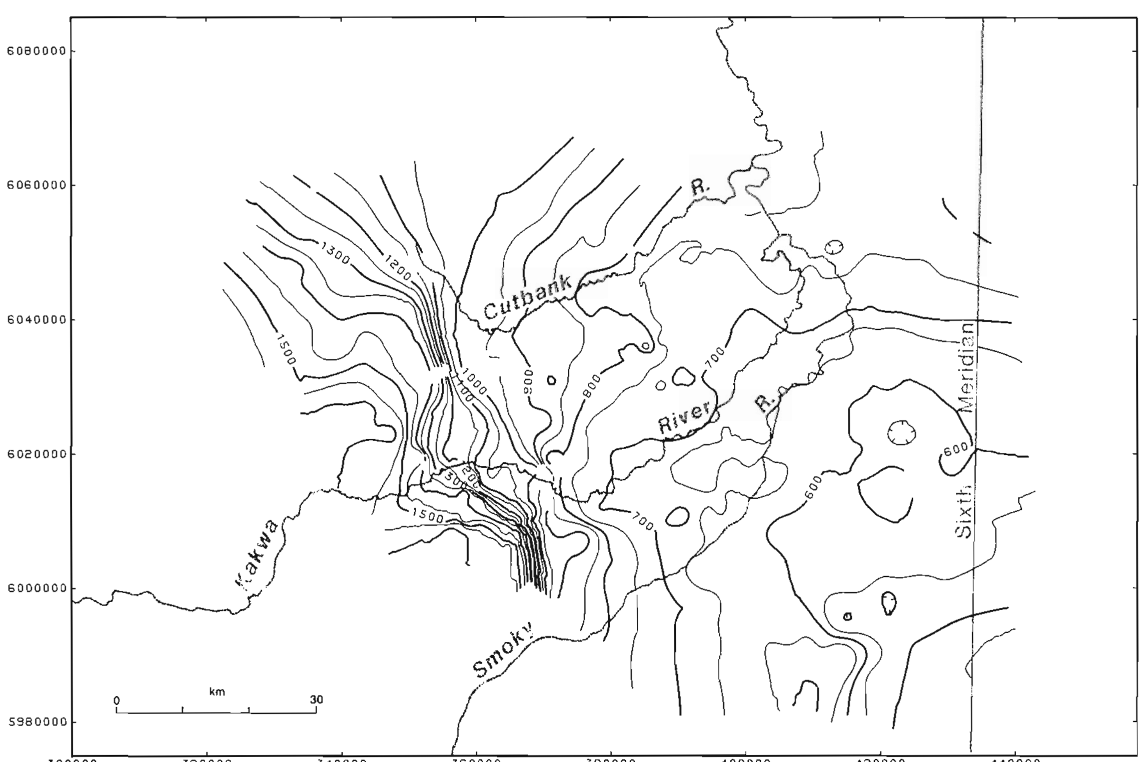


__Figure 15.__ Structure contour map of the base of the lower Coalspur Formation (contour interval 50 m). Geographic grid based upon UTM system.

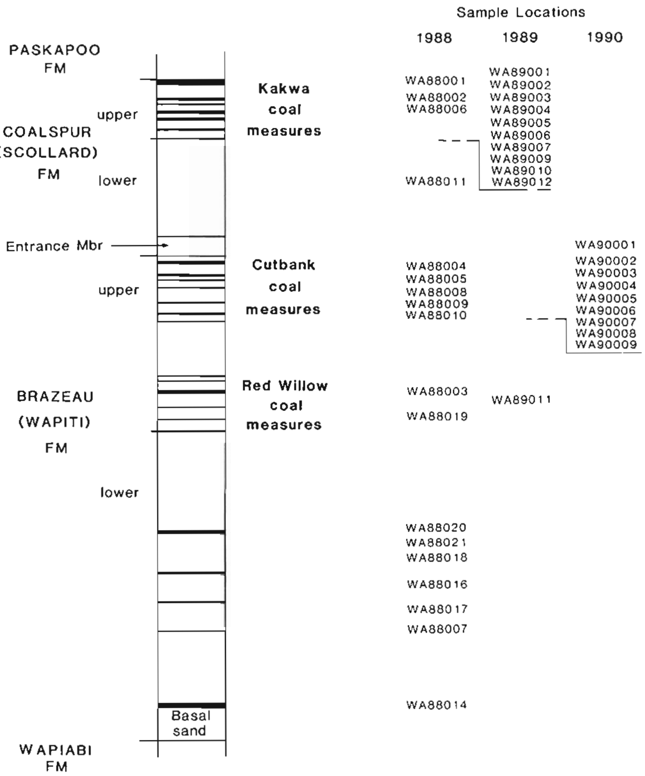


Figure 16. *Relation between coal measures and sample localities. All 1989 sample locations except for WA89011 lie within the Kakwa coal measures. All 1990 sample locations lie within the Cutbank coal measures.*

subsurface data. In the western part of the study area, the coal-bearing interval outcrops along the edges of east-dipping linear ridges of overlying, resistant Entrance Member (Nose Mountain and Morley Hill). Farther to the east the dips become more shallow, the coals lie at depths greater than 250 m below the topographic ridges and outcrops are limited to the Cutbank, Kakwa and Smoky river valleys and tributary creeks. East of the Smoky River (eastern limb of the Alberta Syncline), the coals reappear near surface in the Economy Creek and Simonette River areas. Outcrop localities WA88004, WA88005, WA88008, WA88009, WA88010, WA89005, WA89007 and WA90002 to WA90009 were trenched for detailed seam profiles and sampling. The coal zones observed in these trenches commonly consist of thin beds (30 to 45 cm) of blocky bright coal, interbedded with coaly shale and abundant kaolinitic claystone partings, as illustrated in WA88004 (Fig. 18). Thick coal seam sections without interbedded partings are few; the maximum observed thickness was less than 2.0 m. Boundaries of the partings tend to be gradational and consist of shaly coal or carbonaceous shale. The interbedded nature of the coal zone is illustrated in the measured section for trench WA88010 (Fig. 19).

Figure 17. *Outcrop of Red Willow coal measures, location WA88019, Red Willow River. ISPG photo 3733-5.*

Figure 18. *Outcrop of Cutbank coal measures, location WA88004, Cutbank River. ISPG photo 3733-9.*

Detailed seam correlations, as illustrated in Section A–A′ (Fig. 4), indicate that several of the coal zones within the Cutbank coal measures are correlative over distances greater than 15 km, while individual coal seams are widely variable in thickness and lateral continuity. Cross-section A–A′ illustrates the local coalescing of the coal seams, whereby a coal zone may attain a thickness of greater than 5 m, yet be missing entirely in an adjacent borehole.

Analyses of coal exploration data indicate that the coal zones near the base (A and A1) and near the top (E, F and G) of the Cutbank coal measures are thinner, averaging less than 1 m, whereas the zones in the middle (B, C and D) tend to be thicker, ranging from 2 to 5 m. The upper coals (Zones E, F and G), have been palynologically dated as being equivalent in age to the Battle Formation of the Alberta Plains. The thicker coals of zones B, C and D are believed to be equivalent to the Thompson coal zones of the Alberta Plains.

Several borehole intersections indicate that the upper coal zones have been removed by the erosional downcutting of fluvial channels within the overlying Entrance Member of the lower Coalspur Formation. Subsurface mapping of these channel deposits is not possible, however, because of the limited number of data points.

Kakwa coal measures

Lying stratigraphically above the barren zone of the lower Coalspur Formation are the coal-bearing strata of the Kakwa coal measures. The thickness of the coal

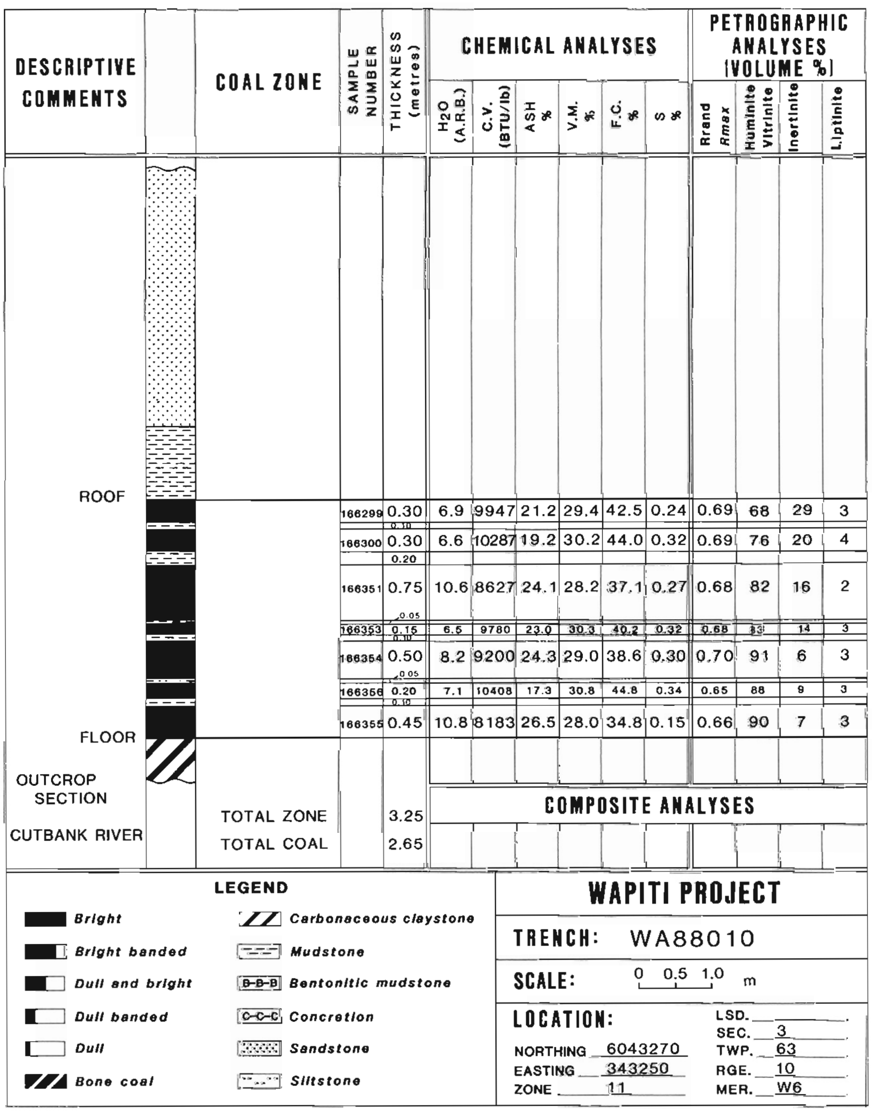


Figure 19. *Measured section of Cutbank coal measures, location WA88010, Cutbank River.*

measures varies from 150 m in the west to less than 110 m along the eastern edge of the study area. Up to 12 coal seams within six major correlative zones have been observed in outcrop and subsurface data analyses. Outcrops are limited to creeks and roadcuts between the Cutbank and Kakwa rivers, southeast of the Smoky River and along the steep escarpments of the Kakwa and Smoky river valleys in the southern region of the study area. In the vicinity of the Kakwa fire tower, the Kakwa coal measures lie near surface, and numerous roadcut exposures were observed. To the east, near the axis of the Alberta Syncline (Twp. 64, Rge. 3, W6M), strata are essentially flat lying and the coals outcrop near the bottom of the Smoky River valley. Farther to the east the Kakwa coal measures dip gently to the west and outcrop along Deep Valley Creek and the Simonette River. Outcrop localities WA88006 along the Kakwa River, localities WA88001, WA89001 to WA89004 and WA89007 to WA89010 along the Smoky River, and localities WA89006 and WA89012 along the Simonette River represent measured sections of individual coal zones from the Kakwa coal measures.

The Kakwa coal beds appear to have developed into thicker accumulations than those of the Cutbank. For example, in WA88001, three zones were excavated, each in excess of 2 m thick, with the upper zone consisting of over 5 m of coal within a 6.5 m interval. Similarly, in WA88006, the upper of three coal zones was 7.0 m thick.

Individual coal seams are generally friable, with thin blocky layers of bright coal. Claystone partings up to 70 cm thick with gradational contacts are present in many of the coal zones. Correlations of individual seams are commonly difficult because of the wide variability of the seam distribution and the limited data sources. Detailed correlation of data from coal exploration holes penetrating the Kakwa coal measures indicates that generally, each zone contains numerous rock partings and that individual seams within the zone commonly tend to coalesce and split (cross-section B-B′, Fig. 5). Coals lower in the stratigraphic interval tend to be thinner than those higher in the section, similar to the trend observed in the Red Willow coal measures. Within the Kakwa coal measures, the upper coals tend to thicken and coalesce from west to east. East of the Smoky River, several of the coal zones have coalesced to form a zone greater than 4.5 m in thickness (WA89012, Fig. 20). Although the data control is poor, there appears also to be a trend whereby the lower coal zones thin from west to east. These trends may be a result of the progradation eastward of the coal-forming conditions with the influx of eastward-aggrading sediments from the Rocky Mountains.

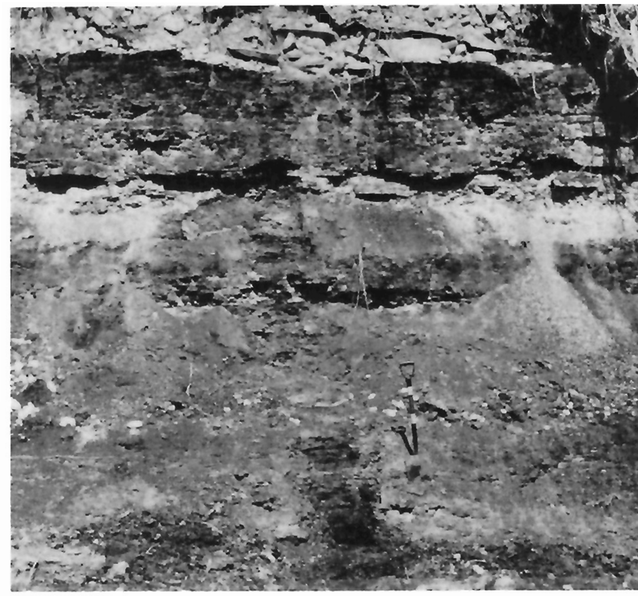


Figure 20. *Outcrop of Kakwa coal measures, location WA89012, Simonette River. ISPG photo 3733-7.*

COAL CHARACTERIZATION

The coals of the post-Wapiabi succession of rocks outcropping in the Wapiti region display a wide range of chemical characteristics, due in part to the thick stratigraphic interval examined as well as the large geographic region over which the samples were collected. Ash contents, on an as received basis (ARB), range from approximately 10 per cent to greater than 30 per cent, with an average of 20 per cent. Several analyses were completed for coaly units that had higher ash contents, but these were defined as shaly coal and not included in the range of values.

Petrographic characteristics

Petrographic examination of the sample material included vitrinite reflectance measurement to determine coal rank and maceral analyses to determine the petrographic composition. For sample preparation and analytical procedures see Bustin et al. (1989).

Preliminary results on the petrographic characteristics of Wapiti coals were discussed in Dawson and Kalkreuth (1989) and showed a vitrinite reflectance range from 0.46% R_{random} (lignite) to 0.74% R_{max} (high volatile A bituminous). Petrographically, the coals were characterized by high amounts of vitrinite macerals, moderate amounts of inertinite, and low amounts of liptinite macerals (Dawson and Kalkreuth, 1989).

In the present report additional data are presented for sample material collected in the field seasons 1989 and 1990. In the discussion below, the sample material has been grouped according to its stratigraphic position within the three major and one lesser coal-bearing sequences (Kakwa coal measures, Cutbank coal measures, Red Willow coal measures, and coals of the lower Wapiti Formation).

Petrographic composition

The maceral group distributions for the various coal zones have been plotted on a ternary diagram (Fig. 21) and are also listed in Tables 2, 3 and 4. All maceral values are quoted on a mineral matter free basis (mmf). A detailed listing of macerals determined within each maceral group (vitrinite, inertinite, liptinite) and type and amounts of mineral matter are given in Appendix 3.

The coal samples of the Kakwa coal measures show a high variability in their petrographic composition with respect to vitrinite and inertinite contents (Fig. 21). Vitrinite contents range from 43 Vol% to as high as 97 Vol%, whereas inertinite contents range from less than 5 Vol% to slightly over 50 Vol%. Liptinite contents are generally low and rarely exceed 5 Vol%.

The coals from the Cutbank coal measures are characterized by somewhat lower inertinite contents (4-30 Vol%) and corresponding higher vitrinite contents (62-92 Vol%; Fig. 21). Liptinite contents are similar to those observed for the coals from the Kakwa coal measures, except for four samples, which have slightly elevated liptinite contents.

Coals of the Red Willow coal measures and the lower Wapiti coals are characterized by the predominance of vitrinite macerals (66-94 Vol%). Total inertinite macerals range from 4-29 Vol%, whereas liptinite contents are low (2-5 Vol%; Fig. 21).

Details of maceral distribution for the Wapiti coals are given in Tables 2, 3 and 4. The major components within the vitrinite group are the macerals vitrinite A (telocollinite) and vitrinite B (desmocollinite); however, the proportions of these two macerals vary widely for the sample set analysed. Some of the samples contained minor to moderate amounts of the maceral corpocollinite (maximum 8.8 Vol%). Vitrodetrinite constituted only a minor proportion of the total amount of vitrinite. Semifusinite, fusinite and inertodetrinite make up the bulk of the inertinite group, while micrinite and macrinite are scarce or

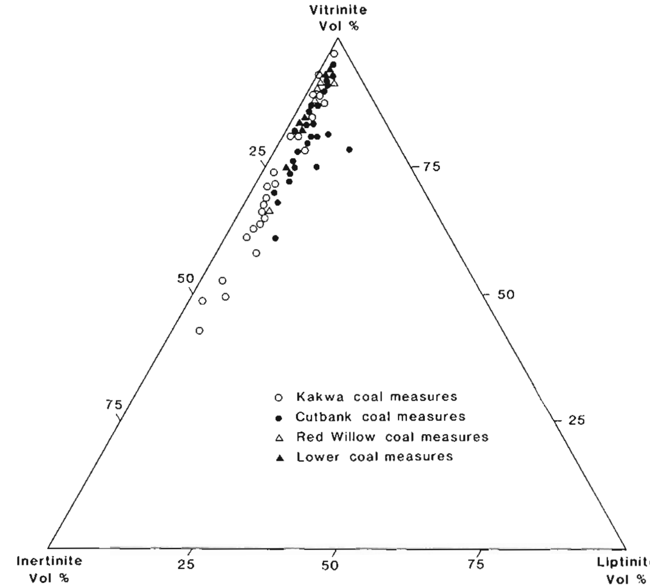


Figure 21. *Ternary diagram showing maceral group distribution in Wapiti coals.*

absent. The liptinite group of the Wapiti coals is dominated by sporinite with minor cutinite, resinite (in-situ and/or detrital), suberinite and traces of other liptinite macerals.

Mineral matter was counted as mineral grains closely associated with the organic matter and as shale particles void of any organic matter. Mineral matter in the Wapiti coals is dominated by shaly material, with only minor amounts of quartz and carbonate. Pyrite content is insignificant in all samples except one, which has a pyrite content of 3 Vol%.

Vitrinite reflectance

Results from vitrinite reflectance measurements are listed in Tables 2, 3 and 4. The values range from 0.35 % R_{random} (lignite/subbituminous) in the Kakwa coal measures (trench WA89002) to 0.74 % R_{max} in the Cutbank coal measures (trench WA89009). Examination of the reflectance variations between samples collected from the same trench indicate that high-ash samples consistently have slightly lower values than samples containing lesser amounts of mineral matter. For considerations of regional reflectance and rank variations for the Wapiti coals, the reflectances from high ash samples were omitted. The reflectances of the remaining samples form the basis for the discussion on regional rank variations for the Wapiti coals. Reflectance limits of A.S.T.M. rank as published by Davis (1978) were used to establish the A.S.T.M. rank levels for the Wapiti coals.

TABLE 2

Red Willow coal measures and lower Wapiti Formation; sample identification, petrographic and chemical characateristics

Red Willow coal measures					Maceral group analyses			Proximate analyses					
Trench	Sample (C no.)	Pellet no.	Thk (m)	R_o %	Vit. %	Int. %	Lipt. %	Moist. as rec.	V.M. D.A.F.	F.C. D.A.F.	Ash % as rec.	S % as rec.	Cal. Val. Mst, A.F.
WA88003	166423	536 /88	1.10	0.67	66	29	5	8.8	35.9	64.0	19.6	0.18	12300
	166320	508 /88	0.45	0.68	91	7	2	9.5	37.1	62.7	10.8	0.25	12398
WA88019	166360	527 /88	0.95	0.68	88	10	2	8.7	38.6	61.4	12.5	0.37	12391
	166372	623 /88	0.95	0.63	90	8	2	9.4	37.1	62.9	8.3	0.24	12382
WA89011	166492	844 /89	1.70	0.66	91	5	4	4.3	43.4	56.6	20.2	0.44	13277
Lower coal measures													
WA88020	166361	529 /88	0.30	0.66	82	15	3	6.7	39.9	60.1	17.8	0.48	12681
WA88020	166357	522 /88	0.10	0.68	83	15	2	7.6	37.5	62.6	16.4	0.28	12414
WA88021	166358	523 /88	0.30	0.56	84	14	2	13.3	40.8	59.4	11.4	0.49	11530
WA88014	166359	524 /88	0.50	0.46	75	21	4	30.5	47.2	53.0	10.4	0.30	8074
WA88018	166362	530 /88	0.20	0.56	92	6	2	17.2	38.4	61.6	5.5	0.52	11332
WA88017	166363	531 /88	0.20	0.55	94	4	2	12.9	41.4	58.4	21.9	0.79	11195

Coals of the Kakwa coal measures outcrop in the south and southeastern part of the study area (Fig. 22). The lowest vitrinite reflectance levels were observed in the most easterly samples, indicating subbituminous coals. The reflectance values increase gradually toward the southwest, placing these coals in a rank range up to high volatile C/B bituminous.

The Cutbank coal measures outcrop in the southwestern part of the study area (Fig. 22). Within that group of coals, highest reflectances occur at two locations in the north, indicating high volatile B and high volatile A bituminous coals. Lower reflectances in the south suggest high volatile C bituminous and subbituminous coals.

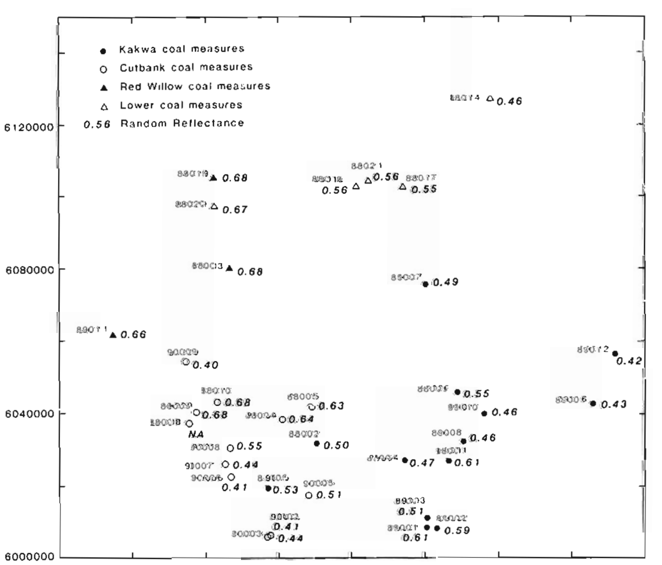


Figure 22. Averaged vitrinite reflectance (%) for Wapiti coals of the study area. A.S.T.M. rank according to Davis (1978). Geographic grid based upon UTM system.

Coal seams of the Red Willow coal measures and the lower Wapiti Formation outcrop in the northern part of the study area (Fig. 22). The reflectances for the most westerly of these coals are indicative of high volatile B bituminous rank, whereas toward the northeast, the reflectances are significantly lower and indicate high volatile C bituminous to subbituminous rank.

Chemical characteristics

Chemical characteristics of the Wapiti coals were determined by proximate analyses (moisture, volatile matter, fixed carbon, ash) and by determination of total sulphur contents and calorific values. The results are listed in Tables 2, 3 and 4.

Proximate analyses

Volatile matter and fixed carbon contents are reported on a dry-ash-free basis to allow comparison with rank levels established by vitrinite reflectance determinations. The data are consistent with rank levels and trends established by reflectance measurements and clearly indicate that all samples fall in a rank range from subbituminous to high volatile B bitumi-

TABLE 3

Cutbank coal measures;
sample identification, petrographic and chemical characteristics

Trench	Sample (C no.)	Pellet no.	Thk (m)	R_o %	Maceral group analyses Vit. %	Int. %	Lipt. %	Proximate analyses Moist. as rec.	V.M. D.A.F.	F.C. D.A.F.	Ash % as rec.	S % as rec.	Cal. Val. Mst, A.F.
WA88004	166324	512 /88	0.55	0.68	92	6	2	12.3	40.9	59.1	35.9	0.22	10410
	166323	511 /88	0.30	0.63	92	5	3	11.4	42.4	57.6	14.3	0.40	11434
	166322	510 /88	0.45	0.62	87	11	2	8.0	40.1	60.0	23.5	0.21	12154
	166321	509 /88	0.12	0.65	73	22	5	7.5	38.5	61.5	22.1	0.25	12487
	166428	538 /88	0.30	0.67	84	12	4	6.7	40.2	59.8	12.8	0.25	12817
WA88005	166325	513 /88	1.50	0.63	87	10	3	7.4	44.2	55.8	36.1	0.34	11879
WA88008	166328	516 /88	0.75	-	75	20	5	11.9	43.8	56.2	12.1	0.29	10687
WA88010	166299	525 /88	0.30	0.69	68	29	3	6.9	40.9	59.1	21.2	0.24	12623
	166300	526 /88	0.30	0.69	76	20	4	6.6	40.7	59.3	19.2	0.32	12731
	166351	517 /88	0.75	0.68	82	16	2	10.6	43.2	56.8	24.1	0.27	11366
	166353	518 /88	0.15	0.68	83	14	3	6.5	43.0	57.0	23.0	0.32	12701
	166354	519 /88	0.50	0.70	91	6	3	8.2	43.0	57.2	24.3	0.30	12153
	166356	521 /88	0.20	0.65	88	9	3	7.1	40.7	59.3	17.3	0.34	12585
	166355	520 /88	0.45	0.66	90	7	3	10.8	44.7	55.5	26.5	0.15	11133
WA88009	166447	498 /88	1.30	0.68	81	14	5	8.2	41.1	58.9	8.0	0.37	12048
WA90002	190152	1111 /90	-	0.41	-	-	-	-	-	-	77.7	-	-
	190151	1112 /90	2.75	0.42	80	15	5	24.4	55.1	44.9	15.3	0.14	7662
	190153	1113 /90	0.90	0.41	78	18	4	19.3	58.0	42.0	28.1	0.14	7879
	190154	1114 /90	-	0.39	-	-	-	-	-	-	71.7	-	-
	190155	1115 /90	1.20	0.40	62	30	8	17.5	59.1	40.9	34.6	0.12	7876
	190156	1116 /90	0.50	0.41	75	16	9	20.6	54.2	45.8	20.0	0.24	7845
WA90003	190157	1117 /90	1.00	0.44	81	13	6	16.7	53.3	46.7	19.7	0.31	8760
	190158	1118 /90	0.30	0.44	91	8	1	12.4	65.4	34.3	54.1	0.13	7105
	190159	1119 /90	0.67	0.44	74	22	4	17.7	52.1	47.9	18.9	0.20	8629
	190160	1120 /90	0.40	0.41	68	26	6	13.8	56.5	43.5	35.6	0.24	8449
	190161	1121 /90	1.00	0.45	70	26	4	12.8	54.5	45.3	30.3	0.22	8782
WA90005	190164	1122 /90	0.90	0.51	78	9	13	4.8	60.2	39.8	47.7	0.48	11222
WA90006A	190162	1123 /90	1.00	0.41	82	11	7	21.0	52.8	46.0	15.8	0.30	7876
WA90007	190163	1124 /90	1.00	0.44	86	11	3	19.1	51.5	48.5	17.6	0.33	8405
WA90008	190165	1125 /90	1.50	0.55	94	3	3	6.0	40.6	59.4	16.7	1.63	12498
WA90009	190166	1126 /90	1.30	0.40	-	-	-	13.3	57.0	43.0	41.3	0.19	8438

nous (volatile matter 31 % (d.a.f.) and fixed carbon 69 % (d.a.f.)). The regional distribution in volatile matter contents for the various coal zones is shown in Figure 23. The pattern is similar to that described for the variations in vitrinite reflectance. Irregularities can be explained by differences in petrographic composition and varying degrees of weathering.

Ash contents in the Wapiti coals are highly variable throughout the study area, even differing significantly in samples collected from the same trench (Tables 2, 3 and 4).

Sulphur contents

The majority of the coals have low sulphur contents (less than 0.5 wt.%; Tables 2, 3 and 4). Slightly higher sulphur contents were determined in two samples from the lower Wapiti Formation (WA88018 = 0.52 wt.% and WA88017 = 0.79 wt.%). The highest sulphur content (1.63 wt.%) was determined in a sample from the Cutbank coal measures (WA90008, Table 3). That

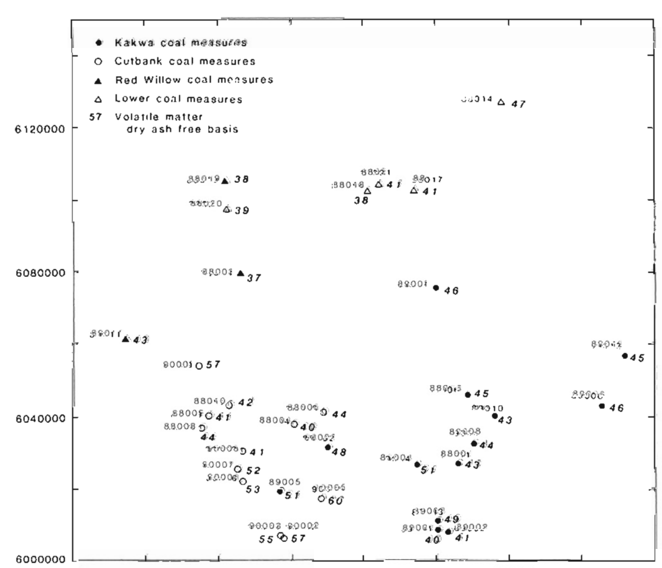


Figure 23. Averaged volatile matter contents (d.a.f.) for Wapiti coals. Geographic grid based upon UTM system.

TABLE 4

Kakwa coal measures; sample identification, petrographic and chemical characteristics

					Maceral group analyses			Proximate analyses					
Trench	Sample (C no.)	Pellet no.	Thk (m)	R_o %	Vit. %	Int. %	Lipt. %	Moist. as rec.	V.M. D.A.F.	F.C. D.A.F.	Ash % as rec.	S % as rec.	Cal. Val. Mst, A.F.
WA88001	166413	533 /88	0.50	0.61	97	1	2	15.7	45.1	55.1	32	0.61	9496
	166414	534 /88	0.10	0.61	85	12	3	9.6	44.9	55.1	24.9	0.69	10908
	166390	532 /88	1.40	0.55	68	28	4	11.3	39.8	60.0	14.4	0.25	10751
WA88002	166421	535 /88	0.75	0.50	56	36	8	27.3	48.3	51.7	10.6	0.11	8667
WA88006	166327	515 /88	0.57	0.56	52	44	4	11.1	44.6	55.4	31	0.32	10694
	166326	514 /88	0.57	0.54	63	33	4	12.1	43.6	56.4	24.4	0.29	10993
WA89001	166480	817 /89	0.50	0.61	78	17	5	9.3	40.1	59.9	22.4	0.4	11049
	166481	818 /89	0.30	0.54	-	-	-	9.2	-	-	76.3	0.04	-
	166482	819 /89	0.30	0.61	81	16	3	9	38.9	61.1	25	0.33	11144
WA89002	166486	820 /89	0.30	0.59	88	9	3	8.9	40.8	59.2	15.9	0.59	11153
WA89003	166485	821 /89	1.20	0.51	72	25	3	10.9	48.5	51.5	27.3	0.46	9664
WA89004	166487	822 /89	1.00	0.47	49	45	6	13.3	51.8	48.2	22.6	0.19	8643
WA89005	166479	829 /89	0.20	0.52	-	-	-	9.2	58.8	41.2	60.7	0.09	-
	166478	828 /89	0.20	0.53	72	25	3	10.6	48.4	51.6	28	0.37	10150
	166477	827 /89	0.10	0.52	-	-	-	11.4	-	-	75.2	0.11	-
	166476	826 /89	1.00	0.51	74	24	2	12.3	51.1	48.9	27	0.26	9226
	166475	825 /89	0.20	0.49	-	-	-	10.9	-	-	87.6	0.04	-
	166474	824 /89	0.70	0.53	78	17	5	10.1	56.2	42.2	39.9	0.34	9022
	166473	823 /89	0.20	0.53	-	-	-	7.2	-	-	66.1	0.29	-
WA89006	166464	836 /89	0.20	0.42	89	10	1	13.1	44.3	55.8	6.8	1.48	10266
	166459	835 /89	0.60	0.41	43	53	4	10.9	43.4	56.6	22.5	0.38	10471
	166458	834 /89	0.20	0.38	-	-	-	13.7	-	-	92.1	0.02	-
	166463	833 /89	0.20	0.44	-	-	-	8.6	62.1	38.3	63.2	0.16	7255
	166461	832 /89	0.70	0.44	61	34	5	10.6	53.5	46.5	46.4	0.21	9067
	166460	831 /89	0.30	0.41	-	-	-	11.2	-	-	91.5	-	-
	166462	830 /89	1.20	0.43	81	17	2	13.5	44.1	55.9	7.3	0.34	10717
WA89007	166469	-	0.15	-	-	-	-	5.7	-	-	86.6	0.05	-
	166472	842 /89	0.50	0.47	72	26	2	7.1	49.4	50.6	48.4	0.23	10746
	166468	841 /89	0.35	0.44	-	-	-	4.5	-	-	93	0.02	-
	166470	840 /89	0.35	0.48	87	9	4	11.5	42.3	57.7	14.2	0.38	11495
	166471	839 /89	0.05	0.47	-	-	-	-	-	-	84.3	0.02	-
	166467	838 /89	0.25	0.47	-	-	-	10.3	56.0	43.7	58.8	0.09	-
	166466	837 /89	0.65	0.50	93	7	0	12.5	39.5	60.5	9.8	0.33	-
WA89010	166488	845 /89	1.20	0.46	88	9	3	10.3	42.9	57.1	12.8	0.69	11162
WA89012	166457	852 /89	0.20	0.40	48	49	3	12.4	48.1	51.9	25.4	0.39	9972
	166453	850 /89	0.50	0.42	-	-	-	10.7	58.1	41.9	51.8	0.15	8122
	166456	851 /89	1.00	0.42	66	30	4	15.5	47.5	52.5	20.1	0.2	9243
	166455	854 /89	0.40	0.41	-	-	-	10.5	-	-	77.8	0.03	-
	166451	849 /89	0.70	0.40	67	29	4	12.2	43.1	56.8	25.1	0.23	10047
	166454	848 /89	0.90	0.39	-	-	-	9.3	77.6	22.4	73.7	0.02	-
	166452	847 /89	1.00	0.40	64	31	5	13.8	42.6	57.4	17.6	0.25	100085
	166491	853 /89	0.05	0.35	-	-	-	12.4	-	-	73.1	0.06	-
	166490	846 /89	0.50	0.42	81	17	2	14	43.5	56.5	8.8	0.32	10500
WA89008	166483	843 /89	1.30	0.46	65	30	5	11.5	43.7	56.1	15.1	0.41	10349
	166484	-	0.05	-	-	-	-	4.1	60.6	39.4	64.7	0.38	-

sample also had the highest amount of optically determined pyrite (3 Vol%). Since the remaining samples were found to contain only traces of pyrite it is suggested that most of the sulphur in the coals is organically bound.

Calorific values

Calorific values for the Wapiti coals are reported on a moist, mineral matter-free basis (Tables 2, 3 and 4). Calorific values range from less than 8300 btu/pound (lignite) for some of the samples from the Cutbank coal measures and lower Wapiti Formation to 13 277 btu/pound (high volatile B bituminous) in a sample from locality WA89011 in the western edge of the study area. The majority of the Wapiti coals are either subbituminous or high volatile C bituminous according to the A.S.T.M. rank classification based on calorific values for low rank coals. The regional variation of rank levels based on averaged calorific levels for the various trenches and coal zones are shown in Figure 24. The changes of rank with respect to geographic position and coal zone are consistent with those described based on vitrinite reflectance.

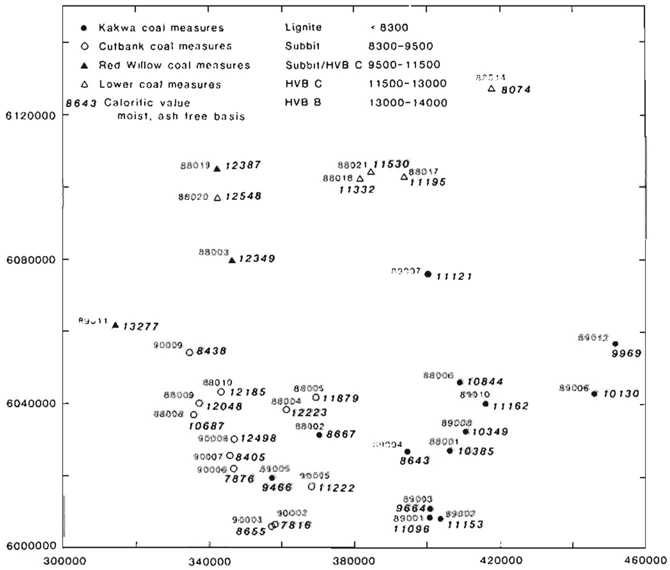


Figure 24. Averaged calorific values (BTU/pound) and inferred A.S.T.M. rank levels for Wapiti coals. Geographic grid based upon UTM system.

COAL RESOURCE POTENTIAL AND MINEABILITY

Red Willow coal measures

The Red Willow coal measures that outcrop along the Wapiti River and its tributaries tend to be relatively thin and discontinuous. Maximum thickness observed in outcrop was 1.9 m although subsurface data indicate that zones up to 4 m are present. Excellent exposures of the coal seams along the Red Willow River reveal the variable nature of the coal beds. Individual seams vary in thickness and the interseam partings display an even wider variability. The coal beds tend to degrade into carbonaceous shales and high-ash bony coal over very short distances.

Although there have been numerous small coal mines developed within the Red Willow coal measures during the last 75 years, most of these mines lie in or near the floors of the river valleys where the coals outcrop and overburden thicknesses are low. Above the valley floors, potential for thick coal lying at shallow depth is limited. It appears that of the three major coal measures within the Wapiti study area, the Red Willow has the lowest potential for contributing to the overall resource of the region.

Cutbank coal measures

Cross-section B–B′ (Fig. 5), which extends from south to north along the Morley Hill/Nose Mountain escarpment, illustrates the variable nature of the coal seams within the Cutbank coal measures. Along this ridge line the coal zones dip gently to the east, outcropping on the western edge of the escarpment. Downslope to the east, the Entrance Member caps the coal measures and forms an east-dipping dip slope for approximately 3 km into the valley of Wolf Creek and the Cutbank River. Coal resources at very shallow depth would lie beneath the Entrance Member in the areas to the east of Nose Mountain and Morley Hill.

Five distinct coal zones (A to F), have been recognized in borehole and outcrop within the Cutbank coal measures in this region. Zones C and D appear to be the most well developed. At the base of the section, zone A is generally less than 0.6 m thick and is considered too thin to be mineable. Zone B, lying approximately 40 to 50 m above zone A, is widely variable in thickness, but attains a maximum thickness of 1.8 m of which 1.1 m is coal. This zone thins to the north to form two seams, each less than 0.6 m thick, separated by 0.6 m of mudstone, and then pinches out to a coal zone less than 0.3 m thick. The area in which zone B attains a mineable thickness appears to be less than 8 km^2, thus the resource potential for this region is limited.

Coal zone C appears to attain a maximum thickness of 3.8 m in the south in borehole 80–4 near Morley Hill, and thins to less than 0.3 m to the northwest near Nose Mountain. The coal zone is composed of 3 seams (C1, C2, and C3 from top to bottom) and totals 2.7 m of total coal. In borehole 80–4 seams C1, C2 and C3 are 0.4 m, 0.8 m and 1.5 m thick, respectively. As with zone B, the area in which coal zone C is of mineable thickness appears to be limited to the region of Morley Hill. In this area, highly variable topography and pronounced valleys limit the areas of shallow, mineable coal.

Zone D represents the thickest and most laterally persistent coal horizon within the Cutbank coal measures. The zone attains a maximum thickness of 12.4 m of which 4.9 m is coal (Fig. 5). This borehole intersection corresponds closely with trench WA90002, in which 6.3 m of coal were observed over a 10.45 m section. In this section, three distinct plies were recognized, D1, D2 and D3. Ply D1 is up to 1.1 m thick with numerous thin claystone partings throughout. Lying approximately 3 m below is ply D2.

This coal seam is up to 2.75 m thick with a minimum of rock partings and forms the main mineable section. Zone D3 lies approximately 4 m below and attains a thickness of up to 0.9 m with several partings less than 0.05 m thick. In this interval it appears that seam D2 would be the major mining horizon while seams D1 and D3 could be considered as additional mineable resources, dependent on the seam quality. To the north, coal zone D pinches out rapidly to less than 1 m over a distance of less than 12 km before thickening again near the south end of Nose Mountain. It appears that the peats that were formed to produce the coals in the Cutbank measures were deposited in a series of restricted bogs surrounded by areas of limited peat deposition, typical of coals deposited in a fluvial environment. The aerial extent of these pods appears to be approximately 10 km^2.

Coal zones E and F are thin, discontinuous beds that lie approximately 20 and 40 m, respectively, above zone D. Both zones are widely variable in thickness and do not appear to attain sufficient thickness to be considered mineable.

Kakwa coal measures

The Kakwa coal measures comprise a stratigraphic interval of approximately 125 m, containing up to 12 coal seams. Detailed stratigraphic correlation of coal beds indicates that four main zones are present, each containing numerous coal beds separated by partings. These zones are defined as 1 to 4 from bottom to top. Here and there thin coals are found either below zone 1 or above zone 4, but these appear to be laterally discontinuous and have not been assigned correlative nomenclature. Table 3 summarizes the range of thickness and coal/rock ratio for the four main zones. If a parameter of minimum mining thickness of 0.6 m is applied, only zones 2 and 3 would be considered to be of mineable thickness over a sufficiently large area to provide an adequate resource base. Zones 1 and 4 do attain sufficient thickness to be considered surface mineable in local areas, however the lateral continuity of the thick development of coal appears to be very limited (see detailed correlation chart, Fig. 4).

Coal zone 2 has three main recognizable seams: A, B and C. Seam A is up to 0.5 m thick and lies from 1.9 to 17.3 m below the main 2B zone. This bed appears to be too thin and separated from the overlying 2B seam by too much interburden to be considered mineable. The 2B seam is well developed and relatively contiguous, ranging in thickness from 0.9 to 2.4 m. In places, the coal bed thins to less than 0.5 m, possibly due to localized channel effects of the surrounding sediments. Thin rock partings are commonly present within the 2B seam, and total coal averages 76 per cent of the total thickness. Lying stratigraphically above the 2B seam is the 2C coal seam. The interburden interval between the two coals varies from less than 1 m to greater than 15 m. Seam 2C is up to 3.0 m thick with a total coal thickness of 1.4 m, and an average of 0.6 m. The coal seam is widely variable in thickness and may be thick enough to be considered mineable (>0.6 m) in local areas. Coal seam 2C should probably be considered as a rider seam that may contain mineable coal, but only in the process of removing overburden to recover the coal from seam 2B.

Lying stratigraphically above zone 2 is coal zone 3. The interval of rock separating the two zones varies from 0 to 25 m, with an average of 10 m. In the northeast part of the study area (Twp. 66, Rge. 1, W6M), the two coal zones coalesce along with zone 4 to form a coal-bearing interval more than 17 m thick.

The lowest coal bed in zone 3 is seam A, a thin, shaly coal unit averaging 0.4 m in thickness. The rock interval separating 3A and overlying seam 3B ranges from 0.5 to 13.7 m with the average being 4.0 m. For most of the study area, seam 3A is too thin to be considered mineable, except to the northeast of the Smoky River, where the coal bed is less than 0.5 m thick below the main 3B seam.

The 3B seam is similar to the 2B seam; the coal bed is relatively contiguous with minor partings. The seam ranges from 0.8 to 2.7 m in thickness and averages 1.3 m total coal for the interval. Seam 3B attains its maximum development in Township 62, Range 6, W6M and thins to less than 1.0 m in Township 63, Range 5, W6M. Farther to the east 3B thickens again to become the dominant seam in the section.

Zone 4 is similar to Zone 1: thin, discontinuous coal seams over a thick stratigraphic interval. The zone is divided into two seams, A and B, both averaging less than 0.6 m in thickness. The anomaly to this stratigraphic interval is in the area northeast of the Smoky River, where zones 2, 3 and 4 have coalesced to form a thick, coaly interval. In this region zone 4 is greater than 0.8 m thick. In the area where the zones have merged, the entire coal interval is greater than 17 m thick, and comprises numerous thin coal seams separated by thin rock partings. Total coal for this interval averages 6.1 m but less than 2.5 m of the coal is contained in seams greater than 0.6 m thick. If the entire zone were considered for mining, significant coal resources exist, but the mine product would contain a very high ash content due to the number of non-removable partings within the section.

CONCLUSIONS

The Wapiti study area, encompassing approximately 185 townships in northwestern Alberta, contains potentially mineable coal resources of Upper Cretaceous to Tertiary age. Three distinct coal measures have been defined: the Red Willow, Cutbank and Kakwa. Other thin, discontinuous coal beds lie near the base of the stratigraphic succession. Up to 12 coal zones are present within each measure and individual seams are widely variable in thickness and lateral continuity. In several localities, the individual coal seams have coalesced to form zones more than 6 m thick. The coal is widely variable in rank, ranging from lignite to high volatile A bituminous, and is suitable for thermal power generation. Regional mapping and subsurface analyses of data have delineated several areas that contain coal seams of potentially mineable thickness at shallow depths. These large areas indicate that the resource potential for surface mineable coal within the Wapiti study area is high and this region should be considered as a major source of thermal coal for future development projects in northern Alberta.

ACKNOWLEDGMENTS

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REFERENCES

Allan, J.A. and Carr, J.L.
1946: Geology and coal occurrences of the Wapiti-Cutbank area, Alberta. Research Council of Alberta, Report no. 48.

Allan, J.A. and Rutherford, R.L.
1934: Geology of central Alberta. Research Council of Alberta, Report 30.

Baofang, L. and Dawson, F.M.
1988: Stratigraphic framework and depositional setting, Judy Creek coalfield, northern Alberta. *In* Current Research, Part D. Geological Survey of Canada, Paper 88-1D, p. 121-128.

Binda, P.L.
1991: The Battle Formation: a lacustrine episode in the late Maastrichtian of Western Canada. *In* Aspects of nonmarine Cretaceous geology, N.J. Mateer and P.J. Chen (eds.). Beijing, China Ocean Press, p. 202-217.

Bustin, M.R., Cameron, A.R., Grieve, D., and Kalkreuth, W.D.
1989: Coal Petrology — Its Principles, Methods and Applications. Geological Association of Canada, Short Course Notes, v. 3, 3rd edition, 273 p.

Christophel, D.C.
1976: Fossil floras of the Smoky Tower locality, Alberta, Canada. Palaeontographica, Abt. B, v. 157, p. 140.

Davis, A.
1978: The measurement of the reflectance of coal macerals — its automation and significance. Pennsylvania State University, Technical Report 10, 88 p.

Dawson, F.M. and Kalkreuth, W.D.
1989: Preliminary results of a continuing study of the stratigraphic context, distribution and characteristics of coals in the Upper Cretaceous to Paleocene Wapiti Group, northwestern Alberta. *In* Contributions to Canadian Coal Geoscience, Geological Survey of Canada, Paper 89-8, p. 43-48.

Dawson, F.M., Jerzykiewicz, T., and Sweet, A.R.
1989: A preliminary analysis of the stratigraphy and sedimentology of the coal-bearing Wapiti Group, northwestern Alberta. *In* Advances in Western Canadian Coal Geoscience. Alberta Research Council, Information Series no. 103, p. 113.

Dawson, G.M.
1881: Report on an exploration from Port Simpson on the Pacific coast to Edmonton on the Saskatchewan, embracing a portion of the northern part of British Columbia and the Peace River country. Geological Survey of Canada, Report of Progress, 1879-80, Part B.

Demchuk, T.D.
1990: Palynostratigraphic zonation of Paleocene strata in the central and south-central Alberta Plains. Canadian Journal of Earth Sciences, v. 27, no. 10, p. 1263-1269.

Eberth, D.A., Braman, D.R., and Tokaryk, T.T.
1990: Stratigraphy, sedimentology and vertebrate paleontology of the Judith River Formation (Campanian) near Muddy Lake, west-central Saskatchewan. Bulletin of Canadian Petroleum Geology, v. 38, p. 387-406.

Jerzykiewicz, T. and McLean, J.R.
1977: Bedded volcanic chert near Coalspur central foothills, Alberta. *In* Current Research, Part B. Geological Survey of Canada, Paper 77-1B, p. 149-155.

1980: Lithostratigraphical and sedimentological framework of coal-bearing Upper Cretaceous and Lower Tertiary strata, Coal Valley area, central Alberta foothills. Geological Survey of Canada, Paper 79-12.

Jerzykiewicz, T. and Sweet, A.R.
1986: The Cretaceous-Tertiary boundary in the central Alberta foothills: I. Stratigraphy. Canadian Journal of Earth Sciences, v. 23, p. 1356-1374.

1988: Sedimentological and palynological evidence of regional climatic changes in Campanian to Paleocene sediments of the Rocky Mountain Foothills, Canada. Sedimentary Geology, v. 59, p. 29–76.

Kramers, J.W. and Mellon, G.B.
1972: Upper Cretaceous–Paleocene coal-bearing strata, northwest-central Alberta Plains. *In* Proceedings First Geological Conference on Western Canadian Coal, G.B. Mellon, J.W. Kramers, and E.J. Seagel (eds.). Research Council of Alberta, Report 60, p. 109–124.

Lerbekmo, J.L., Sweet, A.R., and St. Louis, R.M.
1987: The relationship between the iridium anomaly and palynological floral events at three Cretaceous/Tertiary boundary localities in western Canada. Geological Society of America, Bulletin, v. 99, p. 325–330.

Mack, G.H. and Jerzykiewicz, T.
1989: Provenance of post-Wapiabi sandstones and its implications for Campanian to Paleocene tectonic history of the southern Canadian Cordillera. Canadian Journal of Earth Sciences, v. 26, p. 665–676.

McIver, E.E., Sweet, A.R., and Basinger, J.F.
1991: Sixty-five million year old flowers bearing pollen of the extinct triprojectate complex — a Cretaceous–Tertiary boundary survivor. Review of Palaeobotany and Palynology, v. 70, p. 77–88.

McLean, J.R. and Jerzykiewicz, T.
1980: Biostratigraphical and sedimentological framework of coal-bearing Upper Cretaceous and Lower Tertiary strata, Coal Valley area, central Alberta foothills. Geological Survey of Canada, Paper 79-12.

McLearn, F.H.
1919: Cretaceous, Lower Smoky River, Alberta. Geological Survey of Canada, Summary Report, Part C, p. 17.

McMechan, M. and Dawson, F.M.
1990: Wapiti mapsheet. Geological Survey of Canada, Open File 2313.

Nichols, D.J. and Ott, H.L.
1976: Biostratigraphy and evolution of the *Momipites–Caryapollenites* lineage in the Early Tertiary in the Wind River Basin, Wyoming. Palynology, v. 2, p. 93–112.

1978: Biostratigraphy and evolution of the *Momipites–Caryapollenites* lineage in the Early Tertiary in the Wind River Basin, Wyoming. Palynology, v. 2, p. 93–112.

Nichols, D.J. and Sweet, A.R.
in press: Biostratigraphy of Upper Cretaceous nonmarine palynofloras in a north-south transect of the Western Interior Basin. *In* Geological Association of Canada, Special Paper, W.G.E. Caldwell and E.G. Kauffman (eds.).

Norris, G., Jarzen, D.M., and Awai-Thorne, B.V.
1975: Evolution of the Cretaceous terrestrial palynoflora in Western Canada. *In* The Cretaceous System of the Western Interior of North America, W.G.E. Caldwell (ed.). Geological Association of Canada, Special Paper 13, p. 31–54.

Rosenthal, L., Leckie, D., and Nadon, G.
1984: Depositional cycles and facies relationships within the Upper Cretaceous and Belly River formations of west-central Alberta. Canadian Society of Petroleum Geologists, Guidebook.

Srivastava, S.K.
1970: Pollen biostratigraphy and paleoecology of the Edmonton Formation (Maestrichtian), Alberta, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 7, p. 221–276.

Stott, D.F.
1961: Dawson Creek map area, British Columbia. Geological Survey of Canada, Paper 61-10.

1984: Cretaceous sequences of the Foothills of the Canadian Rocky Mountains. *In* The Mesozoic of Middle North America, D.F. Stott and D.J. Glass (eds.). Canadian Society of Petroleum Geologists, Memoir 9, p. 85–107.

Sweet, A.R.
1980: Appendix 1, Palynology. *In* Lithostratigraphical and sedimentological framework of coal-bearing Upper Cretaceous and Lower Tertiary strata, Coal Valley area, Central Alberta foothills, T. Jerzykiewicz and J.R. McLean. Geological Survey of Canada, Paper 79-12, p. 27–31.

Sweet, A.R. and Braman, D.R.
1989: A distinctive terrestrial palynofloral assemblage from the lower Campanian, Chungo Member, Wapiabi Formation, southwestern Alberta: a key to regional correlations. *In* Contributions to Canadian Coal Geoscience, Geological Survey of Canada, Paper 89-8, p. 32–40.

1992: The KT boundary and contiguous strata in western Canada: interaction between paleoenvironments and palynological assemblages. Cretaceous Research, v. 13, p. 31–79.

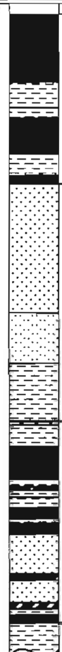
Sweet, A.R., Ricketts, B.D., Cameron, A.R., and Norris, D.K.
1989: An integrated analysis of the Brackett coal basin, Northwest Territories. Geological Survey of Canada, Paper 89-1, p. 85–89.

Wall, J.H. and Sweet, A.R.
1982: Upper Cretaceous–Paleocene stratigraphy, micropaleontology and palynology of the Bow Valley area, Alberta. Canadain Society of Petroleum Geologists, Field Trip (no. 10) Guidebook, 47 p.

APPENDIX 1

Measured coal sections and trench locations

continued on page 2



DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF			0.90										
			0.50										
		166413	0.50	15.7	6457	32.0	23.6	28.8	0.61	0.61	97	1	2
			0.30										
FLOOR			0.10										
	TOTAL ZONE		2.30										
	TOTAL COAL		1.50										
ROOF			[illegible]										
			0.30										
			0.45										
			0.40										
			0.15										
			[illegible]										
			0.15										
			1.05										
			0.08										
			0.30										
	0.08		0.08										
FLOOR		166414	0.10	9.6	8192	24.9	29.4	36.1	0.69	0.61	85	17	3
OUTCROP SECTION	TOTAL ZONE		3.26										
SMOKY RIVER	TOTAL COAL		0.93										

COMPOSITE ANALYSES

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

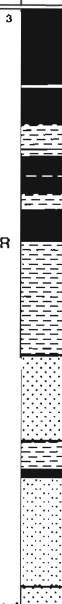
TRENCH: WA88001 Page 1 of 3

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6027150
EASTING 406240
ZONE 11
LSD.
SEC. 30
TWP. 62
RGE. 3
MER. W6

continued on page 3



DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
			2.35										
			0.05										
			0.50										
			0.35										
			0.12										
			0.50										
			0.25										
			0.40										
FLOOR	TOTAL ZONE		6.55										
	TOTAL COAL		5.15										
			0.10										
OUTCROP SECTION													
SMOKY RIVER													

continued from page 1

COMPOSITE ANALYSES

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA88001 Page 2 of 3

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING
EASTING
ZONE
LSD.
SEC.
TWP.
RGE.
MER.

WAPITI PROJECT

TRENCH: WA88001 Page 3 of 3

SCALE: 0 0.5 1.0 m

DESCRIPTIVE COMMENTS	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF	166390	1.40 (comp)	11.3	9203	14.4	29.6	44.6	0.25	0.55	69	29	4
		0.63										
continued from page 2												
OUTCROP SECTION SMOKY RIVER												

COAL ZONE

COMPOSITE ANALYSES

LEGEND

Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
Bentonitic mudstone
Concretion
Sandstone
Siltstone

LOCATION:
NORTHING ____
EASTING ____
ZONE ____
LSD. ____
SEC. ____
TWP. ____
RGE. ____
MER. ____

WAPITI PROJECT

TRENCH: WA88002

SCALE: 0 0.5 1.0 m

DESCRIPTIVE COMMENTS	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF NOT EXPOSED	166421	>1.00	27.3	7748	10.6	30.0	32.1	0.11	0.50	57	35	8
FLOOR												
OUTCROP SECTION KAKWA TOWER												

COAL ZONE

COMPOSITE ANALYSES

LEGEND

Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
Bentonitic mudstone
Concretion
Sandstone
Siltstone

LOCATION:
NORTHING 6031720
EASTING 370600
ZONE 11
LSD. ____
SEC. 4
TWP. 63
RGE. 7
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		166423	1.10	8.8	9889	19.6	25.7	45.8	0.18	0.67	66	29	5
			0.15										
		166320	0.45	9.5	11059	10.8	29.6	50.0	0.25	0.68	91	7	2
FLOOR			0.15										
OUTCROP SECTION	TOTAL ZONE		1.85										
PINTO CREEK	TOTAL COAL		1.55	COMPOSITE ANALYSES									

LEGEND

Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
B-B-B Bentonitic mudstone
C-C-C Concretion
Sandstone
Siltstone

WAPITI PROJECT

TRENCH: WA88003

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6079790
EASTING 346550
ZONE 11
LSD.
SEC. 36
TWP. 67
RGE. 10
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF			0.05										
		166324	0.55	12.3	6673	35.9	21.2	30.6	0.22	0.68	92	6	2
		166323	0.30	11.4	9799	14.3	31.5	42.8	0.40	0.63	92	5	3
			0.20										
			0.05										
			0.60										
			0.05										
		166322	0.45	8.0	9298	23.5	27.5	41.1	0.21	0.62	87	11	2
		166321	0.12	7.5	9727	22.1	27.1	43.3	0.25	0.65	73	22	5
		166428	0.30	6.7	11176	12.8	32.4	48.1	0.25	0.67	84	12	4
FLOOR													
OUTCROP SECTION	TOTAL ZONE		2.70										
CUTBANK RIVER	TOTAL COAL		1.22	COMPOSITE ANALYSES									

LEGEND

Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
B-B-B Bentonitic mudstone
C-C-C Concretion
Sandstone
Siltstone

WAPITI PROJECT

TRENCH: WA88004

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6038350
EASTING 361270
ZONE 11
LSD.
SEC. 28
TWP. 63
RGE. 8
MER. W6

DESCRIPTIVE COMMENTS		COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES: H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	PETROGRAPHIC ANALYSES (VOLUME %): Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF				0.6										
				3.00										
				0.30										
				3.00										
FLOOR			166325	1.50	7.4	7591	36.1	25.0	31.5	0.34	0.63	87	10	3
OUTCROP SECTION CUTBANK RIVER		TOTAL ZONE		8.40	COMPOSITE ANALYSES									
		TOTAL COAL		2.40										

LEGEND

Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
Bentonitic mudstone
Concretion
Sandstone
Siltstone

WAPITI PROJECT

TRENCH: WA88005

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6041790
EASTING 369250
ZONE 11

LSD.
SEC. 5
TWP. 64
RGE. 7
MER. W6

DESCRIPTIVE COMMENTS		COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES: H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	PETROGRAPHIC ANALYSES (VOLUME %): Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
continued on page 2														
ROOF				2.00										
FLOOR		TOTAL ZONE		2.00										
		TOTAL COAL		2.00										
ROOF				4.50										
FLOOR		TOTAL ZONE		4.50										
Covered interval ~ 20 metres		TOTAL COAL		3.50										
ROOF			166327 166326	1.15	11.1 12.1	7379 8311	31.0 24.4	25.8 27.7	32.1 35.8	0.32 0.29	0.56 0.54	52 63	44 33	4 4
FLOOR				0.80										
OUTCROP SECTION KAKWA RIVER		TOTAL ZONE		1.95	COMPOSITE ANALYSES									
		TOTAL COAL		1.15										

LEGEND

Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
Bentonitic mudstone
Concretion
Sandstone
Siltstone

WAPITI PROJECT

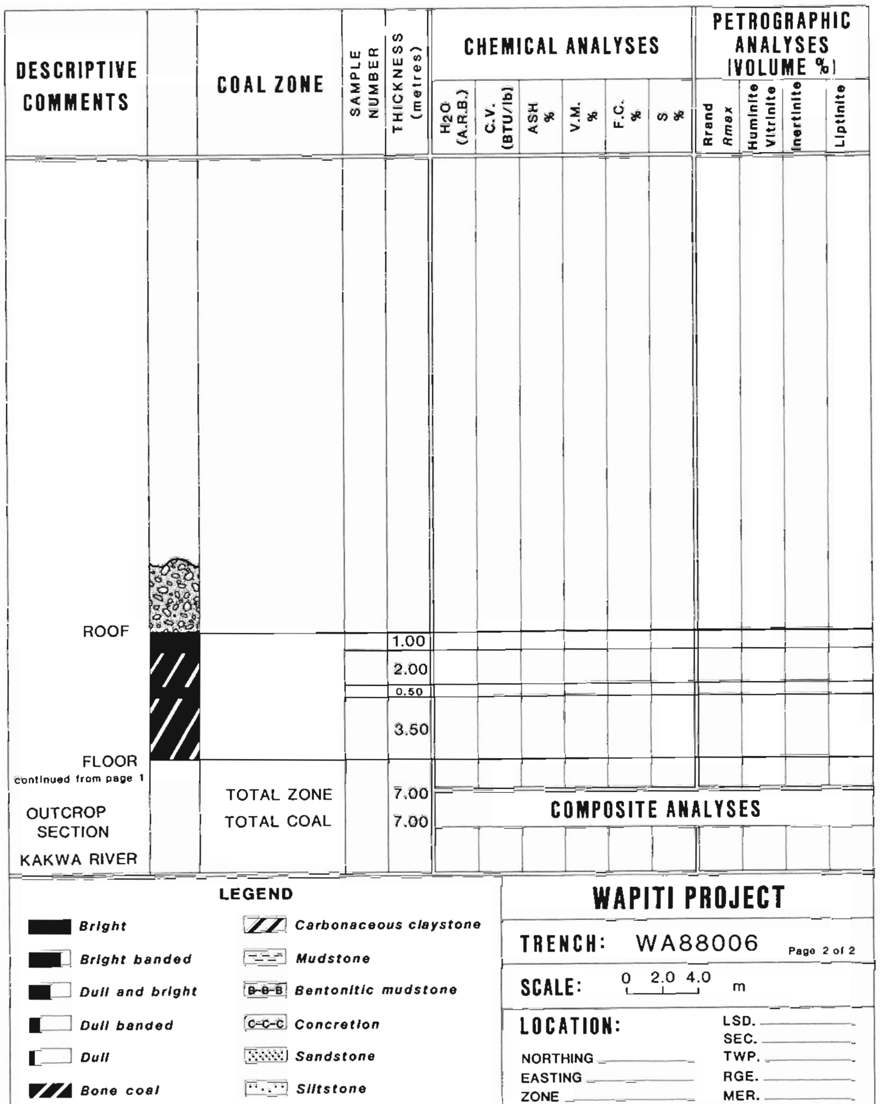
TRENCH: WA88006 Page 1 of 2

SCALE: 0 2.0 4.0 m

LOCATION:

NORTHING 6046200
EASTING 408710
ZONE 11

LSD.
SEC. 20
TWP. 64
RGE. 3
MER. W6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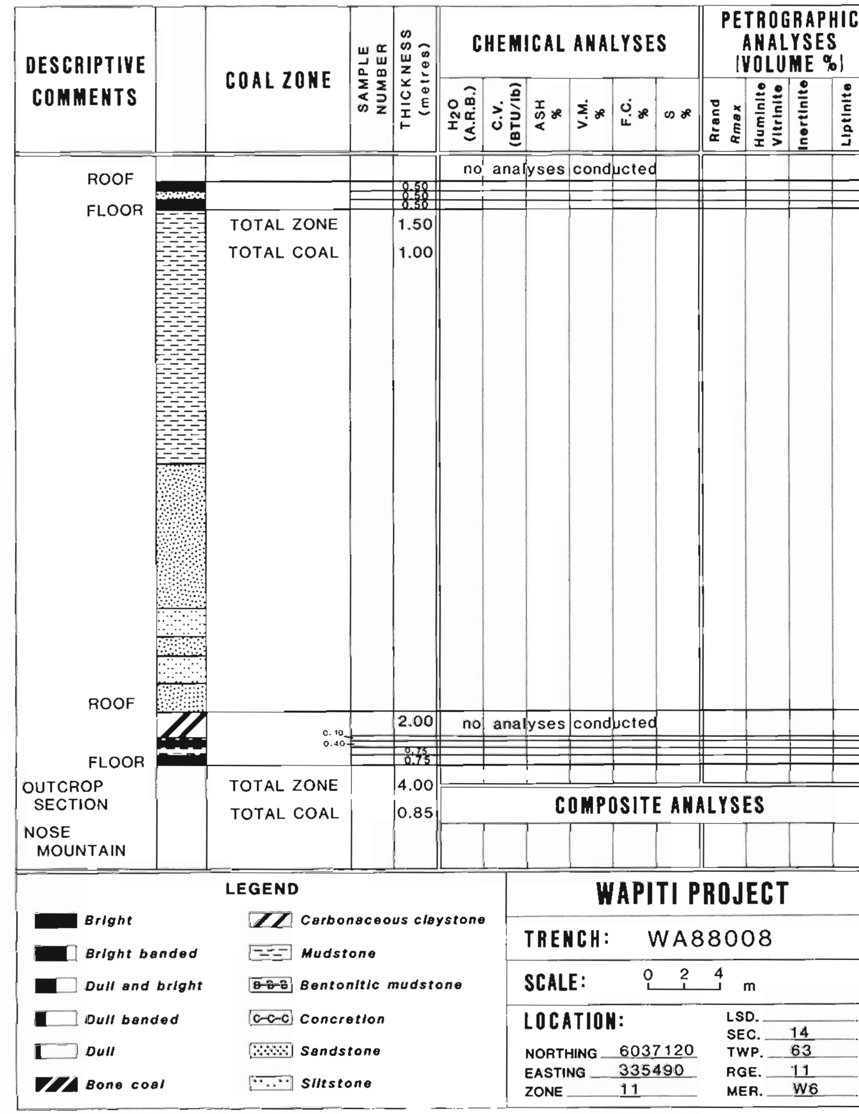
COAL ZONE
SAMPLE NUMBER
THICKNESS (metres)
CHEMICAL ANALYSES
H2O (A.R.B.)
C.V. (BTU/lb)
ASH %
V.M. %
F.C. %
S %
PETROGRAPHIC ANALYSES (VOLUME %)
Rrand
Rmax
Huminite Vitrinite
Inertinite
Liptinite
ROOF
1.00
2.00
0.50
3.50
FLOOR
continued from page 1
TOTAL ZONE
7.00
TOTAL COAL
7.00
COMPOSITE ANALYSES
OUTCROP SECTION
KAKWA RIVER
LEGEND
Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
Bentonitic mudstone
Concretion
Sandstone
Siltstone
WAPITI PROJECT
TRENCH: WA88006
Page 2 of 2
SCALE: 0 2.0 4.0 m
LOCATION:
NORTHING
EASTING
ZONE
LSD.
SEC.
TWP.
RGE.
MER.


DESCRIPTIVE COMMENTS
COAL ZONE
SAMPLE NUMBER
THICKNESS (metres)
CHEMICAL ANALYSES
H2O (A.R.B.)
C.V. (BTU/lb)
ASH %
V.M. %
F.C. %
S %
PETROGRAPHIC ANALYSES (VOLUME %)
Rrand
Rmax
Huminite Vitrinite
Inertinite
Liptinite
ROOF
no analyses conducted
0.50
0.50
0.50
FLOOR
TOTAL ZONE
1.50
TOTAL COAL
1.00
ROOF
2.00
no analyses conducted
0.10
0.40
0.75
0.75
FLOOR
TOTAL ZONE
4.00
TOTAL COAL
0.85
COMPOSITE ANALYSES
OUTCROP SECTION
NOSE MOUNTAIN
LEGEND
Bright
Bright banded
Dull and bright
Dull banded
Dull
Bone coal
Carbonaceous claystone
Mudstone
Bentonitic mudstone
Concretion
Sandstone
Siltstone
WAPITI PROJECT
TRENCH: WA88008
SCALE: 0 2 4 m
LOCATION:
NORTHING 6037120
EASTING 335490
ZONE 11
LSD.
SEC. 14
TWP. 63
RGE. 11
MER. W6

WAPITI PROJECT

TRENCH: WA88009

SCALE: 0 0.5 1.0 m

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		166447	1.30	8.2	11084	8.0	34.4	49.4	0.37	0.74	81	14	5
FLOOR													
OUTCROP SECTION	TOTAL ZONE		1.30	COMPOSITE ANALYSES									
CUTBANK RIVER	TOTAL COAL		1.30										

Column groups: CHEMICAL ANALYSES (H2O to S); PETROGRAPHIC ANALYSES (VOLUME %) (Rrand Rmax to Liptinite).

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

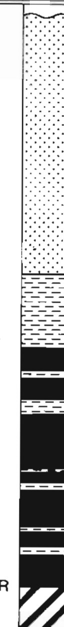
LOCATION:

NORTHING 6040460
EASTING 337350
ZONE 11
LSD.
SEC. 36
TWP. 63
RGE. 11
MER. W6

WAPITI PROJECT

TRENCH: WA88010

SCALE: 0 0.5 1.0 m



DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		166299	0.30	6.9	9947	21.2	29.4	42.5	0.24	0.69	68	29	3
			0.10										
		166300	0.30	6.6	10287	19.2	30.2	44.0	0.32	0.69	76	20	4
			0.20										
		166351	0.75	10.6	8627	24.1	28.2	37.1	0.27	0.68	82	16	2
			0.05										
		166353	0.15	6.5	9780	23.0	30.3	40.2	0.32	0.68	83	14	3
			0.10										
		166354	0.50	8.2	9200	24.3	29.0	38.6	0.30	0.70	91	6	3
			0.05										
		166356	0.20	7.1	10408	17.3	30.8	44.8	0.34	0.65	88	9	3
			0.10										
		166358	0.45	10.8	8183	26.5	28.0	34.8	0.15	0.66	90	7	3
FLOOR													
OUTCROP SECTION	TOTAL ZONE		3.25	COMPOSITE ANALYSES									
CUTBANK RIVER	TOTAL COAL		2.65										

Column groups: CHEMICAL ANALYSES (H2O to S); PETROGRAPHIC ANALYSES (VOLUME %) (Rrand Rmax to Liptinite).

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

LOCATION:

NORTHING 6043270
EASTING 343250
ZONE 11
LSD.
SEC. 3
TWP. 63
RGE. 10
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES						PETROGRAPHIC ANALYSES (VOLUME %)			
				H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF / FLOOR		166359	0.45	30.5	7234	10.4	27.9	31.3	0.30	0.46	75	21	4
OUTCROP SECTION SMOKY RIVER	TOTAL ZONE		0.45	COMPOSITE ANALYSES									
	TOTAL COAL		0.45										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA88014

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6127130
EASTING 417760
ZONE 11

LSD.
SEC. 31
TWP. 72
RGE. 2
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES						PETROGRAPHIC ANALYSES (VOLUME %)			
				H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF		166360	1.90	8.7	10842	12.5	30.4	48.4	0.37	0.68	88	10	2
FLOOR		166372		9.4	11354	8.3	30.5	51.8	0.24	0.63	90	8	2
OUTCROP SECTION RED WILLOW RIVER	TOTAL ZONE		1.90	COMPOSITE ANALYSES									
	TOTAL COAL		1.90										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA88019

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6104960
EASTING 342270
ZONE 11

LSD.
SEC. 16
TWP. 70
RGE. 10
MER. W6

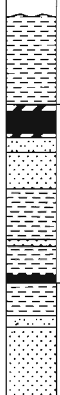
WAPITI PROJECT

TRENCH: WA88020

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6097190, EASTING 342590, ZONE 11; LSD. ___, SEC. 28, TWP. 69, RGE. 10, MER. W6

OUTCROP SECTION WAPITI RIVER



DESCRIPTIVE COMMENTS	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF		[illegible]										
	166361	0.30	6.7	10424	17.8	30.1	45.4	0.48	0.66	82	15	3
		[illegible]										
		0.20										
		0.50										
		0.70										
		0.10										
		0.40										
FLOOR	166357	0.10	7.6	10378	16.4	28.5	47.6	0.28	0.68	81	15	2

COAL ZONE	THICKNESS (metres)
TOTAL ZONE	2.45
TOTAL COAL	0.40

COMPOSITE ANALYSES

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA88021

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6104170, EASTING 384680, ZONE 11; LSD. ___, SEC. 23, TWP. 70, RGE. 6, MER. W6

OUTCROP SECTION WAPITI RIVER

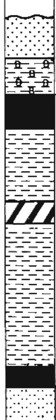
DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF			0.20										
	0.05												
		166358	0.30	13.3	10216	11.4	30.7	44.7	0.49	0.56	84	14	2
			0.20										
			0.10										
FLOOR			0.10										

COAL ZONE	THICKNESS (metres)
TOTAL ZONE	0.95
TOTAL COAL	0.30

COMPOSITE ANALYSES

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone



DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
			0.50										
ROOF		166480	0.50	9.3	8574	22.4	27.4	40.9	0.40	0.61	78	17	5
			1.00										
		166481	0.30	9.2		76.3			0.04	0.54			
			2.00										
FLOOR		166482	0.30	9.0	8358	25.0	25.7	40.3	0.33	0.61	81	16	3
OUTCROP SECTION				COMPOSITE ANALYSES									
BOLTON CREEK	TOTAL ZONE		4.10										
	TOTAL COAL		1.10										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA89001

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6008820
EASTING 400750
ZONE 11
LSD.
SEC. 27
TWP. 60
RGE. 4
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF			1.00										
			0.30										
			0.20										
		166486	0.30	8.9	9380	15.9	30.7	44.5	0.59	0.59	88	9	3
FLOOR													
OUTCROP SECTION				COMPOSITE ANALYSES									
BOLTON CREEK	TOTAL ZONE		1.80										
	TOTAL COAL		0.60										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA89002

SCALE: 0 0.5 1.0 m

LOCATION:

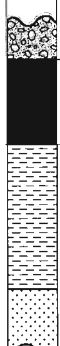
NORTHING 6008350
EASTING 403400
ZONE 11
LSD.
SEC. 26
TWP. 60
RGE. 4
MER. W6

WAPITI PROJECT

TRENCH: WA89003

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6011400; EASTING 400750; ZONE 11; LSD. ; SEC. 3; TWP. 61; RGE. 4; MER. W6



DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		166485	1.20	10.9	7026	27.3	30.0	31.8	0.46	0.51	72	25	3
FLOOR													
OUTCROP SECTION	TOTAL ZONE		1.20	COMPOSITE ANALYSES									
SMOKY RIVER	TOTAL COAL		1.20										

WAPITI PROJECT

TRENCH: WA89004

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6027240; EASTING 394800; ZONE 11; LSD. ; SEC. 24; TWP. 62; RGE. 5; MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
			0.50										
			2.00										
ROOF			0.60										
			0.30										
		166487	1.00	13.3	6690	22.6	33.2	30.9	0.19	0.47	49	45	6
FLOOR			[illegible]										
OUTCROP SECTION	TOTAL ZONE		1.90	COMPOSITE ANALYSES									
	TOTAL COAL		1.60										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA89005

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6019650 EASTING 357150 ZONE 11 LSD. SEC. 30 TWP. 61 RGE. 8 MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF			0.40										
			0.20										
			0.20										
			0.50										
		166479	0.20	9.2		60.7	17.7	12.4	0.09	0.52			
		166478	0.20	10.6	7308	28.0	29.7	31.7	0.37	0.53	72	25	3
		[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]			
		166476	1.00	12.3	6735	27.0	31.0	29.7	0.26	0.51	74	24	2
		166475	0.20	10.9		87.6			0.04	0.49			
		166474	0.70	10.1	5422	39.9	28.1	21.1	0.34	0.53	78	17	5
FLOOR		166473	0.20	7.2		66.1			0.29	0.53			
OUTCROP SECTION REDROCK CK.	TOTAL ZONE		3.90	COMPOSITE ANALYSES									
	TOTAL COAL		1.90										

WAPITI PROJECT

TRENCH: WA89007

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6075700 EASTING 400250 ZONE 11 LSD. SEC. 21 TWP. 67 RGE. 4 MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF			0.30										
		166469	0.15	5.7		86.6			0.05				
		166472	0.50	7.1	5545	48.4	22.0	22.5	0.23	0.47	72	26	2
		166468	0.35	4.5		93.0			0.02	0.44			
		166470	0.35	11.5	9863	14.2	31.4	42.9	0.38	0.48	87	9	4
	166471		[illegible]			[illegible]			[illegible]	[illegible]			
		166467	0.25	10.3		58.8	17.3	13.5	0.09	0.47			
		166466	0.65	12.5		9.8	30.7	47.0	0.33	0.50	93	7	0
FLOOR			0.20										
OUTCROP SECTION SMOKY RIVER	TOTAL ZONE		2.35	COMPOSITE ANALYSES									
	TOTAL COAL		1.50										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- Bentonitic mudstone
- Concretion
- Sandstone
- Siltstone

WAPITI PROJECT — TRENCH: WA89008

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		166483	1.30	11.5	8786	15.1	32.1	41.2	0.41	0.46	65	30	5
FLOOR			0.20										
		[illegible]	0.05	3.1		54.7	18.9	[illegible]	0.18				
OUTCROP SECTION													
SMOKY RIVER	TOTAL ZONE		1.30	COMPOSITE ANALYSES									
	TOTAL COAL		1.30										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA89008

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6032400
EASTING 410500
ZONE 11

LSD.
SEC. 9
TWP. 63
RGE. 3
MER. W6

WAPITI PROJECT — TRENCH: WA89009

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
	Top of zone was not excavated due to covered interval			NO ANALYSES DUE TO QUALITY						COMPLETED OF OUTCROP			
			0.30										
			0.20										
			0.60										
			0.30										
			0.20										
			0.30										
			0.80										
FLOOR													
HIGHLY WEATHERED OUTCROP SECTION													
SMOKY RIVER	TOTAL ZONE		>2.7	COMPOSITE ANALYSES									
	TOTAL COAL		>1.7										

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA89009

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6043650
EASTING 416150
ZONE 11

LSD.
SEC. 18
TWP. 64
RGE. 2
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES						PETROGRAPHIC ANALYSES (VOLUME %)			
				H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
FLOOR		166488	1.20	10.3	9733	12.8	33.0	43.9	0.69	0.46	88	9	3
OUTCROP SECTION				COMPOSITE ANALYSES									
SMOKY RIVER	TOTAL ZONE		1.20										
	TOTAL COAL		1.20										

LEGEND

Bright	Carbonaceous claystone
Bright banded	Mudstone
Dull and bright	Bentonitic mudstone
Dull banded	Concretion
Dull	Sandstone
Bone coal	Siltstone

WAPITI PROJECT

TRENCH: WA89010

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6040300
EASTING 415950
ZONE 11

LSD.
SEC. 6
TWP. 64
RGE. 2
MER. W6

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES						PETROGRAPHIC ANALYSES (VOLUME %)			
				H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF		166492	1.70	4.3	10595	20.2	32.8	42.7	0.44	0.66	91	5	4
FLOOR													
OUTCROP SECTION				COMPOSITE ANALYSES									
NARRAWAY RIVER	TOTAL ZONE		1.70										
	TOTAL COAL		1.70										

LEGEND

Bright	Carbonaceous claystone
Bright banded	Mudstone
Dull and bright	Bentonitic mudstone
Dull banded	Concretion
Dull	Sandstone
Bone coal	Siltstone

WAPITI PROJECT

TRENCH: WA89011

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6061400
EASTING 314650
ZONE 11

LSD.
SEC. 34
TWP. 65
RGE. 13
MER. W6

WAPITI PROJECT — TRENCH: WA89012

Descriptive Comments	Sample Number	Thickness (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	Ash %	V.M. %	F.C. %	S %	Rrand / Rmax	Huminite / Vitrinite	Inertinite	Liptinite
ROOF		0.20										
	166457	0.20	12.4	7439	26.4	29.9	32.3	0.39	0.40	48	49	3
	166453	0.50	10.7	3915	51.8	21.8	15.7	0.15	0.42			
	166456	1.00	15.5	7385	20.1	30.6	33.8	0.20	0.42	66	30	4
	166455	0.40	10.5		77.8			0.03	0.41			
	166451	0.70	12.2	7525	25.1	27.0	35.6	0.23	0.40	67	29	4
	166454	0.90	9.3		73.7	13.2	3.8	0.02	0.39			
	166452	1.00	13.8	8310	17.6	29.2	39.4	0.25	0.40	64	31	5
	166491	0.05	12.4		73.1			0.06	0.35			
FLOOR	166490	0.50	14.0	9576	8.8	33.6	43.6	0.32	0.42	81	17	2

OUTCROP SECTION
DEEP VALLEY CREEK

TOTAL ZONE 4.95
TOTAL COAL 3.40

COMPOSITE ANALYSES

LEGEND: Bright; Bright banded; Dull and bright; Dull banded; Dull; Bone coal; Carbonaceous claystone; Mudstone; Bentonitic mudstone; Concretion; Sandstone; Siltstone

WAPITI PROJECT

TRENCH: WA89012

SCALE: 0 0.5 1.0 m

LOCATION:
NORTHING 6056550
EASTING 451900
ZONE 11
LSD.
SEC. 29
TWP. 64
RGE. 25
MER. W5

WAPITI PROJECT — TRENCH: WA90002

Descriptive Comments	Sample Number	Thickness (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	Ash %	V.M. %	F.C. %	S %	Rrand / Rmax	Huminite / Vitrinite	Inertinite	Liptinite
		0.30										
		0.10										
		0.20										
		0.05										
		0.10										
		0.45										
		0.90										
	190155	1.20	17.5	5151	34.6	28.3	19.6	0.12	0.40	62	30	8
		0.20										
	190153	0.90	19.3	5665	28.1	30.5	22.1	0.14	0.41	78	18	4
		0.05										
FLOOR	190151	2.75	24.4	6490	15.3	33.2	27.1	0.14	0.42	80	15	5

Outcrop Section
Morley Hill

TOTAL ZONE 10.45
TOTAL COAL 6.30

COMPOSITE ANALYSES

LEGEND: Bright; Bright banded; Dull and bright; Dull banded; Dull; Bone coal; Carbonaceous claystone; Mudstone; Bentonitic mudstone; Concretion; Sandstone; Siltstone

WAPITI PROJECT

TRENCH: WA90002 page 1 of 2

SCALE: 0 0.5 1.0 m

LOCATION:
NORTHING 6006500
EASTING 357825
ZONE 11
LSD.
SEC.
TWP.
RGE.
MER.

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
			2.00										
ROOF			0.20										
			0.20										
		190156	0.50	20.6	6276	20.0	32.2	27.2	0.24	0.41	75	16	9
	0.06		0.10										

COMPOSITE ANALYSES

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA90002 page 2 of 2

SCALE:

LOCATION:

NORTHING ______ EASTING ______ ZONE ______

LSD. ______ SEC. ______ TWP. ______ RGE. ______ MER. ______

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		190161	1.00	12.8	6121	30.3	31.0	25.8	0.22	0.45	70	26	4
	0.06		0.10										
			1.30										
			0.10										
		190160	0.40	13.8	5441	35.6	28.6	22.0	0.24	0.41	68	26	6
	0.06		0.30										
	0.06		0.15										
			0.10										
			0.20										
			0.20										
			0.60										
		190159	0.67	17.7	6998	18.9	33.0	30.4	0.20	0.44	74	22	4
	0.06	190158	0.15 / 0.15	12.4	3261	54.1	21.9	11.5	0.13	0.44	91	8	1
		190157	1.00	16.7	7034	19.7	33.9	29.7	0.31	0.44	81	13	6
FLOOR	TOTAL ZONE		6.67										
	TOTAL COAL		4.07										
Outcrop Section Morley Hill													

COMPOSITE ANALYSES

LEGEND

- Bright
- Bright banded
- Dull and bright
- Dull banded
- Dull
- Bone coal
- Carbonaceous claystone
- Mudstone
- B-B-B Bentonitic mudstone
- C-C-C Concretion
- Sandstone
- Siltstone

WAPITI PROJECT

TRENCH: WA90003

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6006400 EASTING 357925 ZONE 11

LSD. ______ SEC. ______ TWP. ______ RGE. ______ MER. ______

WAPITI PROJECT

TRENCH: WA90004

SCALE: 0 0.5 1.0 m

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
			1.50										
			0.10										
-B-B	0.05		0.30										
			1.50										
FLOOR													
	TOTAL ZONE		3.45										
	TOTAL COAL		3.00										

COMPOSITE ANALYSES

LOCATION:
NORTHING ____ EASTING ____ ZONE ____
LSD. ____ SEC. ____ TWP. ____ RGE. ____ MER. ____

LEGEND
- *Bright*
- *Bright banded*
- *Dull and bright*
- *Dull banded*
- *Dull*
- *Bone coal*
- *Carbonaceous claystone*
- *Mudstone*
- B-B-B *Bentonitic mudstone*
- C-C-C *Concretion*
- *Sandstone*
- *Siltstone*

WAPITI PROJECT

TRENCH: WA90005

SCALE: 0 0.5 1.0 m

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H_2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
		190164	0.90	4.8	5869	47.7	28.6	18.9	0.48	0.51	78	9	13
Outcrop Section Kakwa River													

COMPOSITE ANALYSES

LOCATION:
NORTHING 6017600 EASTING 368475 ZONE 11
LSD. ____ SEC. ____ TWP. ____ RGE. ____ MER. ____

LEGEND
- *Bright*
- *Bright banded*
- *Dull and bright*
- *Dull banded*
- *Dull*
- *Bone coal*
- *Carbonaceous claystone*
- *Mudstone*
- B-B-B *Bentonitic mudstone*
- C-C-C *Concretion*
- *Sandstone*
- *Siltstone*

WAPITI PROJECT

TRENCH: WA90006

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6022400 EASTING 346925 ZONE 11 LSD. SEC. TWP. RGE. MER.

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand% Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		190162	1.00	21.7	6632	15.8	33.4	29.1	0.30	0.41	82	11	7
FLOOR	0.02												
	TOTAL COAL		1.00										

COMPOSITE ANALYSES

LEGEND

Bright · Bright banded · Dull and bright · Dull banded · Dull · Bone coal · Carbonaceous claystone · Mudstone · Bentonitic mudstone · Concretion · Sandstone · Siltstone

WAPITI PROJECT

TRENCH: WA90007

SCALE: 0 0.5 1.0 m

LOCATION: NORTHING 6025850 EASTING 345475 ZONE 11 LSD. SEC. TWP. RGE. MER.

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	Rrand% Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
			0.60										
		190163	1.00	19.1	6926	17.6	32.6	30.7	0.33	0.44	86	11	3
	0.02												
FLOOR			0.30										
	TOTAL ZONE		1.92										
	TOTAL COAL		1.30										
Outcrop Section Nose Mtn. South													

COMPOSITE ANALYSES

LEGEND

Bright · Bright banded · Dull and bright · Dull banded · Dull · Bone coal · Carbonaceous claystone · Mudstone · Bentonitic mudstone · Concretion · Sandstone · Siltstone

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	PETROGRAPHIC ANALYSES (VOLUME %) Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF ?													
		190165	1.50	6.0	10411	16.7	31.4	45.9	1.63	0.55	94	3	3
FLOOR													
Outcrop Section Nose Mtn. Road				COMPOSITE ANALYSES									

LEGEND

Bright	Carbonaceous claystone
Bright banded	Mudstone
Dull and bright	Bentonitic mudstone
Dull banded	Concretion
Dull	Sandstone
Bone coal	Siltstone

WAPITI PROJECT

TRENCH: WA90008

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6031025 LSD. ___
EASTING 346875 SEC. ___
ZONE 11 TWP. ___
RGE. ___
MER. ___

DESCRIPTIVE COMMENTS	COAL ZONE	SAMPLE NUMBER	THICKNESS (metres)	CHEMICAL ANALYSES H2O (A.R.B.)	C.V. (BTU/lb)	ASH %	V.M. %	F.C. %	S %	PETROGRAPHIC ANALYSES (VOLUME %) Rrand Rmax	Huminite Vitrinite	Inertinite	Liptinite
ROOF													
		190166	1.30	13.3	4953	41.3	25.9	19.5	0.19	0.40			
FLOOR	TOTAL ZONE		1.30										
	TOTAL COAL		1.30										
Outcrop Section Muddy Creek Road				COMPOSITE ANALYSES									

LEGEND

Bright	Carbonaceous claystone
Bright banded	Mudstone
Dull and bright	Bentonitic mudstone
Dull banded	Concretion
Dull	Sandstone
Bone coal	Siltstone

WAPITI PROJECT

TRENCH: WA90009

SCALE: 0 0.5 1.0 m

LOCATION:

NORTHING 6054300 LSD. ___
EASTING 334750 SEC. ___
ZONE 11 TWP. ___
RGE. ___
MER. ___

APPENDIX 2

List of species referred to in palynological discussions

A. Cutpick Hill section, lowest 35 m; early loranthaceous suite of Norris et al. (1975); early late Campanian.
Aquilapollenites drumhellerensis Srivastava, 1969
A. sp. cf. *A. quadrilobus* Rouse, 1957
A. sp. cf. *A. stelckii* Srivastava, 1968
A. trialatus var. *variabilis* Tschudy and Leopold, 1971
Fibulapollis scabratus Tschudy, 1969
Mancicorpus unicus (Chlonova) Stanley, 1970
Umbosporites callosus Newman, 1965

B. Cutpick Hill section, middle part; later loranthaceous suite of Norris et al. (1975); mid-late Campanian.
Aquilapollenites clairireticulatus Samoilovich, 1965
A. mirabilis Srivastava, 1968
A. rigidus Tschudy and Leopold, 1971
A. turbidus Tschudy and Leopold, 1971
Azonia cribrata Wiggins, 1976
A. recta (Bolkhovitina) Samoilovich, 1961
A. sufflata Wiggins, 1976
Pulcheripollenites krempii Srivastava, 1969

C. Cutpick Hill section, upper part; *Cranwellia* suite of Norris et al. (1975); latest Campanian.
Anacolsoidites sp.
Aquilapollenites funkhouseri Srivastava, 1968
A. quadrilobus Rouse, 1957
A. rectus Tschudy, 1969
Cranwellia rumseyensis Srivastava, 1966
Erdtmanipollis procumbentiformis (Samoilovich) Krutzsch, 1966
Expressipollis sp. cf. *E. barbatus* Chlonova, 1961
Liliacidites complexus (Stanley) Leffingwell, 1971
Mancicorpus calvus (Tschudy and Leopold) Tschudy, 1973
M. tripodiformis (Tschudy and Leopold) Tschudy, 1973
Orbiculapollis globosus Chlonova, 1961
Senepites drumhellerensis Srivastava, 1969

D. Red Willow coal zone; *Cranwellia* suite of Norris et al. (1975); latest Campanian to earliest Maastichtian.
Mancicorpus albertensis Srivastava, 1968
Trudopollis meekerii Newman, 1965
Kurtzipites andersonii Srivastava, 1982

E. Cutbank coal measures; *Scollardia trapaformis* Zone VI of Srivastava, 1970.
Aquilapollenites augustus Srivastava, 1969
A. delicatus Stanley, 1961 var. *delicatus*
A. quadrilobus Rouse, 1957
A. senonicus (Mchedlishvili) Tschudy and Leopold, 1971
Liliacidites complexus (Stanley) Leffingwell, 1971
Mancicorpus gibbus Srivastava, 1968
Orbiculapollis lucida Chlonova, 1961
Scollardia trapaformis Srivastava, 1967

F. Nose Mountain section, uppermost part; *Wodehouseia spinata* Zone VIII of Srivastava (1970), *Aquilapollenites bertillonites* subzone; early late Maastrichtian.
Aquilapollenites augustus Srivastava, 1969
A. bertillonites Funkhouser, 1961
A. delicatus var. *delicatus*
A. quadrilobus Rouse, 1957
Liliacidites complexus (Stanley) Leffingwell, 1971
Mancicorpus gibbus Srivastava, 1968
M. rostratus Srivastava, 1968
Orbiculapollis lucida Chlonova, 1961
Wodehouseia spinata Stanley, 1961

G. Smoky River section, *Wodehouseia spinata* Zone VIII of Srivastava (1970), *Leptopecopites pococki* subzone of Srivatava (1970); late late Maastrichtian.
Aquilapollenites delicatus var. *collaris* Tschudy and Leopold, 1971
Myricipites scabratus Norton, 1969
Tricolpites microreticulatus Belsky, Boltenhagen and Potonié, 1965
Aquilapollenites reductus Srivastava, 1968
A. reticulatus (Mchedlishvili) Tschudy and Leopold, 1971
Tricolpites parvistriatus Norton, 1967
Wodehouseia spinata Stanley, 1961

H. Kakwa coal measures, *Wodehouseia fimbriata* Zone VIII of Srivastava (1970); early Paleocene.
Alnipollenites trina (Stanley) Norton and Hall, 1969
Azolla schopfii Dijkstra, 1961
Paraalnipollenites alterniporus (Simpson) Srivastava, 1975
Tricolpites bathyreticulatus Stanley, 1965
Wodehouseia fimbriata Stanley, 1961

I. Kakwa coal measures, *Wodehouseia fimbriata* Zone VIII of Srivastava (1970); early Paleocene.
Alnipollenites trina (Stanley) Norton and Hall, 1969
A. verus Potonié, 1931
Aquilapollenites spinulosus Funkhouser, 1961
Brevicolporites colpella Anderson, 1960
Caryapollenites imparalis Nichols and Ott, 1978
C. prodromus Nichols and Ott, 1978
Cranwellia subtilis Sweet, 1986
Ericaceoipollenites rallus Stanley, 1965
Insulapollenites rugulatus Leffingwell, 1971
Momipites leffingwellii Nichols and Ott, 1978
Momipites triorbicularis (Leffingwell) Nichols, 1973
M. ventifluminis Nichols and Ott, 1978
M. waltmanensis Nichols and Ott, 1978
M. wyomingensis Nichols and Ott, 1978
Paraalnipollenites alterniporus (Simpson) Srivastava, 1975
Tilia danei Anderson, 1960
Tricolpites bathyreticulatus Anderson, 1960
Ulmipollenites undulosus Wolff, 1934

APPENDIX 3

Detailed mineral matter and maceral analyses

Trench	Sample	Pellet no.	R_o %	Vit A	Vit B	V'det	Total Vit.	S. Fus	Fus	I'det	Mac	Mic	Total inert	Spore	Cutin	Insitu Resin	Detro Resin	Suberin	Other	Total Lipt.	Maceral Total	Qtz	Clay	Carb	Pyr	Mineral Total	Shale
Red Willow coal measures																											
				Vitrinite				Inertinite						Liptinite								Mineral in coals					
WA88003	166423	536 /88	0.67	27.3	37.1	1.4	65.7	13.1	9.5	6.5	-	-	29.2	3.8	-	0.8	0.3	-	0.3	5.2	100.0	2.6	1.0	-	-	3.7	0.8
	166320	508 /88	0.68	59.3	31.5	-	90.8	6.3	0.5	0.5	-	-	7.3	1.0	-	0.5	-	0.5	-	2.0	100.0	1.2	1.0	-	-	2.2	0.0
WA88019	166360	527 /88	0.68	43.4	44.9	0.2	88.5	4.2	1.7	4.0	-	-	10.0	0.7	0.2	0.5	-	-	-	1.5	100.0	1.0	0.2	0.2	-	1.5	0.0
	166372	623 /88	0.63	49.7	40.6	-	90.3	3.1	2.3	1.8	0.5	-	7.7	0.8	0.3	0.8	-	-	0.3	2.0	100.0	3.7	0.5	-	-	4.2	0.5
WA89011	166492	844 /89	0.66	46.0	41.0	4.0	91.0	2.0	2.0	1.0	-	-	5.0	3.0	1.0	-	-	-	-	4.0	100.0	1.0	5.0	-	-	6.0	0.0
Lower coal measures																											
WA88020	166361	529 /88	0.66	41.3	37.2	2.2	81.6	4.0	2.0	9.4	-	-	15.4	2.2	0.2	0.2	0.2	-	-	3.0	100.0	4.5	-	-	-	4.5	0.9
WA88020	166357	522 /88	0.68	55.6	27.3	0.5	83.3	4.0	5.0	5.0	0.5	-	14.5	2.3	-	-	-	-	-	2.3	100.0	3.8	-	-	-	3.8	0.7
WA88021	166358	523 /88	0.56	38.1	45.8	0.3	84.0	4.5	3.8	5.5	0.3	-	14.0	1.8	-	0.3	-	-	-	2.0	100.0	1.0	0.2	-	-	1.2	0.2
WA88014	166359	524 /88	0.46	40.3	34.0	0.5	74.8	6.8	7.8	6.0	-	0.3	20.8	3.5	0.8	-	0.3	-	-	4.5	100.0	0.2	1.2	0.2	-	1.7	2.4
WA88018	166362	530 /88	0.56	55.5	36.9	-	92.5	2.8	1.0	1.8	-	-	5.5	1.8	0.2	-	-	-	-	2.0	100.0	1.2	0.5	-	-	1.7	2.4
WA88017	166363	531 /88	0.55	56.3	36.2	1.5	93.9	0.5	1.5	2.3	-	-	4.3	1.0	0.2	0.3	0.3	-	-	1.8	100.0	2.1	4.3	0.2	-	6.7	6.4
Cutbank coal measures																											
WA88004	166324	512 /88	0.68	74.8	17.6	-	92.4	3.6	0.7	1.8	-	-	6.1	0.4	-	0.4	-	-	0.7	1.4	100.0	1.7	1.4	0.3	-	3.5	23.4
	166323	511 /88	0.63	45.8	45.6	0.5	91.9	2.0	0.5	2.0	-	-	4.5	1.0	1.5	0.8	-	0.3	-	3.5	100.0	1.0	1.2	-	-	2.2	5.6
	166322	510 /88	0.62	40.3	47.0	-	87.3	6.8	2.3	2.3	-	-	11.3	0.8	-	0.5	-	-	0.3	1.5	100.0	2.7	1.0	-	-	3.6	2.4
	166321	509 /88	0.65	34.3	38.3	0.3	72.9	9.0	7.0	5.5	-	-	21.6	3.8	-	1.3	-	0.3	0.3	5.5	100.0	1.5	1.0	0.2	-	2.7	0.7
	166428	538 /88	0.67	45.8	37.8	-	83.5	4.0	3.3	5.3	-	-	12.5	2.3	0.8	0.5	-	0.5	-	4.0	100.0	0.2	0.2	-	-	0.5	0.0
WA88005	166325	513 /88	0.63	35.5	48.7	2.8	87.1	3.8	1.6	4.7	-	-	10.1	1.6	0.3	0.3	-	-	0.6	2.8	100.0	7.0	3.4	-	-	10.4	12.3
WA88008	166328	516 /88	-	31.0	44.1	-	75.1	10.8	3.8	5.5	-	-	20.2	2.0	1.0	-	-	-	1.8	4.8	100.0	1.2	0.5	0.2	-	2.0	0.7
WA88010	166299	525 /88	0.69	21.5	45.3	1.0	67.8	10.8	9.3	9.0	-	-	29.0	2.3	-	-	0.8	-	0.3	3.3	100.0	3.6	0.5	0.5	-	4.5	0.9
	166300	526 /88	0.69	26.5	49.0	-	75.5	7.5	4.3	8.5	0.3	-	20.5	2.8	0.3	1.0	-	-	-	4.0	100.0	3.3	0.7	0.2	-	4.3	0.0
	166351	517 /88	0.68	38.5	41.5	2.3	82.3	3.0	8.0	4.5	-	-	15.5	1.8	0.3	-	-	-	0.3	2.3	100.0	4.0	0.7	0.7	-	5.4	7.2
	166353	518 /88	0.68	39.3	42.8	1.0	83.0	4.5	5.0	4.3	-	-	13.8	1.8	0.8	0.5	0.3	-	-	3.3	100.0	3.6	0.5	-	-	4.1	0.7
	166354	519 /88	0.70	51.4	39.5	0.5	91.5	2.3	1.0	2.6	-	-	5.9	1.8	-	0.5	-	-	0.3	2.6	100.0	3.7	1.0	0.7	-	5.4	3.1
	166356	521 /88	0.65	39.3	48.5	-	87.8	5.0	1.0	3.5	-	-	9.5	2.3	-	0.3	-	0.3	-	2.8	100.0	5.0	0.5	-	-	5.4	1.2
	166355	520 /88	0.66	51.2	37.5	1.3	90.0	1.6	2.6	2.4	-	-	6.6	1.8	0.5	0.8	-	0.3	-	3.4	100.0	3.7	2.0	-	-	5.7	4.0
WA88009	166447	498 /88	0.68	46.5	33.0	1.3	80.8	3.9	4.4	4.9	0.3	0.3	13.8	1.3	1.3	1.6	1.3	-	-	5.5	100.0	0.7	2.7	3.9	-	7.3	10.2
WA90002	190152	1111 /90	0.41	high ash		-																					
	190151	1112 /90	0.42	32.0	48.0	-	80.0	4.0	3.0	8.0	-	-	15.0	3.0	-	-	-	-	2.0	5.0	100.0	-	6.0	-	-	6.0	-
	190153	1113 /90	0.41	35.0	43.0	-	78.0	6.0	6.0	6.0	-	-	18.0	3.0	-	-	-	-	1.0	4.0	100.0	-	21.0	-	-	21.0	-
	190154	1114 /90	0.39	high ash		-																					
	190155	1115 /90	0.40	20.0	41.0	1.0	62.0	4.0	9.0	17.0	-	-	30.0	5.0	-	-	-	-	3.0	8.0	100.0	-	44.0	-	-	44.0	-
	190156	1116 /90	0.41	28.0	47.0	-	75.0	3.0	3.0	10.0	-	-	16.0	8.0	-	-	-	-	1.0	9.0	100.0	-	16.0	-	-	16.0	-
WA90003	190157	1117 /90	0.44	48.0	33.0	-	81.0	4.0	4.0	5.0	-	-	13.0	3.0	-	-	1.0	-	2.0	6.0	100.0	4.0	2.0	-	-	6.0	-
	190158	1118 /90	0.44	51.0	40.0	-	91.0	3.0	4.0	1.0	-	-	8.0	1.0	-	-	-	-	-	1.0	100.0	-	54.0	-	-	54.0	-
	190159	1119 /90	0.44	27.0	47.0	-	74.0	7.0	9.0	6.0	-	-	22.0	3.0	-	-	-	-	1.0	4.0	100.0	-	13.0	-	-	13.0	-
	190160	1120 /90	0.41	19.0	47.0	2.0	68.0	4.0	10.0	12.0	-	-	26.0	4.0	-	-	-	-	2.0	6.0	100.0	-	35.0	-	-	35.0	-
	190161	1121 /90	0.45	27.0	40.0	3.0	70.0	7.0	9.0	10.0	-	-	26.0	2.0	-	-	-	-	2.0	4.0	100.0	6.0	12.0	-	-	18.0	-
WA90005	190164	1122 /90	0.51	46.0	18.0	14.0	78.0	1.0	1.0	7.0	-	-	9.0	3.0	-	-	6.0	-	4.0	13.0	100.0	5.0	31.0	-	-	36.0	-
WA90006A	190162	1123 /90	0.41	32.0	49.0	1.0	82.0	2.0	3.0	6.0	-	-	11.0	5.0	-	-	-	-	2.0	7.0	100.0	-	6.0	-	-	6.0	-
WA90007	190163	1124 /90	0.44	40.0	46.0	-	86.0	3.0	2.0	6.0	-	-	11.0	2.0	-	-	1.0	-	-	3.0	100.0	4.0	8.0	-	-	12.0	-
WA90008	190165	1125 /90	0.55	77.0	13.0	4.0	94.0	-	1.0	1.0	-	-	3.0	1.0	-	-	-	-	2.0	3.0	100.0	8.0	3.0	-	3	14.0	-

APPENDIX 3 (cont.)

Kakwa coal measures

				Vitrinite				Inertinite						Liptinite								Minerals in coal					
Trench	Sample	Pellet no.	R_o %	Vit A	Vit B	V'det	Total Vit.	S fus	Fus	I'det	Mac	Mic	Total Inert	Spore	Cutin	Insitu Resin	Detro Resin	Suberin	Other	Total Lipt.	Maceral Total	Qtz	Clay	Carb	Pyr	Mineral Total	Shale
WA88001	166413	533 /88	0.61	84.3	11.9	1.1	97.2	0.7	0.4	1.1	-	-	2.1	0.4	-	0.4	-	-	-	0.7	100.0	-	1.7	-	-	1.7	25.1
	166414	534 /88	0.61	52.5	29.4	3.4	85.3	1.6	2.2	7.8	-	-	11.6	3.1	-	-	-	-	-	3.1	100.0	1.4	10.2	-	-	11.6	10.8
	166390	532 /88	0.55	38.0	29.3	1.3	68.5	10.8	6.5	9.3	0.8	-	27.3	3.3	0.3	0.5	-	-	0.3	4.3	100.0	1.5	0.7	0.5	-	2.7	0.7
WA88002	166421	535 /88	0.50	28.3	28.1	0.5	56.9	10.0	6.0	18.0	0.3	0.8	35.1	6.5	0.5	1.0	-	-	-	8.0	100.0	0.7	-	-	-	0.7	0.5
WA88006	166327	515 /88	0.56	29.4	21.2	1.4	51.9	11.8	10.7	21.4	-	-	44.0	2.5	0.3	0.8	0.3	0.3	-	4.1	100.0	3.2	6.4	0.2	-	9.9	28.2
	166326	514 /88	0.54	44.2	17.5	1.3	63.0	7.1	8.5	17.7	-	-	33.3	3.2	-	-	-	0.3	0.3	3.7	100.0	1.0	1.5	0.3	-	2.8	17.6
WA89001	166480	817 /89	0.61	55.0	22.0	1.0	78.0	5.0	7.0	5.0	-	-	17.0	5.0	-	-	-	-	-	5.0	100.0	-	5.0	-	-	5.0	15.0
	166481	818 /89	0.54	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166482	819 /89	0.61	60.0	20.0	1.0	81.0	7.0	4.0	5.0	-	-	16.0	2.0	-	1.0	-	-	-	3.0	100.0	1.0	1.0	-	-	2.0	6.0
WA89002	166486	820 /89	0.59	45.0	41.0	2.0	88.0	2.0	5.0	2.0	-	-	9.0	3.0	-	-	-	-	-	3.0	100.0	1.0	1.0	-	-	2.0	7.0
WA89003	166485	821 /89	0.51	47.0	24.0	1.0	72.0	5.0	5.0	14.0	1.0	-	25.0	1.0	-	1.0	-	-	-	3.0	100.0	1.0	4.0	-	-	5.0	10.0
WA89004	166487	822 /89	0.47	24.0	25.0	-	49.0	12.0	12.0	20.0	1.0	-	45.0	6.0	-	-	-	-	-	6.0	100.0	2.0	4.0	-	-	6.0	2.0
WA89005	166479	829 /89	0.52	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166478	828 /89	0.53	23.0	48.0	1.0	72.0	8.0	10.0	7.0	-	-	25.0	2.0	-	-	1.0	-	-	3.0	100.0	6.0	3.0	-	-	9.0	2.0
	166477	827 /89	0.52	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166476	826 /89	0.51	32.0	41.0	1.0	74.0	9.0	9.0	5.0	1.0	-	24.0	2.0	-	-	-	-	-	2.0	100.0	2.0	3.0	-	-	5.0	5.0
	166475	825 /89	0.49	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166474	824 /89	0.53	40.0	32.0	6.0	78.0	2.0	7.0	8.0	-	-	17.0	3.0	-	-	1.0	-	1.0	5.0	100.0	4.0	7.0	-	-	11.0	32.0
	166473	823 /89	0.53	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WA89006	166464	836 /89	0.42	54.0	35.0	-	89.0	4.0	3.0	3.0	-	-	10.0	1.0	-	-	-	-	-	1.0	100.0	1.0	-	-	-	1.0	0.0
	166459	835 /89	0.41	20.0	23.0	-	43.0	18.0	15.0	20.0	-	-	53.0	4.0	-	-	-	-	-	4.0	100.0	2.0	1.0	-	-	3.0	1.0
	166458	834 /89	0.38	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166463	833 /89	0.44	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166461	832 /89	0.44	36.0	21.0	4.0	61.0	8.0	11.0	14.0	1.0	-	34.0	5.0	-	-	-	-	-	5.0	100.0	2.0	4.0	-	-	6.0	37.0
	166460	831 /89	0.41	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166462	830 /89	0.43	55.0	26.0	-	81.0	5.0	5.0	6.0	1.0	-	17.0	1.0	-	-	1.0	-	-	2.0	100.0	2.0	5.0	-	-	7.0	0.0
WA89007	166469	? /89	-	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166472	842 /89	0.47	34.0	29.0	9.0	72.0	15.0	4.0	7.0	-	-	26.0	2.0	-	-	-	-	-	2.0	100.0	2.0	10.0	-	-	12.0	36.0
	166468	841 /89	0.44	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166470	840 /89	0.48	47.0	40.0	-	87.0	4.0	3.0	2.0	-	-	9.0	3.0	1.0	-	-	-	-	4.0	100.0	2.0	1.0	-	-	3.0	0.0
	166471	839 /89	0.47	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166467	838 /89	0.47	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166466	837 /89	0.50	61.0	32.0	-	93.0	3.0	3.0	-	-	-	7.0	-	-	-	-	-	-	-	100.0	1.0	-	-	-	1.0	0.0
WA89010	166488	845 /89	0.46	58.0	29.0	1.0	88.0	2.0	4.0	3.0	-	-	9.0	2.0	1.0	-	-	-	-	3.0	100.0	1.0	3.0	-	-	4.0	2.0
WA89012	166457	852 /89	0.40	12.0	35.0	1.0	48.0	10.0	24.0	15.0	-	-	49.0	3.0	-	-	-	-	-	3.0	100.0	5.0	3.0	-	-	8.0	4.0
	166453	850 /89	0.42	47.0	19.0	-	66.0	8.0	17.0	5.0	-	-	30.0	3.0	-	-	-	-	-	4.0	100.0	-	2.0	1.0	-	3.0	2.0
	166456	851 /89	0.42	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166455	854 /89	0.41	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166451	849 /89	0.40	51.0	14.0	2.0	67.0	7.0	10.0	11.0	-	-	29.0	4.0	-	-	-	-	-	4.0	100.0	4.0	1.0	-	-	5.0	6.0
	166454	848 /89	0.39	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166452	847 /89	0.40	41.0	23.0	-	64.0	11.0	13.0	7.0	-	-	31.0	4.0	-	-	-	-	-	5.0	100.0	1.0	3.0	-	-	4.0	6.0
	166491	853 /89	0.35	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	166490	846 /89	0.42	51.0	30.0	-	81.0	5.0	10.0	2.0	-	-	17.0	1.0	1.0	-	-	-	-	2.0	100.0	1.0	-	-	-	1.0	0.0
WA89008	166483	843 /89	0.46	38.0	26.0	1.0	65.0	6.0	13.0	10.0	1.0	-	30.0	5.0	-	-	-	-	-	5.0	100.0	1.0	1.0	-	-	2.0	3.0
	166484	? /89	-	high ash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 4

Localities for figured specimens

GSC locality **C-166271**; WA88004.
Wolf Creek: NTS 83L/6; 54°28'40"N, 119°08'35"W; upper Wapiti Formation, Cutbank coal measures.

GSC locality **C-166274**; 88-JO-WA-7-3; grey shale.
Cutpick Hill section: NTS 83L/3; 54°04'30N, 119°09'25"W; Nomad Member, Puskwaskau Formation.

GSC locality **C-166277**; WA88007.
Cutpick Hill section: NTS 83L/3; 54°04'30"N, 119°09'25"W; lower part of Wapiti Formation.

GSC localities **C-166280, C-166281, C-166282**; WA88007.
Cutpick Hill section: NTS 83L/3; 54°04'30"N, 119°09'25"W; middle part of Wapiti Formation.

GSC locality **C-166292**; WA88O19.
Red Willow River: NTS 83L/11; 55°04'05"N, 119°28'10"W; NTS 83L/11; middle part of Wapiti Formation.

GSC locality **C-166333**; WA88007.
Cutpick Hill section: NTS 83L/3; 54°04'30"N, 119°09'25"W; lower part of Wapiti Formation.

GSC locality **C-166346**; WA88007.
Cutpick Hill section: NTS 83L/3; 54°04'30"N, 119°09'25"W; middle part of Wapiti Formation.

GSC localities **C-166366** and **C-166367**; WA88014.
Bezanson: NTS 83M/8; 55°17'00"N, 118°17'30"W; lower part of Wapiti Formation.

GSC locality **C-166371**; WA88017.
NTS 83L/11; 55°03'40"N, 118°51'25"W; NTS 83L/11; middle part of Wapiti Formation.

GSC locality **C-166374**; WA88018.
Nighthawk: NTS 83M/2; 55°03'25"N, 118°51'25"W; middle part of Wapiti Formation.

GSC locality **C-166375**; WA88019.
Red Willow River: NTS 83L/11; 55°04'05"N, 119°28'10"W; NTS 83L/11; middle part of Wapiti Formation.

GSC locality **C-166376**; WA88020.
Wapiti River: NTS 83L/11; 54°59'54"N, 119°27'40"W; middle part of Wapiti Formation.

GSC locality **C-166381**; WA88025.
Highway 595: NTS 83L/11; 54°06'00"N, 118°50'40"W; palynological assemblage of early late Maastrichtian age and therefore age equivalent to the uppermost part of the Wapiti Formation.

GSC localities **C-166395** and **C-116397**; WA88008.
Nose Mountain, west: NTS 83L/11; 54°27'30"N, 119°32'25"W; uppermost Wapiti Formation.

GSC locality **C-166398**; WA88009.
Nose Mountain, east: NTS 83L/11; 54°30'35"N, 119°01'10"W; uppermost Wapiti Formation.

GSC locality **C-166432**; WA88004.
Wolf Creek: NTS 83L/6; 54°28'40"N, 119°08'35"W; upper Wapiti Formation, Cutbank coal measures.

GSC locality **C-166436**; WA88005.
Cutbank River: NTS 83L/11; 54°30'35"N, 119°01'10"W; upper Wapiti Formation, Cutbank coal measures.

GSC locality **C-166457**; DJA-89-89012-9.
Deep Valley Creek: NTS 83K/12; 54°33'55"N, 118°44'40"W; upper Coalspur Formation, Kakwa coal measures.

GSC localities **C-166460, C-166461** and **C-166464**; WA89006.
Simonette River: NTS 83K/12; 54°32'03"N, 118°49'55"W; lower Paskapoo Formation.

GSC locality **C-166465**; WA89007.
Smoky River: NTS 83L/15; 54°49'18"N, 118°33'20"W; middle Wapiti Formation.

GSC locality **C-166484**; WA89008.
Smoky River: NTS 83L/8; 54°25'55"N, 118°27'20"W; upper Coalspur Formation, Kakwa coal measures.

GSC locality **C-166492**; WA88010.
Cutbank River: NTS 83L/11; 54°30'35"N, 119°01'10"W; upper Wapiti Formation, Cutbank coal zone.

GSC locality **C-188153**; JO89038.
Smoky River Section, along highway 40: NTS 83L/2; 54°05' N, 119°52'W; uppermost Wapiti Formation.

GSC locality **C-188165**; JO89024.
Smoky River Section, along highway 40: NTS 83L/2; 54°08' N, 119°48.5'W; upper Coalspur.

GSC localities **C-188170** and **C-188172**; JO8900R and JO89032, respectively.
Cutbank Section: NTS 83L/10; 54°40'N, 118°45'W; upper part of Wapiti Formation, Cutbank coal measures.

GSC localities **C-190109, C-190110**; **C-190112**; SLA90015.
Smoky Tower Plant Locality (Christophel, 1976): NTS 83L/8; 54°17'10"N, 118°25'25"W; Paskapoo Formation.

GSC locality **C-190117**; SLA90017.
Smoky Fire Tower: forestry trunk road, roadcut north of tower; NTS 83L/8; 54°24'25"N, 118°17'40"W; Paskapoo Formation.

GSC localities **C-221461** and **C-221466**; DB90035.
East bank of Smoky River: NTS 83L/8; 54°24'40"N, 118°23'30"W; lower Coalspur Formation.

PLATES 1 to 4

In the figure explanations, the species name is followed by the GSC type number, slide number, microscope coordinate (Olympus Vanox-T No. 606009), GSC locality number (for additional information on the locality see Appendix 4) and field locality number (see map Fig. 3). The slides containing the figured specimens are in temporary storage at the Institute of Sedimentary and Petroleum Geology, Calgary.

PLATE 1

All figures x1000

Figures 1–21. Early late Campanian [equivalent to the early and late loranthaceous suites of Norris et al. (1975) and the *Aquilapollenites trialatus* Zone of Sweet et al. (1989)]; Paskwaskau Formation, Nomad Member and lower part of Wapiti Formation.

1. *Umbosporites callosus* Newman, 1965; GSC 106426, P3249–5c, 118.4 x 4.6, GSC locality C–166333, WA88007–13.
2. *Aquilapollenites clarireticulatus* (Samoilovich) Tschudy, 1969; GSC 106427, P3250–2d, 111.3 x 9.8, GSC locality C–166367, WA88014–8.
3. *A. mirabilis* Srivastava, 1968; GSC 106428, P3249–7c, 116.2 x 14.8, GSC locality C–166277, WA88007–17.
4. *A.* sp. cf. *A. turbidus* Tschudy and Leopold, 1971; heteropolar species with the major polar dome psilate; GSC 106429, P3249–7c, 121.1 x 6.1, GSC locality C–166277, WA88007–17.
5. *A.* sp. cf. *A. quadrilobus* Rouse, 1957; uniformly with fine spines; GSC 106430, P3249–7c, 137.0 x 17.1, GSC locality C–166277, WA88007–17.
6. *A. trialatus* var. *variabilis* Tschudy and Leopold, 1971; GSC 106431, P3249–3c, 110.8 x 10.6, GSC locality C–166274, WA88007–3.
7. *A. trialatus* var. *uniformis* Tschudy and Leopold, 1971; GSC 106432, P3250–2c, 118.4 x 17.6, GSC locality C–166367, WA88014–8.
8. *A. turbidus* Tschudy and Leopold, 1971; GSC 106433, P3250–2d, 111.6 x 16.8, GSC locality C–166367, WA88014–8.
9. *A. stelckii* Srivastava, 1968; GSC 106434, P3250–1b, 113.2 x 14.3, GSC locality C–166366, WA88014–2.
10. *Azonia* sp. cf. *A. hirsuta* (Samoilovich) Wiggins, 1976; specimen with well developed apertures whereas the original description of *A. hirsuta* was for specimens lacking obvious apertures; GSC 106435, P3250–2c, 111.9 x 15.3, GSC locality C–166367, WA88014–8.
11. *A. recta* (Bolkhovitina) Samoilovich, 1961; GSC 106436, P3249–5d, 121.4 x 3.3, GSC locality C–166333, WA88007–13.
12. *A. sufflata* Wiggins, 1976; GSC 106437, P3250–2d, 125.8 x 12.3, GSC locality C–166367, WA88014–8.
13. *Mancicorpus anchoriforme* Mchedlishvili, 1961; GSC 106438, P3249–3c, 120.7 x 7.3, GSC locality C–166274, WA88007–3.
14. *Pulcheripollenites krempii* Srivastava, 1969; form with relatively long colpi; GSC 106439, P3249–7d, 107.2 x 12.3, GSC locality C–166277, WA88007–17.
15. *Pleurospermaepollenites* sp.; GSC 106440, P3250–2d, 110.6 x 12.6, GSC locality C–166367, WA88014–8.
16. *Weylandipollis retiformis* Takahashi, 1964; GSC 106441, P3250–2d, 130.7 x 16.8, GSC locality C–166367, WA88014–8.
17. *Sindorapollis* sp.; GSC 106442, P3250–1a, 119.4 x 9.8, GSC locality C–166366, WA88014–2.
18. *Siberiapollis* sp.; GSC 106443, P3249–8b, 119.4 x 6.3, GSC locality C–166367, WA88014–8.
19. *Proteacidites thalmannii* Anderson, 1960; GSC 106444, P3250–1c, 117.6 x 10.7, GSC locality C–166366, WA88014–2.
20. *Fibulapollis scabratus* Tschudy, 1969; GSC 106445, P3249–7d, 124.6 x 6.7, GSC locality C–166277, WA88007–17.
21. *Cranwellia*? sp.; GSC 106446, P3249–7d, 130.2 x 8.7, GSC locality C–166277, WA88007–17.

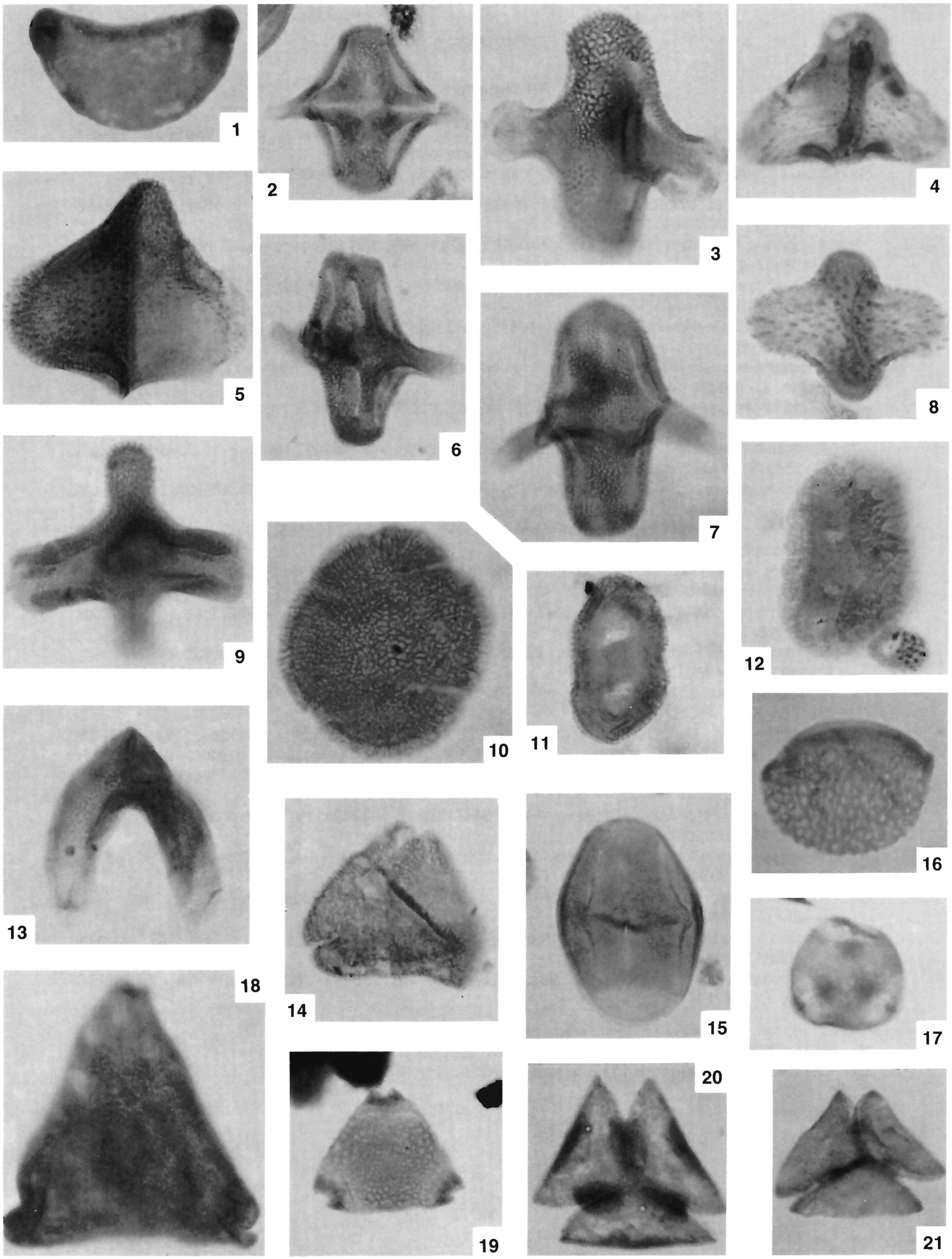

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PLATE 2

All figures x1000

Figures 1–14, 17–23. Latest Campanian to earliest Maastrichtian [equivalent to the *Cranwellia* suite of Norris et al. (1975) and the *Triprojectus unicus* Zone of Sweet et al. (1989)]; middle part of Wapiti Formation including coals and other rock units associated with the Red Willow coal measures.

1. *Aquilapollenites trialatus* Rouse, 1957; GSC 106447, P3244–2c, 117.6 x 18.4, GSC locality C–166292, WA88019–3.
2. *A. oblatus* Srivastava, 1968; GSC 106448, P3249–10b, 115.6 x 19.8, GSC locality C–166280, WA88007–27a.
3. *A. funkhouseri* Srivastava, 1968; GSC 106449, P3249–10b, 107.6 x 19.2, GSC locality C–166280, WA88007–27a.
4. *A. augustus* Srivastava, 1969; GSC 106450, P3244–2c, 123.4 x 11.2, GSC locality C–166292, WA88019–3.
5. *A. quadrilobus* Rouse, 1957; uniformly with fine spines, GSC 106451, P3249–13b, 108.7 x 7.8, GSC locality C–166281, WA88007–33.
6. *A. drumhellerensis* Srivastava, 1969; GSC 106452, P3244–2c, 128.6 x 7.2, GSC locality C–166292, WA88019–3.
7. *A. rigidus* Tschudy and Leopold, 1971; GSC 106453, P3244–1b, 109.4 x 15.6, GSC locality C–-166375, WA88019–1.
8. *Erdtmanipollis procumbentiformis* (Samoilovich) Krutzsch, 1966; GSC 106454, P3249–11b, 118.3 x 18.8, GSC locality C–166346, WA88007–27b.
9. *Mancicorpus calvus* (Tschudy and Leopold) Tschudy, 1973; GSC 106455, P3249–10b, 117.2 x 14.4, GSC locality C–166280, WA88007–27a.
10. *M. tripodiformis* (Tschudy and Leopold) Tschudy, 1973; GSC 106456, P3249–14b, 121.4 x 20.4, GSC locality C–166282, WA88007–43.
11. *M. albertensis* Srivastava, 1968; GSC 106457, P3245–1c, 107.6 x 13.4, GSC locality C–166376, WA88020–3.
12. *Cranwellia rumseyensis* Srivastava, 1966; GSC 106458, P3244–1b, 116.4 x 9.8, GSC locality C–166375, WA88019–1.
13. *Kurtzipites andersonii* Srivastava, 1981; GSC 106459, P3245–1b, 124.3 x 13.4, GSC locality C–166376, WA88020–3.
14. *Siberiapollis* sp.; GSC 106460, P3249–14b, 112.8 x 14.2, GSC locality C–166282, WA88007–43.
17. *Loranthacites* sp.; GSC 106463, P3255–1c, 118.3 x 10.2, GSC locality C–166374, WA88018–1.
18. *Liliacidites mirus* Srivastava, 1969; GSC 106464, P3249–13c, 117.8 x 12.5, GSC locality C–166281, WA88007–33.
19. *Translucentipollis plicatilis* Chlonova, 1961; GSC 106465, P3249–11b, 127.6 x 14.6, GSC locality C–166346, WA88007–27b.
20. *Senipites drumhellerensis* Srivastava, 1969, GSC 106466, P3249–13c, 113.6 x 16.3, GSC locality C–166281, WA88007–33.
21. *Triatriopollenites* sp. cf. *T. costatus* Norton, 1969; GSC 106467, P3249–13c, 113.8 x 15.3, GSC locality C–166281, WA88007–33.
22. *Tricolpites interangulus* Newman, 1965; GSC 106468, P3249–13c, 113.2 x 15.6, GSC locality C–166281, WA88007–33.
23. *Scabrastephanocolpites albertensis* Srivastava, 1969; GSC 106469, P3249–14c, 118.4 x 14.8, GSC locality C–166282, WA88007–43.

Figures 15, 16. *Trudopollis meekeri* Newman, 1965

15. GSC 106461, P3255–1a, 115.4 x 19.3, GSC locality C–166374, WA88018–1.
16. GSC 106462, P3254–1c, 133.6 x 14.1, GSC locality C–166371, WA88017–1.

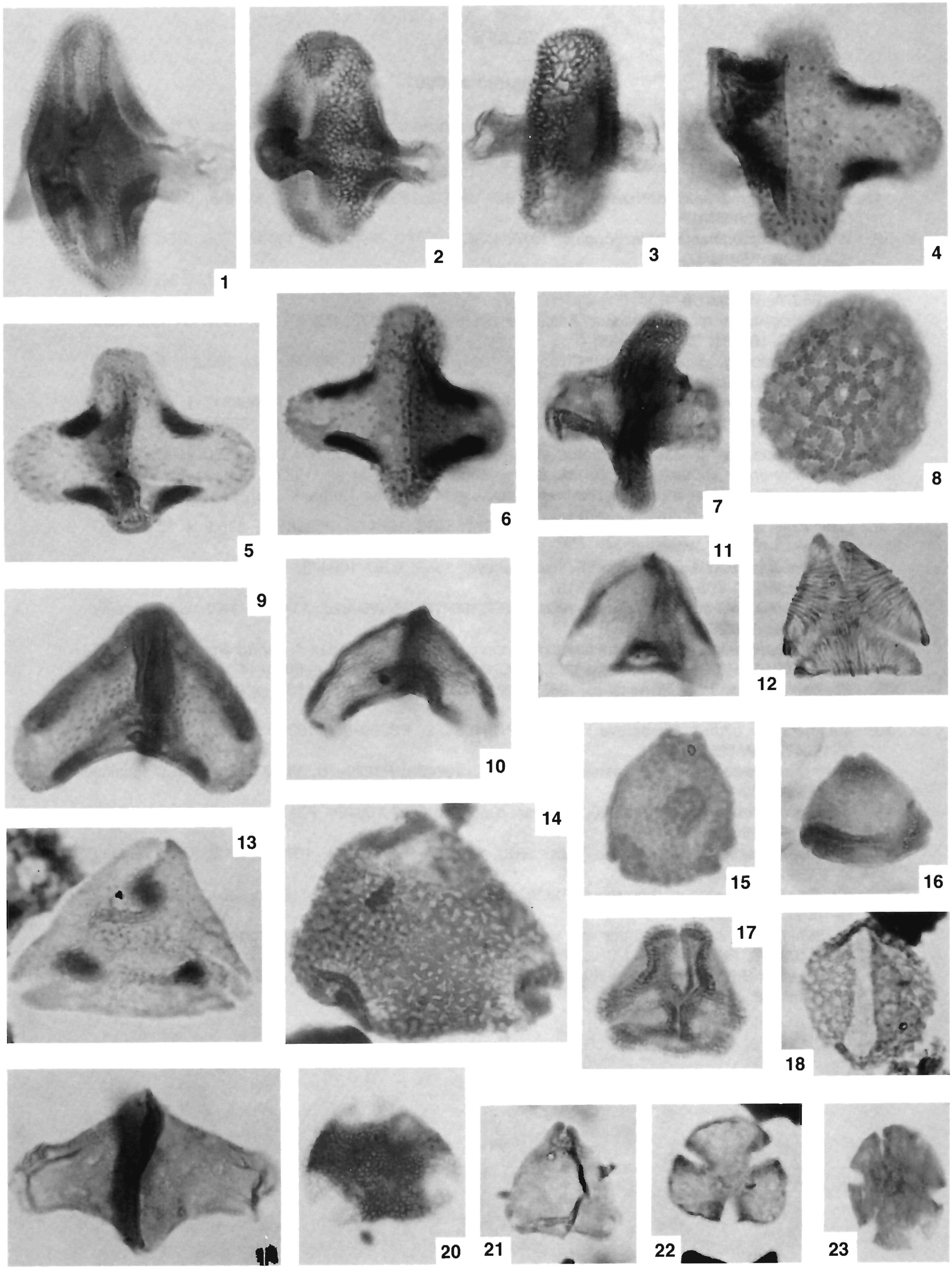
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PLATE 3

All figures x1000

Figures 1–7. Latest Campanian to earliest Maastrichtian [equivalent to the *Cranwellia* suite of Norris et al. (1975) and the *Triprojectus unicus* Zone of Sweet et al. (1989)]; middle part of Wapiti Formation including coals and other rock units associated with the Red Willow coal measures.

1. *Azonia strictiparva* Frederiksen, 1990; GSC 106470, P3254–1b, 115.2 x 15.3, GSC locality C–166371, WA88017–1.
2. *Wodehouseia edmontonicola* Wiggins, 1976; GSC 106471, P3424–1c, 114.8 x 7.5, GSC locality C–166465, WA89007–1.
3. *Kurtzipites trispissatus* Anderson, 1960; GSC 106472, P3255–1c, 110.1 x 17.3, GSC locality C–166374, WA88018–1.
4. *Orbiculapollis* sp. cf. *O. globosus* Chlonova, 1961; GSC 106473, P3249–13c, 111.7 x 16.6, GSC locality C–166281, WA88007–33.
5. *Expressipollis* sp. cf. *E. barbatus* Chlonova, 1961; GSC 106474, P3249–13b, 108.2 x 8.7, GSC locality C–166281, WA88007–33.
6. *E.* sp.; GSC 106475, P3254–1b, 119.2 x 16.6, GSC locality C–166371, WA88017–1.
7. *Anacolosidites* sp.; GSC 106476, P3254–1b, 115.5 x 14.6, GSC locality C–166371, WA88017–1.

Figures 8–19. Late early Maastrichtian [equivalent to the *Scollardia trapaformis* Zone of Srivastava (1970) and the *Mancicorpus gibbus–Scollardia trapaformis* Zone of Sweet et al. (1989)]; upper part of Wapiti Formation including coals and other rock units associated with the Cutbank coal measures.

8. *Liliacidites complexus* (Stanley) Leffingwell, 1971; GSC 106477, P3238–1c, 108.8 x 13.0, GSC locality C–166395, WA88008–9.
9. *Wodehouseia gracile* (Samoilovich) Pokrovaskaya, 1966; GSC 106478, P3468–20c, 121.8 x 8.4, GSC locality C–188170, JO8900R–18.
10. *Mancicorpus rostratus* Srivastava, 1968; GSC 106479, P3468–22c, 114.8 x 14.0, GSC locality C–188172, JO8903–2b,
11. *Aquilapollenites* sp. (has expanded ectexine in axial regions as found in *A. sentus* Srivastava, 1968); GSC 106480, P3239–3c, 118.3 x 11.8, GSC locality C–166432, WA88004–11.
12. *Scollardia trapaformis* Srivastava, 1966; GSC 106481, P3239–1b, 113.6 x 16.0, GSC locality C–166271, WA88004–1.
13. *Mancicorpus gibbus* Srivastava, 1968; GSC 106482, P3289–2b, 109.6 x 19.3, GSC locality C–166492, WA88010–6.
14. *Pulcheripollenites krempii* Srivastava, 1969; GSC 106483, P3239–1b, 119.2 x 19.8, GSC locality C–166271, WA88004–11.
15. *Aquilapollenites delicatus* Stanley, 1961 var. *delicatus*; GSC 106484, P3235–2c, 124.8 x 9.8, GSC locality C–166436, WA88005–7.
16. *Orbiculapollis lucidus* Chlonova, 1961; GSC 106485, P34682–2d, 107.4 x 21.6, GSC locality C–188172, JO89032–2b.
17. *Aquilapollenites amicus* Srivastava, 1968; GSC 106486, P3239–1b, 118.2 x 22.4, GSC locality C–166271, WA88004–1.
18. *A. delicatus* var. *collaris* Tschudy and Leopold, 1971; form with a relatively short major polar dome; GSC 106487, P3235–2c, 114.0 x 20.1, GSC locality C–166436, WA88005–7.
19. *A. augustus* Srivastava, 1969; GSC 106488, P34682–20b, 134.3 x 18.4, GSC locality C–188172, JO8900R–18.

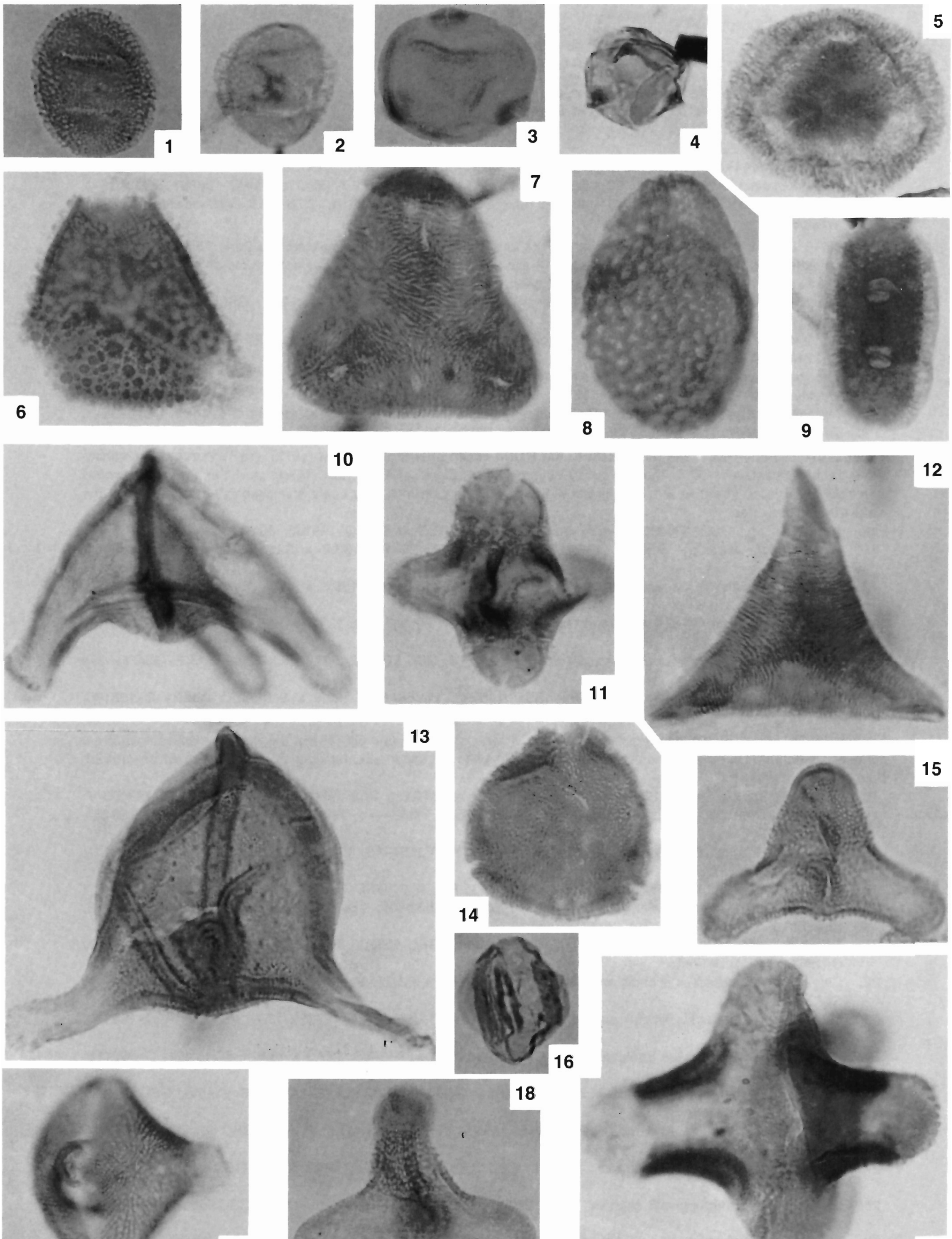
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PLATE 4

All figures x1000

Figures 1–4. Earliest late Maastrichtian [equivalent to the lower part of the *Wodehouseia spinata* Zone VIII of Srivastava (1970), and the *Porosipollis porosus* Zone of Sweet et al. (1989)]; uppermost part of the Wapiti Formation.

1. *Aquilapollenites delicatus* Stanley, 1961 var. *delicatus*; GSC 106489, P3290–1c, 117.8 x 12.8, GSC locality C–166398, WA88009–1.
2. *A. bertillonites* Funkhouser, 1961; GSC 106490, P3290–1c, 126.1 x 17.8, GSC locality C–166398, JO89038–1.
3. *Wodehouseia spinata* Stanley, 1961; GSC 106491, P3238–3b, 123.4 x 9.7, GSC locality C–166397, JO89038–1.
4. *Porosipollis porosus* (Mchedlishvili) Krutzsch, 1969; GSC 106492, P3242–1b, 128.8 x 7.8, GSC locality C–166381, WA88025.

Figures 5–9. Late late Maastrichtian [equivalent to the upper part of the *Wodehouseia spinata* Zone VIII, *Leptopecopites* (*Polycolpites*) *pocockii* subzone of Srivastava (1970) and the *Myrtipites scabratus–Aquilapollenites delicatus* var. *collaris* zone of Sweet et al. (1989)]; lower Scollard Formation.

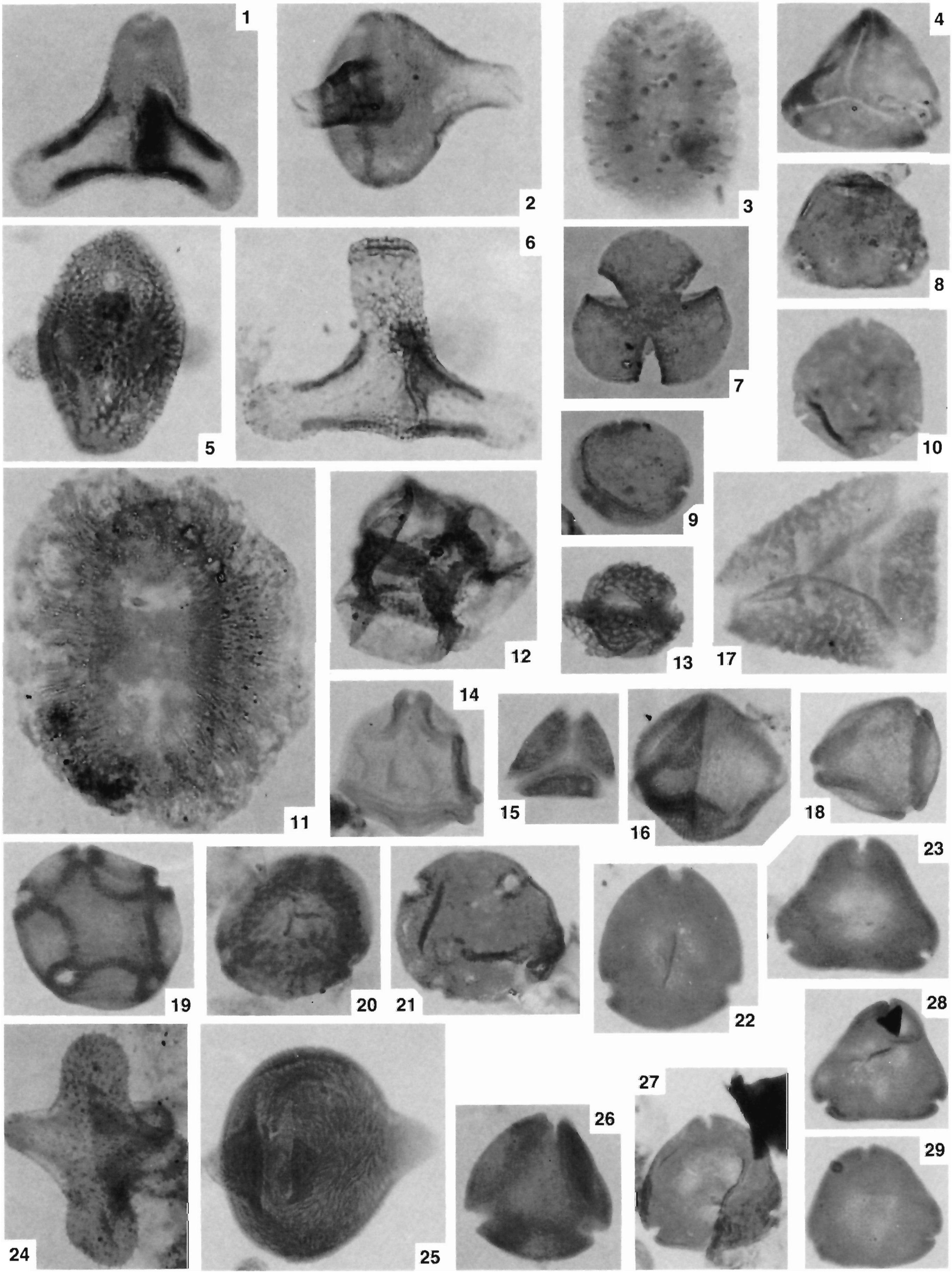
5. *Aquilapollenites reductus* Srivastava, 1968; GSC 106493, P3805–7e, 131.8 x 12.7, GSC locality C–221466, DB90035–7.
6. *A. delicatus* var. *collaris* Tschudy and Leopold, 1971; GSC 106494, P3805–2e, 123.7 x 12.4, GSC locality C–221461, DB90035–2.
7. *Tricolpites microrteticulatus* Belsky, Boltenhagen and Potonié, 1965; GSC 106495, P3805–7f, 129.0 x 10.8, GSC locality C–221466, DB90035–7.
8. *Myrtipites scabratus* Norton, 1969; GSC 106496, P3805–7f, 129.2 x 3.6, GSC locality C–221466, DB90035–7.
9. *Tricolpites parvistriatus* Norton, 1967; GSC 106497, P3805–7f, 121.5 x 18.3, GSC locality C–221466, DB90035–7.

Figures 10–15. Early Paleocene [equivalent to the P1/P2 zones of Nichols and Ott (1978), the *Wodehouseia fimbriata* Zone IX of Srivastava (1970), the *Momipites wyomingensis* Zone of Demchuk (1990); and the *Paraalnipollenites alterniporus* Zone of Sweet et al. (1989)]; upper Scollard Formation including coals and associated rock units of the Kakwa coal measures.

10. *Kurtzipites* sp.; GSC 106498, P3468–15d, 121.6 x 9.2, GSC locality C–188165, JO89024.
11. *Wodehouseia fimbriata* Stanley, 1961; GSC 106499, P3425–1b, 138.2 x 9.8, GSC locality C–166484, WA89008–1.
12. *Ericaceoipollenites rallus* Stanley, 1965; GSC 106500, P3468–15c, 135.3 x 15.8, GSC locality C–188165, JO89024.
13. *Tricolpites anguloluminosus* Anderson, 1960; GSC 106501, P3468–15d, 124.4 x 14.8, GSC locality C–188165, JO89024.
14. *Paraalnipollenites alterniporus* (Simpson) Srivastava, 1975; GSC 106502, P3427–9d, 127.6 x 15.2, GSC locality C–166457, WA89012–9.
15. *Syncolporites minimus* Leffingwell, 1971; GSC 106503, P3468–15d, 120.8 x 9.1, GSC locality C–188165, JO89024.

Figures 16–29. Middle Paleocene [equivalent to the P3 zone of Nichols and Ott (1978), the *Aquilapollenites spinulosus* zone of Demchuk (1990); and the *Aquilapollenites spinulosus–Wodehouseia capillata* Zone of Sweet et al. (1989)]; Paskapoo Formation.

16. *Cranwellia subtilis* Sweet, 1986; GSC 106504, P3584–7d, 116.8 x 11.2, GSC locality C–166464, WA89006–7.
17. *Insulapollenites rugulatus* Leffingwell, 1971; GSC 106505, P3584–7c, 119.5 x 4.2, GSC locality C–166464, WA89006–7.
18. *Alnipollenites trina* (Stanley) Norton, 1969; GSC 106506, P3584–4d, 130.0 x 19.0, GSC locality C–166461, WA89006–3.
19. *A. verus* Potonié, 1931; GSC 106507, P3682–1b, 131.2 x 12.8, GSC locality C–190109, SLA90015–1.
20. *Ulmipollenites undulosus* Wolff, 1934; GSC 106508, P3682–4d, 126.2 x 11.6, GSC locality C–190112, SLA90015–4.
21. *Tilia danei* Anderson, 1960; specimen with four apertures; GSC 106509, P3684–1a, 116.0 x 16.3, GSC locality C–190117, SLA90017–1.
22. *Caryapollenites imparalis* Nichols and Ott, 1978; GSC 106510, P3682–2a, 111.4 x 20.2, GSC locality C–190110, SLA90015–2.
23. *Momipites waltmanensis* Nichols and Ott, 1978; GSC 106511, P3682–2a, 127.3 x 12.7, GSC locality C–190110, SLA90015–2.
24. *Aquilapollenites spinulosus* Funkhouser, 1961; GSC 106512, P3682–4C, 127.3 x 18.6, GSC locality C–190112, SLA90015–4.
25. *Parviprojectus* sp. cf. *P. striatus* Mchedlisvili, 1961; GSC 106513, P3682–1a, 114.6 x 10.6, GSC locality C–190109, SLA90015–1.
26. *Brevicolporites colpella* Anderson, 1960; GSC 106514, P3584–7d, 116.1 x 14.6, GSC locality C–166464, WA89006–7.
27. *Momipites ventifluminis* Nichols and Ott, 1978; GSC 106515, P3684–1d, 126.9 x 12.3, GSC locality C–190117, SLA90017–1.
28. *M. triorbicularis* (Leffingwell) Nichols, 1973; GSC 106516, P3584–4d, 135.6 x 16.8, GSC locality C–166461, WA89006–3.
29. *M. wyomingensis* Nichols and Ott, 1978; GSC 106517, P3584–3c, 112.4 x 16.2, GSC locality C–166460, WA89006–2.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