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Palynostratigraphy of Paleocene strata of the central Alberta Plains

by

Thomas D. Demchuk

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Palynostratigraphy of Paleocene strata of the central Alberta Plains submitted by Thomas D. Demchuk in partial fulfilment of the requirements for the degree of Master of Science.

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Supervisor

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Chaitanya Singh ....

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Date ...October 2, 1987...

ABSTRACT

Fossil Juglandaceous pollen are abundant within palynofloral assemblages from the early Tertiary of western North America. These pollen are considered to have evolved rapidly and have widespread geographic distribution making them ideally suited for regional biostratigraphic correlations. A modification to the *Momipites-Caryapollenites* palynofloral lineage of Wyoming has permitted zonation of the Paleocene strata of the central Alberta Plains. Paleocene strata from the base of the Nevis coal seam of the Scollard Formation to the top of the Paskapoo Formation can be divided into six zones, based on the first appearances and subsequent ranges of species of *Momipites* and *Caryapollenites* plus other stratigraphically restricted species.

The P1 and P2 Zones are identified within the Ardley coal zone of the Scollard Formation. P1 Zone extends from the base of the Nevis seam (Cretaceous-Tertiary boundary) to the base of the Ardley seam, and is characterized by *Wodehouseia fimbriata*. Three species of *Momipites* viz. *M. wyomingensis*, *M. waltmanensis* and *M. leffingwellii* first appear in the P2 Zone, which includes strata from the Ardley seam to the top of the Scollard Formation.

Above the palynologically barren sandstones of the lower Paskapoo Formation, a P3 Zone assemblage of diverse *Momipites* (*M. ventifluminis*, *M. annellus*, *M. actinus*, and *M. triorbicularis*), *Caryapollenites prodromus*, *Aquilapollenites spinulosus* and *Tiliaepollenites danei* is present. The P4 Zone is characterized by further diversification of *Caryapollenites* in the forms *C. wodehousei* and *C. imparalis*.

The P5 Zone assemblage of the upper Paskapoo Formation contains *Caryapollenites inelegans*, *Pistillipollenites mcgregorii* and *Insulapollenites rugulatus*. Consistent within the *Momipites-Caryapollenites* palynofloral lineage, the species *Momipites leffingwellii* is conspicuously absent from this assemblage. The P6 Zone displays a further depletion of *Momipites* in that *M. waltmanensis*, *M. actinus* and *M. triorbicularis* do not range above the base of the P6 Zone. Both P5 and P6 Zone

assemblages are dominated by *Momipites wyomingensis* and *M. ventifluminis*.

Fundamental differences between the Alberta and Wyoming Juglandaceous lineages include the absence of *Momipites* in the P1 Zone, and the paucity of *Caryapollenites* in the upper Paleocene of Alberta. These differences may reflect latitudinal zoning of the paleoflora between Alberta and Wyoming during the Paleocene.

ACKNOWLEDGEMENTS

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My sincere appreciation to Art Sweet of the Geological Survey of Canada for his helpful comments and an office door that is always open; and also to Eric Beresford (formerly of Obed Mountain Coal Company) and Craig Accott of Obed who allowed the writer access to the mine for sampling on numerous occasions.

Finally, deep heartfelt thanks to my father, mother and brother who never really understood all the time spent at the university, but were supportive nonetheless.

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I. INTRODUCTION

OBJECTIVES AND METHODOLOGY

The purpose of this research is to construct a palynostratigraphic zonation scheme for Paleocene strata of the Scollard and Paskapoo Formations in the central Alberta Plains (Figures 1 and 2). Such a zonation scheme will be useful in identifying and correlating the economic coal seams of the Ardley and Obed-Marsh coal zones, which in turn will assist in resource evaluation and in interpretation of coal seam geometry and facies relationships. At present, correlation of these Paleocene strata is tenuous because no regional stratigraphic markers are available. Outcrops of Scollard and Paskapoo Formation strata in central Alberta are relatively few and discontinuous. With the exception of palynoforal remains, fossils are very scarce. The megaflora has been described by Bell (1949).

Palynostratigraphy is the application of palynology in solving stratigraphic problems. In this study, reliance has been placed on the ranges of those forms found in previous studies to be stratigraphically useful. Some aspects of abundance have been noted, but are not the prime basis for stratigraphic interpretations. This zonation scheme is modelled after the one originally proposed for Wyoming by Nichols and Ott (1978) and other studies from Alberta (Snead 1969, Srivastava 1970, Jerzykiewicz and Sweet 1986a, 1986b, Sweet 1986), Saskatchewan (Sweet, 1978), and the central United States Plains (Stanley 1965, Norton and Hall 1969, Leffingwell 1971, and Tschudy 1971) (Figure 3).

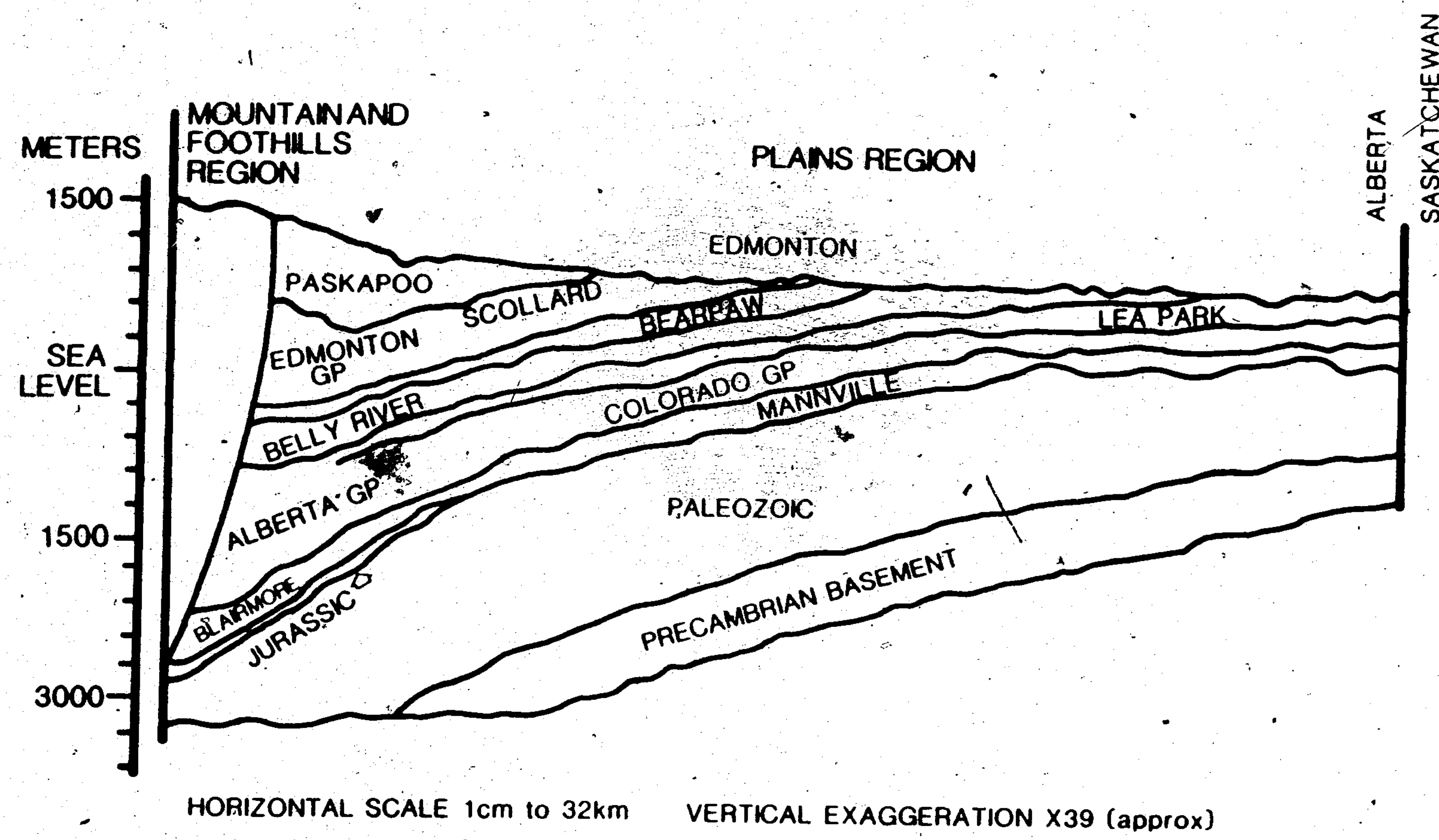

Figure 1. Generalized cross-section illustrating the stratigraphy of the Alberta Syncline (modified after ERCB-79).

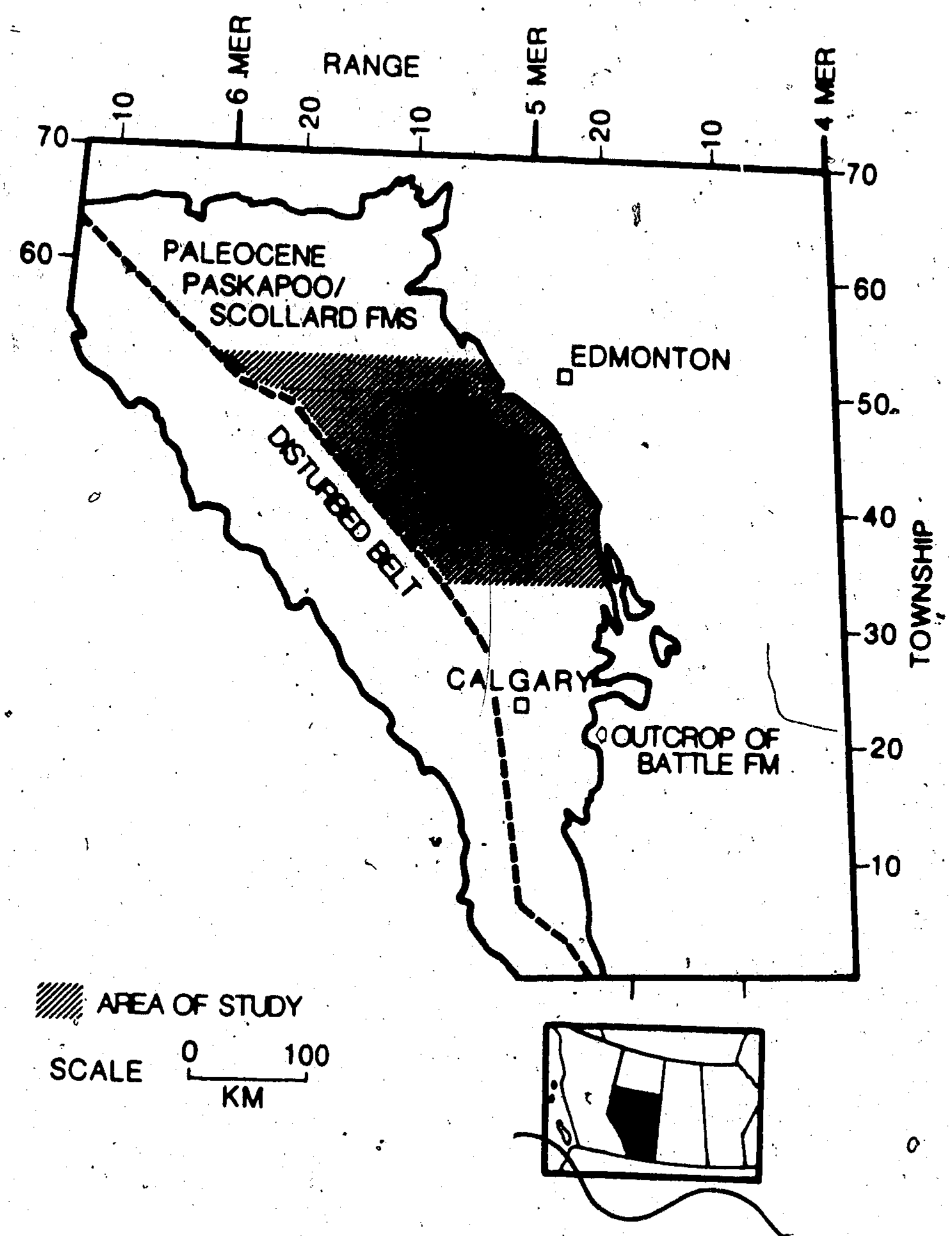

Figure 2. Location of study area.

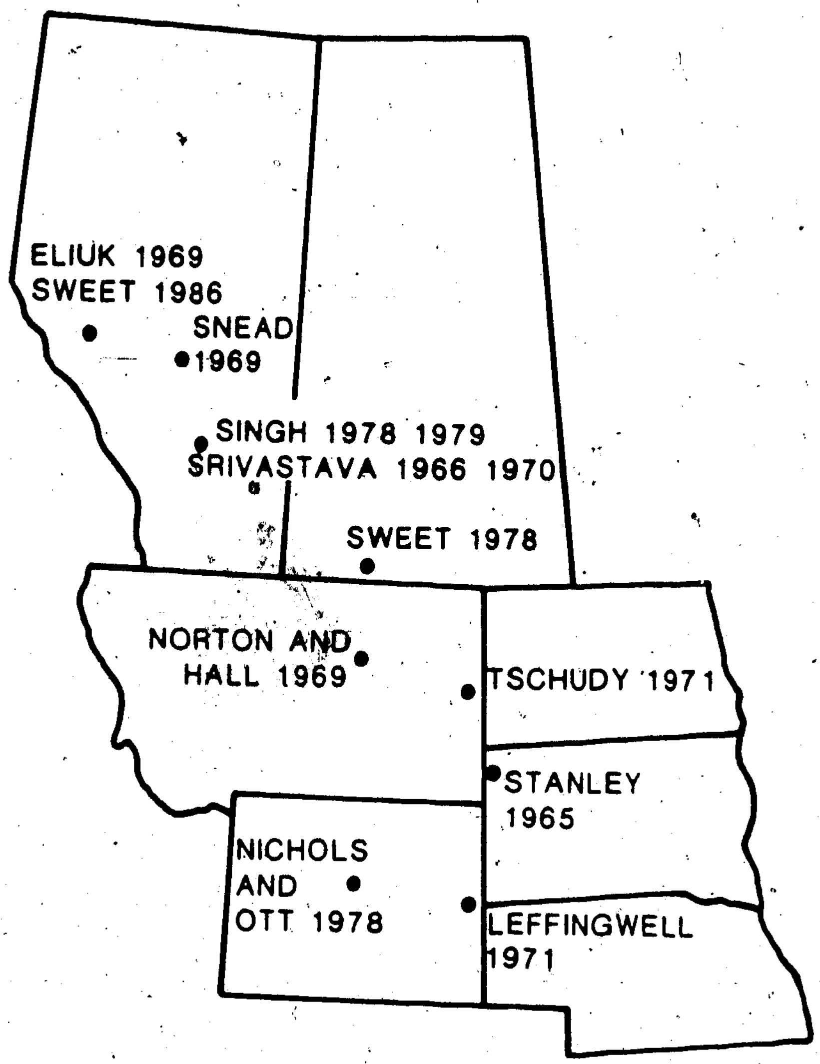

Figure 3. Locations of pertinent previous studies of uppermost Cretaceous and Paleocene palynostratigraphy (Singh 1978, in Russell and Singh 1978; Singh 1979, in Lerbekmo *et al.*, 1979; Sweet 1986, in Jerzykiewicz and Sweet, 1986a).

AREA OF STUDY

This study is limited to Paleocene strata of the Scollard and Paskapoo Formations of the central Alberta Plains. It does not extend to the Porcupine Hills and Willow Creek Formation strata of the southern Plains, or the Wapiti Formation to the north.

In the Red Deer area, core material was sampled from three Alberta Research Council coal exploration coreholes. These coreholes are located in the vicinity of Haynes (CH-2-82), Lacombe (CH-3-82) and Clive (CH-4-82). As well, palynology slides of the original organic residues obtained from the Wizard Lake corehole (CH-65-1) of Snead (1969) were re-examined (Figure 4). Each corehole produced a continuous section of uppermost Cretaceous and Paleocene strata. Five outcrop localities considered to be stratigraphically significant were also sampled for palynology. These localities were chosen largely because of their importance with respect to other fossil groups (ie. mammals and/or megaflora), or because there was some question as to their relative stratigraphic age. These localities are Hand Hills, Joffre Bridge, Delburne, Blindman/Burbank and Crestomere School (Figure 4).

Six exposures plus two coreholes were described and sampled from the Obed-Marsh coal zone in the upper Paskapoo Formation near the Foothills north of Hinton (Figure 5). The six exposures include four along the mine access corridor, plus two mine pit exposures. The two coreholes from the preliminary exploratory drilling provided strata from the entire coal zone. This area was included to determine the stratigraphic age of the Obed-Marsh coal zone on the western limb of the Alberta Syncline, relative to Paleocene strata in the central Plains.

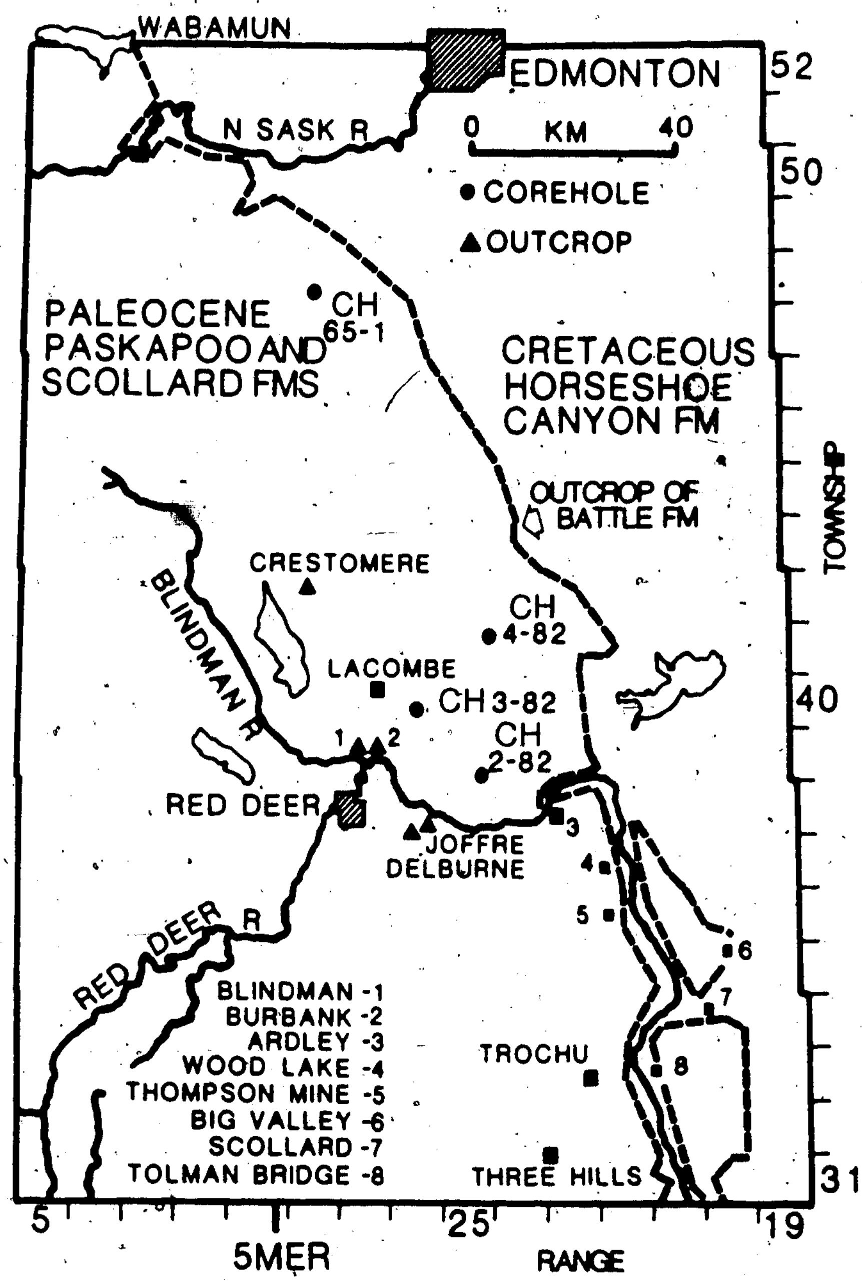

Figure 4. Corehole and outcrop localities of this study, plus outcrop localities of previous works.

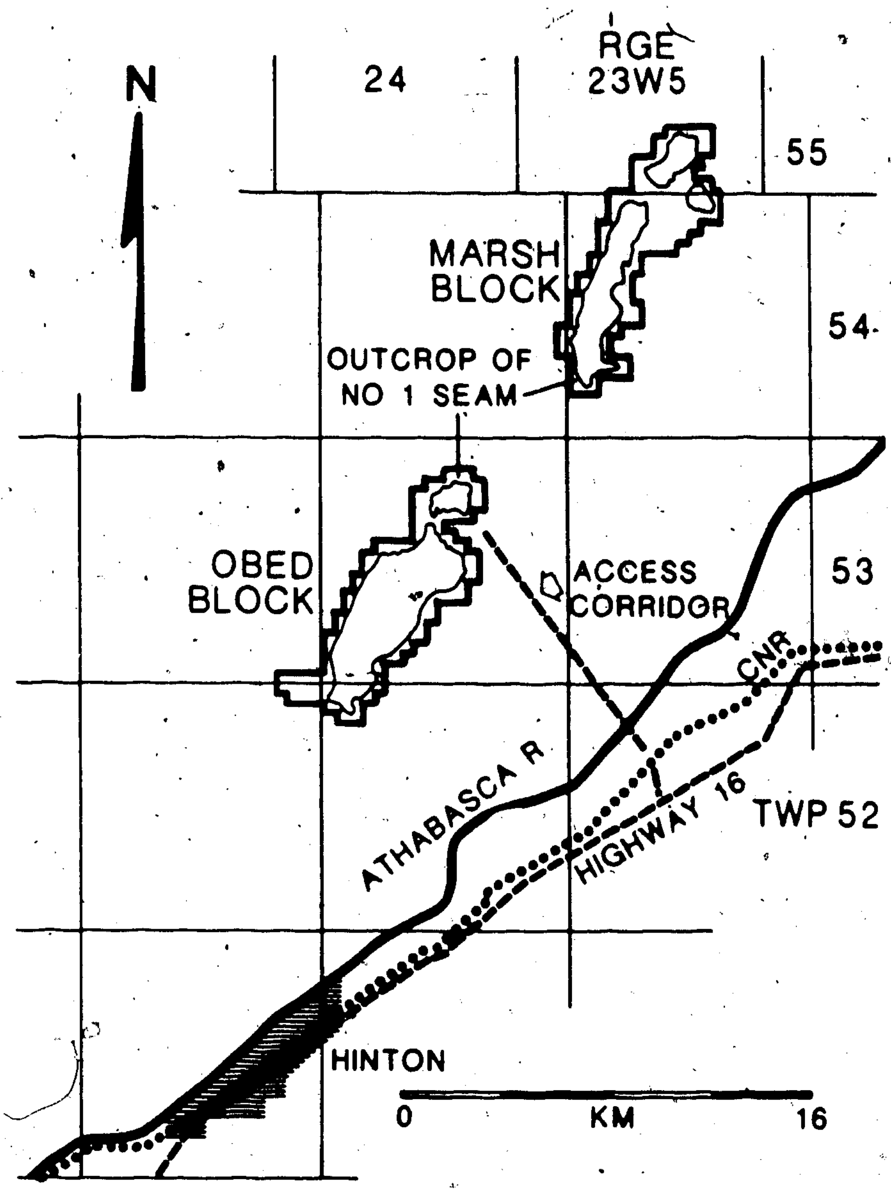

Figure 5. Map of the Obed-Marsh minesite locality (after Leitch, 1983).

II. GENERAL STRATIGRAPHY

The Edmonton Group of late Cretaceous and Paleocene age is comprised of a variable sequence of interbedded, interlensing sandstone, siltstone, mudstone, shale and coal. It is divided into four formations: in ascending order, the Horseshoe Canyon, Whitemud, Battle and Scollard Formations. The latter is overlain by the Paskapoo Formation (Gibson, 1977) (Figure 6). In the Red Deer River valley, the Edmonton Group attains a maximum thickness of 400 m and thins eastwards (Figure 1). Towards the Foothills the Edmonton Group thickens dramatically and loses its distinctive character as it grades into the upper Brazeau and Coalspur Formations of the Saunders Group (Jerzykiewicz and McLean 1980, Jerzykiewicz 1985) (Figure 7).

The Battle and Whitemud Formations are the most distinctive and easily recognized of this upper Cretaceous-Tertiary rock succession (Irish and Havard, 1968) (Plate 1). The Battle has been used as the datum for numerous studies of the Ardley coal zone, and can be traced in the subsurface because of characteristic geophysical log responses.

The first description of Edmonton strata outcropping along the banks of the North Saskatchewan River was given by Selwyn (1874) who referred to them as the "Edmonton Series". Further descriptions of the Edmonton Series by Tyrrell (1887) included all those beds between the Bearpaw shale and the Ardley coal zone outcropping in the Red Deer River valley. In a comprehensive report by Allan and Sanderson (1945) the Edmonton received formational status. Irish (1970), in recognizing the Whitemud and Battle Formations, correspondingly raised the Edmonton to Group status and identified a Scollard Member. Gibson (1977) subsequently raised the Scollard to a formation, placing the upper contact of the Edmonton Group at the top of the Scollard Formation (Figure 6).

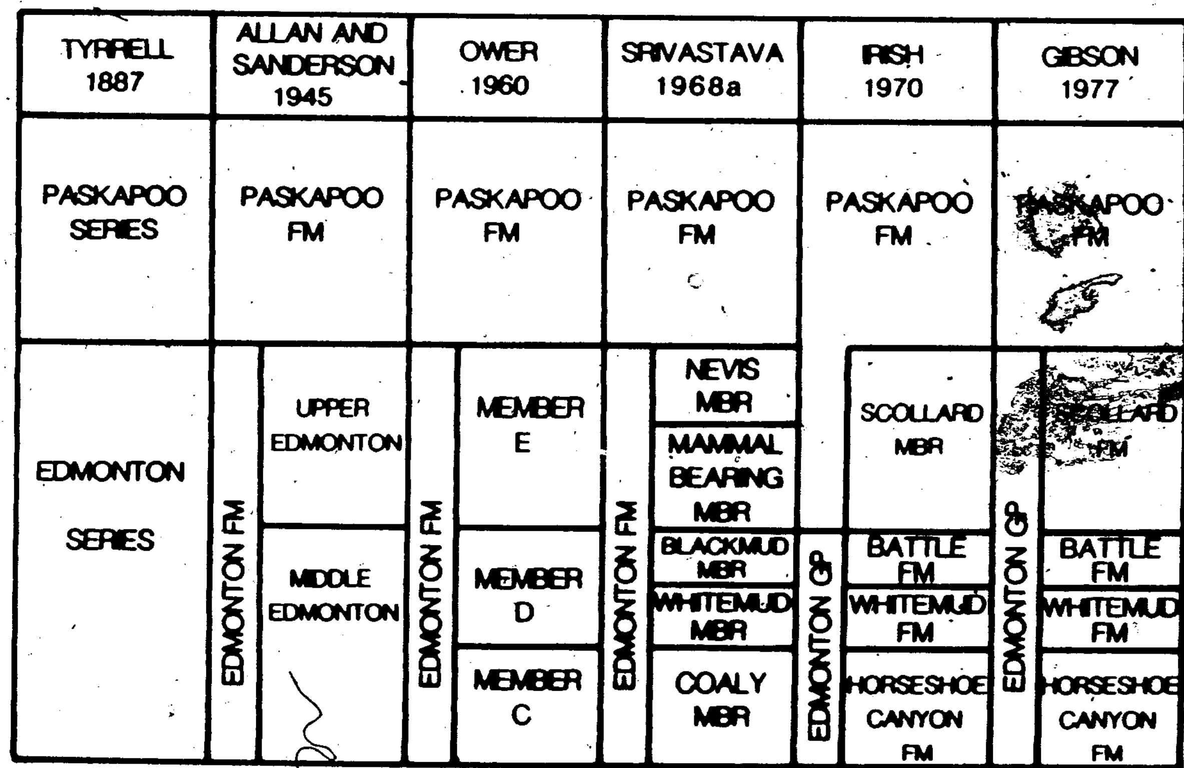

Figure 6. Evolution of nomenclature for uppermost Cretaceous and Paleocene strata of the central Alberta Plains. Nomenclature utilized in this study is that of Gibson (1977).

Plate 1. Panoramic view of uppermost Cretaceous and Paleocene strata of the Red Deer River valley (looking west at Dry Island Buffalo Jump Provincial Park). Buttes in the foreground are capped by dark Battle Formation, cliffs in the background are formed by Paskapoo Formation (slide courtesy of C. Singh).

SCOLLARD FORMATION

The name Scollard was first used by Irish (1970) in referring to the coal-bearing member above the Battle Formation. He placed it within the Paskapoo Formation. Gibson (1977) recognized the mappability of this coal-bearing interval and raised the Scollard to a formation within the Edmonton Group. This sequence had been referred to by previous workers as the Upper Edmonton Member (Allan and Sanderson, 1945) and Member E of the Edmonton Formation (Ower, 1960).

The Scollard Formation consists of an interbedded, interfingering sequence of argillaceous sandstone, siltstone, mudstone, shale and coal, with minor amounts of bentonite and tuff. This formation attains a maximum thickness of 85 m in the Huxley-Trochu area, thinning to 50 m at Ardley (Figure 4). Gibson (1977) interpreted the Scollard Formation to have been deposited by a prograding braided river system. However, Alberta Research Council geologists (Richardson *et al.*, 1986) envisage large meandering rivers dissecting a swampy alluvial plain with large shallow lakes. The accumulation of peat with periodic influxes of clastic material was controlled by thrustal loading events in the Cordillera and subsequent subsidence of the alluvial plain (McLean and Jerzykiewicz, 1978).

The Ardley coal zone of the Scollard Formation is comprised of the Nevis (no. 13), Ardley (no. 14) and upper Ardley coal seams (Gibson, 1977) (Figure 8, Plate 2). The numbered seams were originally identified by Allan and Sanderson (1945) who utilized them as stratigraphic markers. Campbell (1967) recognized a distinctive sequence of bentonite markers within the Ardley seam and drew attention to the thinning of the Nevis-Ardley interval in the Ardley area.

In a comprehensive subsurface study of the Ardley coal zone, Holter *et al.* (1975) (Figure 8) identified many regional trends. Noted was the lack of upper Ardley coal development and thinning of the section to the south of the Red Deer area. To the north, correlations became tenuous due to the development of

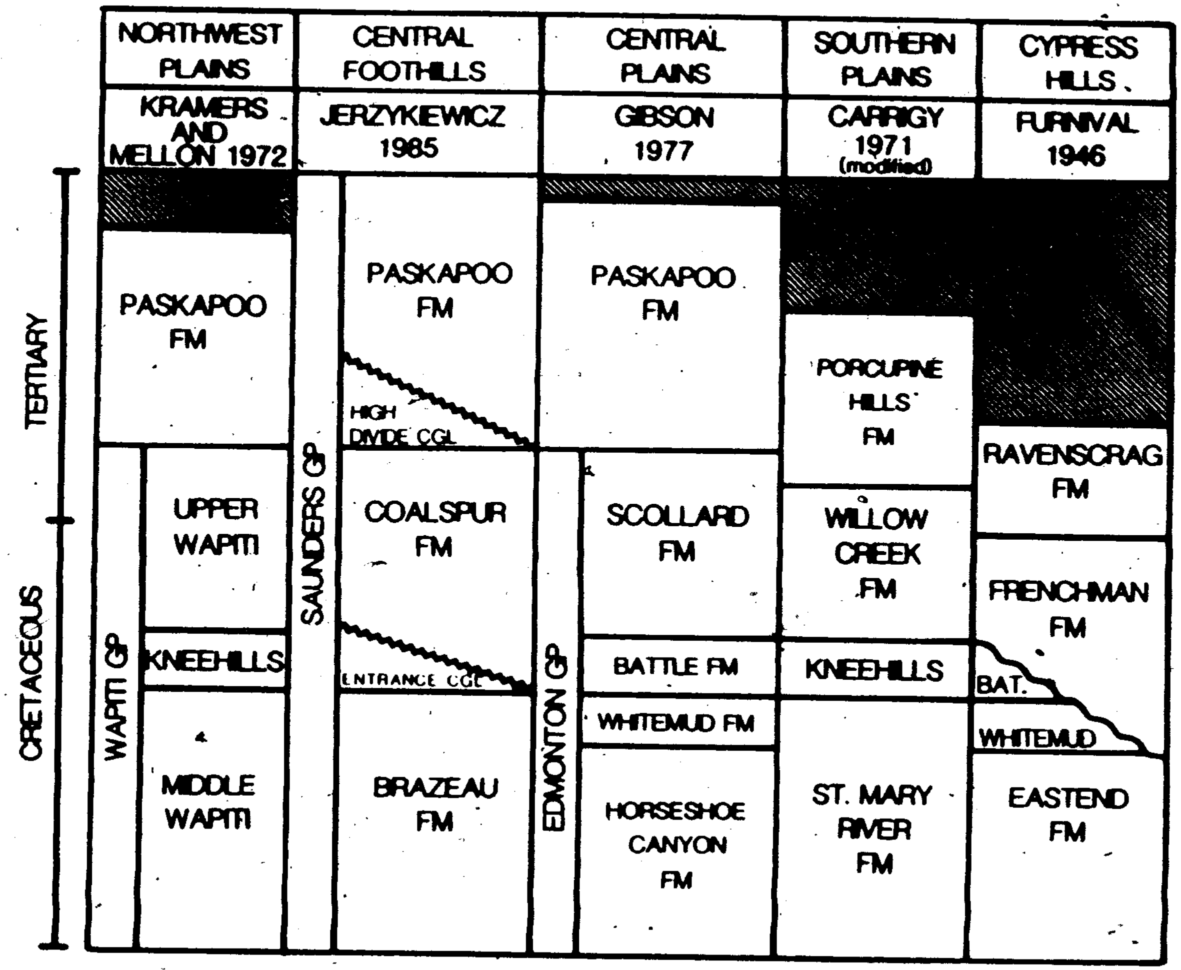

Figure 7. Correlation of uppermost Cretaceous and Paleocene strata of Alberta.

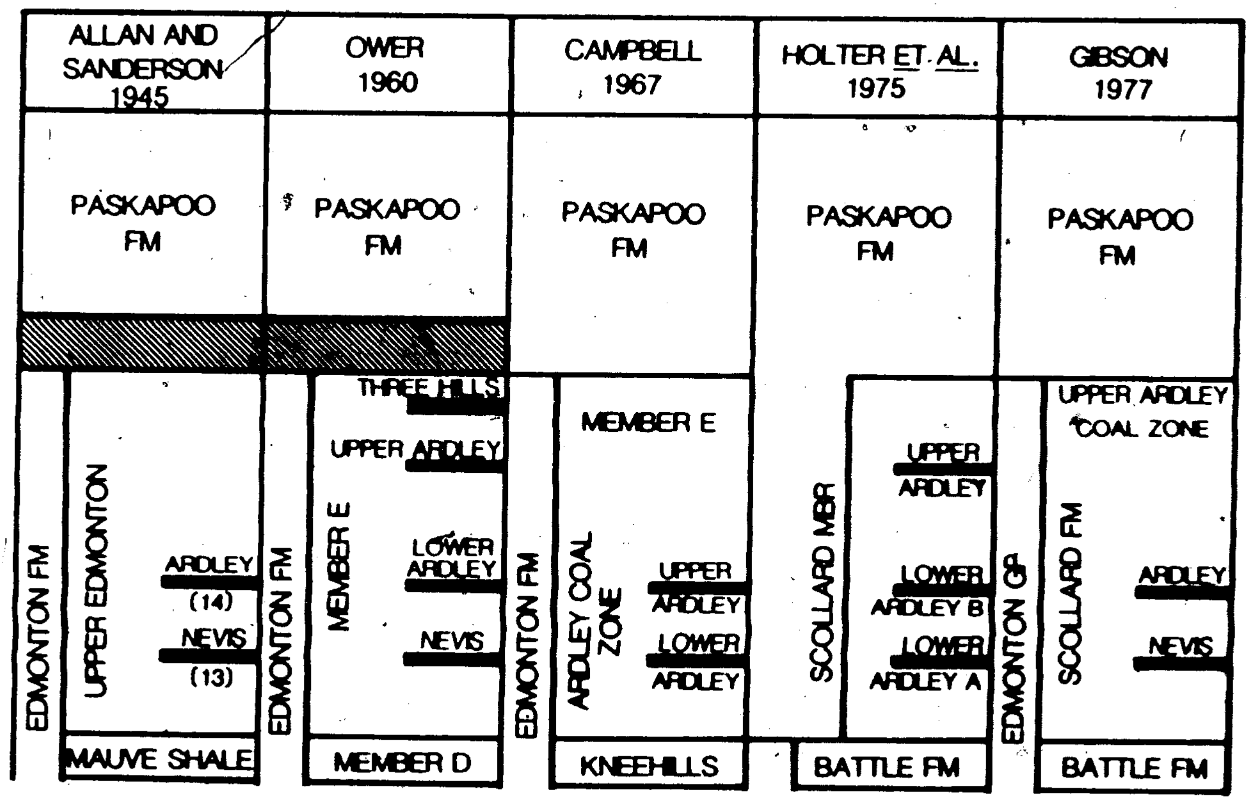

Figure 8. Evolution of lower Paleocene coal seam nomenclature.
Nomenclature utilized in this study is that of Gibson (1977).

upper Ardley seams and a well developed Nevis seam corresponding to anomalous thinning of the Ardley.

Gibson (1977) redescribed the coal seams of the Edmonton Group using the nomenclatural approach utilized by Allan and Sanderson (1945) identifying 15 prominent seams or coal-bearing intervals within the Red Deer River valley (Figure 8). Gibson (1977) also noted the thinning of the interval above the top of the Battle Formation northwards from the Scollard area and attributed this to the regional pattern of Scollard Formation deposition. Russell (1983) considered the thinner section to be due to a regional unconformity between the Battle and Scollard Formations.

Lerbekmo and Coulter (1985) also noted the reduction of section between the Battle Formtion and Ardley seam from 57 m at Scollard to only 26 m at Wood Lake (Figure 4). At this reduced section the Nevis seam is not present, as was also indicated by Allan and Sanderson (1945) who offered no explanation. On the basis of magnetostratigraphy and palynology, Lerbekmo and Coulter (1985) placed a disconformity at the base of a sandstone below the Ardley coal, and considered erosion or non-deposition at this level to account for the reduction in thickness and lack of a Nevis seam.

CRETACEOUS-TERTIARY BOUNDARY

The Cretaceous-Tertiary boundary has been identified as occurring at the base of the Nevis seam (Sweet and Hills, 1984) (Plate 2). Dinosaur remains had erroneously been reported as occurring above the Ardley seam (Sternberg, 1949), but these were re-located and re-measured as occurring approximately 4.5 m below the Nevis seam (Lerbekmo *et al.*, 1979). Palynologically, a microfloral extinction has been confirmed within the Nevis seam by numerous workers (Snead 1969, Srivastava 1970, Russell and Singh 1978, and Lerbekmo *et al.* 1979). After detailed analysis of

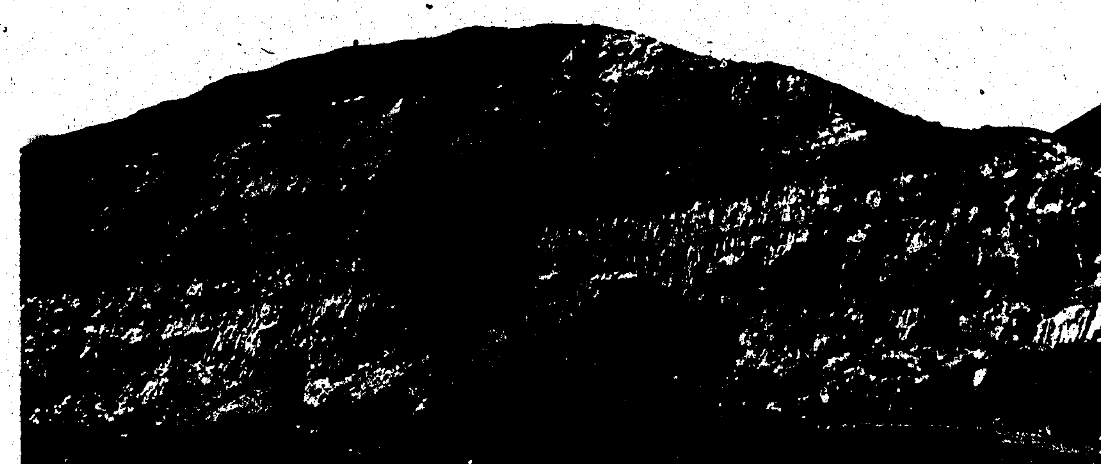

Plate 2. Photo illustrating stratigraphic relationship of the Nevis seam (lower carbonaceous horizon) and Ardley seam (capping outcrop). Nevis seam demarcates the Cretaceous-Tertiary boundary. (Dry Island Buffalo Jump Provincial Park) (slide courtesy of C. Singh).

this interval, the palynofloral extinction was placed at the base of the Nevis seam by Sweet and Hills (1984).

In both Canada and the United States, the Cretaceous-Tertiary boundary has been delineated palynologically. From New Mexico to western Alberta, the shift from a diverse angiosperm-rich late Maestrichtian flora to a low diversity, early Paleocene gymnosperm and miospore dominated flora, has been utilized to identify this boundary. It has also been shown that many Maestrichtian pollen and spores terminate their upward range at an iridium anomaly. This phenomenon has been well documented in the United States central Plains (Orth *et al.* 1981, Smit and van der Kaars 1984, Tschudy *et al.* 1984, Alvarez *et al.* 1984) and in correlative strata in Canada (Jerzykiewicz *et al.* 1984, Sweet and Hills 1984, Lerbekmo and Coulter 1985, Jerzykiewicz and Sweet 1986a, Lerbekmo and St. Louis 1986, Nichols *et al.* 1986, Lerbekmo *et al.* in press). This iridium anomaly is not restricted to North America, as it has been located worldwide, extensively in the northern hemisphere, and more recently in the southern hemisphere.

In both Canada and the United States, all areas share a diverse Maestrichtian angiosperm flora and the extinction of many morphologically complex species. In the U.S. sections, Tschudy *et al.* (1984) have considered catastrophic destruction of the vegetation to have taken place, resulting in vacant vegetal niches. Immediately above this extinction and corresponding iridium anomaly, Tschudy has identified a fern "spore-spike" which he believes represents a recolonization of the vegetation before the return to angiosperm dominance in the Paleocene. In contrast to this, in western Canada, Sweet (in Jerzykiewicz and Sweet, 1986a) has found that for several centimeters above the iridium anomaly and extinction, angiosperm pollen dominance persists before a shift to the miospore-gymnosperm assemblage equivalent to Tschudy's fern spore-spike. Also, at higher levels (tens of centimeters above the anomaly) the assemblage is dominated by gymnosperms.

Two hypotheses have been proposed to explain the sequence of events at the Cretaceous-Tertiary boundary; a) the impact of an extra-terrestrial body (Alvarez, 1983) and b) deep volcanism or mantle plume activity (McLean, 1985). The sequence of palynological assemblages at the boundary described by Tschudy *et al.* (1984) supports the idea of some type of catastrophic event and recolonization from refugia. Lerbekmo *et al.* (in press) downplay the catastrophe but do believe that some type of extraordinary happening occurred.

PASKAPOO FORMATION

The name Paskapoo was first used by Tyrrell (1887) in referring to the buff-weathering, cliff-forming sandstones in the Red Deer area (Plate 1). The lower contact was placed at the top of the Big Seam (Ardley seam) and it was assumed that the Edmonton graded upwards into the Paskapoo. Allan and Sanderson (1945) identified a Paskapoo Formation, and the contact with the underlying Edmonton strata was considered to be an erosional disconformity marking the Cretaceous-Tertiary boundary. Irish (1970) in defining the Scollard Member, lowered the base of the Paskapoo Formation to the top of the Battle Formation. Gibson (1977), in characterizing the Scollard Formation, reverted to Allan and Sanderson's (1945) definition of the base of the Paskapoo Formation as the base of the first major thick sandstone above the uppermost coal seam of the Ardley coal zone.

Following Gibson's (1977) usage, the basal sandstone of the Paskapoo Formation is usually separated from the underlying Scollard Formation by a recognizable scour surface (Plate 3). The Paskapoo is described as a series of non-marine sandstones, bentonitc shales, lignites and conglomerates (Carrigy, 1971). Very little sedimentological study has been carried out on the Paskapoo Formation other than the work of Carrigy (1970, 1971), whose petrographic studies included both the Paskapoo and its correlative to the south, the Porcupine Hills Formation (Figure 7). The

Paskapoo Formation is believed to have been deposited in a fluvial environment, but the lack of good outcrop has hampered comprehensive sedimentologic interpretation. The formation comprises the bedrock over a large area of Alberta from the south-central to north-central Plains. The recently discovered Obed-Marsh coal zone lies within the Upper Paskapoo Formation adjacent the central Alberta Foothills. No stratigraphic or sedimentologic study has been carried out on these strata other than the initial exploratory work of Union Oil (1979).

SCOLLARD-PASKAPOO CONTACT

Allan and Sanderson (1945) listed six criteria for distinguishing between Edmonton (Scollard) and Paskapoo strata:

1) uniformity of Edmonton strata
2) bentonite in the Edmonton, absent in the Paskapoo
3) conglomeratic nature of the basal Paskapoo and highly oxidized nature at contact with Edmonton
4) lower 300 feet of Paskapoo is quartzose sand, Edmonton is feldspathic and finer grained
5) Edmonton weathers in rounded slopes, Paskapoo is cliff-forming
6) color and induration are different

Allan and Sanderson (1945) further believed this contact to represent a major disconformity with as much as 400 feet of relief down to the Mauve Shale (Battle Formation). This was later questioned by Ower (1960), then by Campbell (1967) who stated,

> "..certainly in some localities there is a break in deposition at the base of the sandstone (eg. Ardley cliff), but in other cases, thick-bedded, buff-weathered sandstone rest directly and conformably on the Ardley coal zone. There appears to be no clear cut break in sedimentation between the Edmonton and Paskapoo Formations so that several hundred feet of strata overlying the Ardley coal zone cannot be assigned with certainty to either formation..."

Snead (1969) later added to the question of a disconformity stating,

> "...exposures of beds adjacent to the inferred position of the Edmonton/Paskapoo contact along the Red Deer River and its tributaries are too discontinuous and the lithologies of the two

formations too variable to detect the presence of a regional disconformity in the section on the basis of gross lithology alone..."

Plate 3. Photo illustrating the nature of the contact between the Scollard and Paskapoo Formations. Coarse-grained, blocky sandstones of the Paskapoo Formation overlying cross-bedded, finer-grained sandstones of the upper Scollard Formation (Dry Island Buffalo Jump Provincial Park) (slide courtesy of C. Singh).

III. PALEONTOLOGY OF THE SCOLLARD AND PASKAPOO FORMATIONS

VERTEBRATES

Brown (1914) was the first to collect vertebrate fossils along the Red Deer River valley from a site known as Erickson's Landing, in the Paskapoo Formation just upstream from the Joffre bridge (Figure 4). These vertebrate fossils were identified by Matthew (1914) and then later redescribed by Simpson (1927). Brown (1914) also compared the dinosaur fauna of the Edmonton Group with that of the Lance Formation of Wyoming and Belly River-Oldman Formations of Alberta, concluding that taxonomically, the Edmonton fauna was more closely associated with that of the Belly River Formation.

Sternberg (1947, 1949), collecting from the Edmonton Group, showed that typical Lancian dinosaurs occurred only above the Kneehills Tuff, in contrast to a different dinosaur assemblage below the Tuff (Edmonton assemblage). This Lancian assemblage from the upper Edmonton (lower Scollard Formation) is the youngest dinosaur fauna identified in Alberta. In his description of the upper Edmonton however, Sternberg (1949) mis-identified the coal seams and reported dinosaur remains from above the Ardley seam, thereby implying that strata were Upper Cretaceous in age up to and including the Ardley seam.

In attempting to place the Cretaceous-Tertiary boundary using palynofloral and dinosaurian extinctions, Russell and Singh (1978) were hampered by Sternberg's (1949) earlier report of dinosaur remains above the Ardley seam in the Ardley area, even though a palynological break was identified at the level of the Nevis seam. Dr. D.A. Russell, in re-examining Sternberg's original field notes and sections, did not locate the skeletons of *Tyrannosaurus rex* (later identified as *Dynamosaurus* sp. by Russell, but never published), and *Triceratops albertensis*, but from field measurements calculated them as occurring between the Nevis and Ardley seams. Applying Brown's (1962) scheme of placing the Cretaceous-Tertiary boundary at the lowest bed of lignite (coal) above the highest stratigraphically unreworked dinosaur remains, Russell and Singh (1978) placed the boundary at the base of the Ardley seam.

Lerbekmo *et al.* (1979) located Sternberg's original section and some of the dinosaur remains. The *Tyrannosaurus* skeleton was measured as occurring 10.5 m below the Nevis seam. Since the *Triceratops albertensis* remains were measured by Sternberg as being 20 ft (6 m) above the *Tyrannosaurus rex, Triceratops albertensis* must have been about 4.5 m below the Nevis seam. The Cretaceous-Tertiary boundary was therefore lowered to the Nevis seam, corresponding with the palynological break.

In a summary by Krause (1978), mammalian fossils from a number of Alberta sites were placed in a biostratigraphic framework constructed by Gingerich (1975) and Rose (1977). The Paleocene was subdivided by Gingerich (1975) on plesiadapiform primates, which are common fossils in the non-marine, middle to late Paleocene strata of North America (Figure 9). Six sites utilized by Krause (1978) included three from the Paskapoo Formation; the Swan Hills site (north-central Alberta), Erickson's Landing and Canyon Ski Quarry on the Red Deer River. Also included were two sites from the Porcupine Hills Formation (the Calgary and Cochrane II sites). A locality from the upper Ravenscrag Formation of southern Saskatchewan was the Roche Percee' site (Figure 10).

Due to the appearance of the form *Plesiadapsis rex*, the Erickson's Landing site was assigned a middle Tiffanian age (Figure 9). From the identification of *P. churchillii* and on carpolestid evidence, the Roche Percee', Swan Hills and Canyon Ski Quarry sites were assigned late (but not latest) Tiffanian ages. Although recovery was poor, from carpolestid evidence the Cochrane II site was considered early Tiffanian in age, and the Calgary site late Torrejonian.

Lithostratigraphic implications of this mammalian evidence included the fact

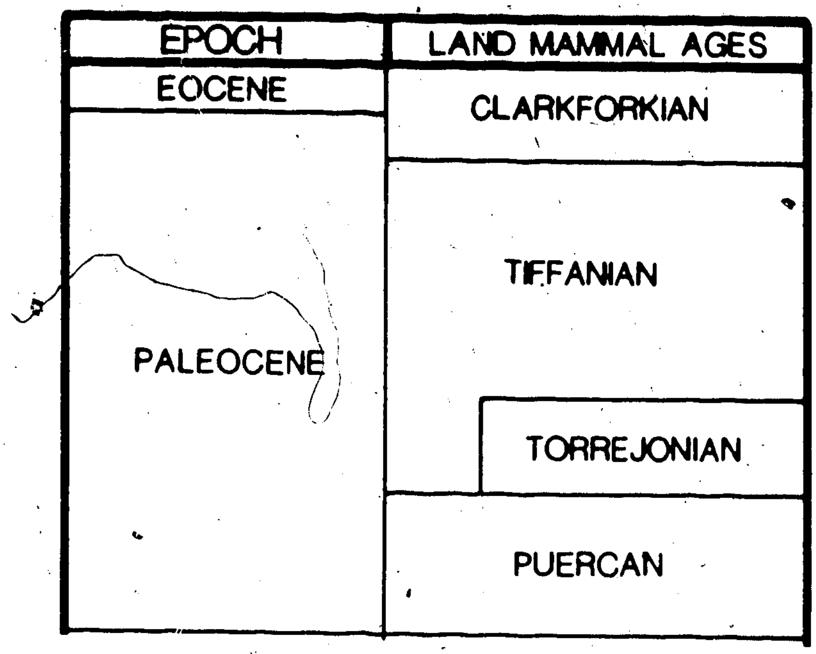

Figure 9. Stages of the Paleocene (modified from Wood *et al.*, 1941, R.C. Fox pers. comm., 1987).

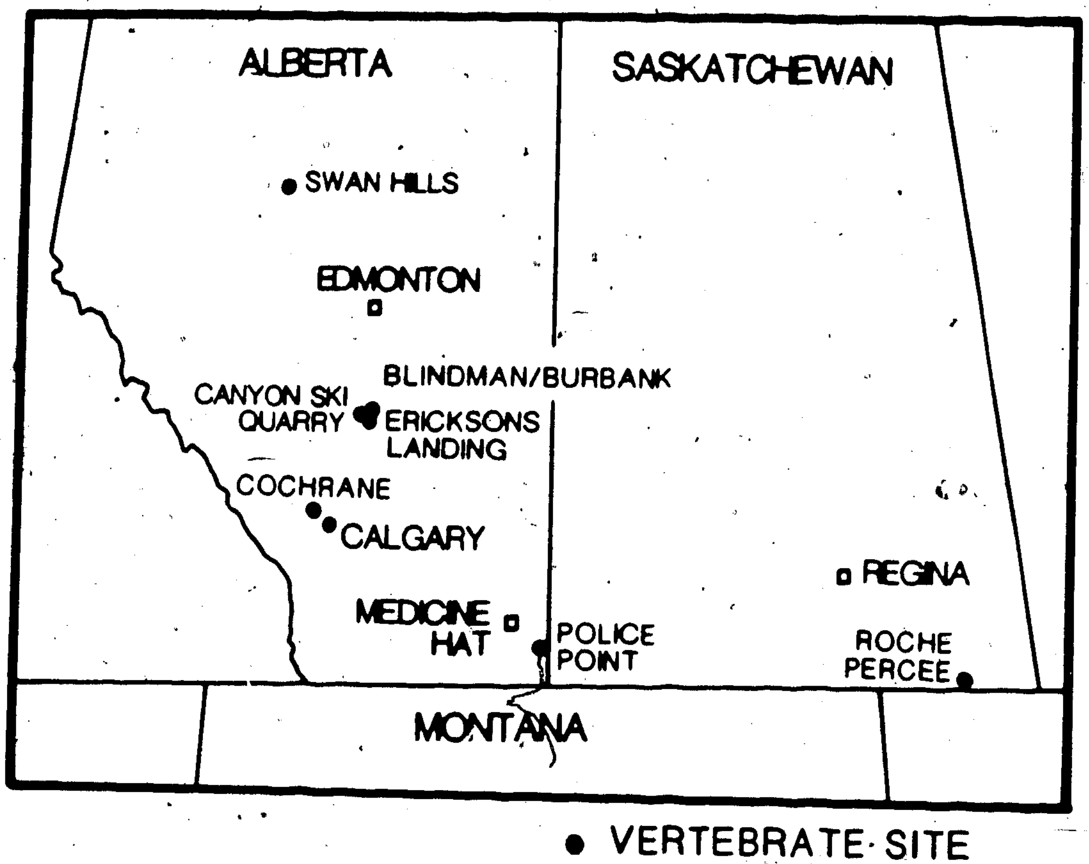

Figure 10. Paleocene vertebrate fossil localities of western Canada (after Krause, 1978).

that the Paskapoo Formation contains assemblages much younger than those recovered from the Porcupine Hills Formation. This contradicted the claim of Carrigy (1971) that the Porcupine Hills Formation overlies and is therefore younger than the Paskapoo.

Fox (1987, pers. comm.) has also examined the mammalian assemblages from these Alberta sites. Although he states that the framework proposed by Gingerich (1975) and Rose (1977) is more complicated than originally stated, and not wholly applicable to Alberta assemblages, there is no disagreement with the ages calculated by Krause (1978) for these Alberta sites. In addition to these localities, assemblages from near the junction of the Blindman and Red Deer Rivers indicate an early late Tiffanian age (Fox 1984a, b) (Figure 10).

MEGAFLORA

One of the first reports of megafloral fossils from the Paleocene of Alberta was made by Penhallow (1902) who examined fossils from the banks of the Blindman River. The most comprehensive study was undertaken by Bell (1949), who investigated numerous localities from the Alberta Plains and Foothills of uppermost Cretaceous and Paleocene age. In his exhaustive collections, Bell (1949) identified two distinct paleofloral breaks; one corresponding to the Kneehills Tuff, the other between the Edmonton and Paskapoo Formations. Very few plant species from the Scollard Formation ranged into the Paskapoo, and 75 percent of those species found in the Paskapoo had no recorded distribution in the Cretaceous. Bell (1949) concluded that the floras of the Paskapoo Formation and that of the Ravenscrag Formation studied by Berry (1935) were essentially identical and therefore of the same approximate age. Also compared were the floras of the Paskapoo to that of the Fort Union Formation collected by Knowlton (1919). Of the 37 species identified from the Paskapoo, 23 were present in the Fort Union and 17 were characteristic of these two formations. From this, the Paskapoo was interpreted as being the same age as part of the Fort Union Formation, which was considered to be Paleocene.

Other stratigraphic conclusions by Bell (1949) were that floras collected from the roof rock of the Mynheer seam in the Foothills were Paleocene in age, but distinctly older than the Paleocene assemblage from the Paskapoo Formation collected at the Blindman River locality. He also recognized an early Paleocene assemblage from the Porcupine Hills Formation.

Chandrasekharam (1974) studied plant megafossils from the Genesee locality west of Edmonton. From a fossil horizon above the Ardley correlative, he identified a Paleocene assemblage and suspected that the Cretaceous-Tertiary boundary lay at a shallow depth below the fossil bed. In a similar study, Christophel (1979) examined plant fossils from the Smokey Tower locality north of Hinton, Alberta. He interpreted these fossils as Paleocene in age, but was unable to precisely place this locality stratigraphically due to the lack of a marker horizon (ie. Battle Formation).

Recently, the Paskapoo Formation of the Joffre and Blindman localities has come under investigation. Hickey and Peterson (1978) tentatively regarded the age of the Blindman locality as middle to early late Paleocene (Torrejonian or Tiffanian). This was based on the general aspect of the flora, the absence of early and late Paleocene species, and the presence of the fern *Lastria goldiana*. In later studies, Stockey and Crane (1983), Taylor and Stockey (1984) and Crane and Stockey (1985) have identified many new Paleocene species of *Cercidiphyllum*-like plants from both the Joffre and Blindman localities. Their interpretation of these plant fossils does not contradict a Tiffanian age for these localities from fossil mammal investigations.

MOLLUSKS

The first report on late Cretaceous and Tertiary mollusks in the Canadian Plains was made by Whiteaves (1885, 1887). Warren (1926) and Russell (1926) listed and discussed molluskan faunas of the Edmonton Group and Paskapoo Formation, which were further studied by Russell (1929, 1931, 1932), who described a rich terrestrial Paleocene fauna. Dyer (1930) also described some new species of non-marine Upper Cretaceous and Paleocene fauna from Alberta. Allan and Sanderson (1945) in their comprehensive study, reported on a large collection of non-vertebrate fossils from the Edmonton and Paskapoo, including fresh water and terrestrial gastropods and fresh water pelecypods.

The most extensive study of molluskan fauna was undertaken by Tozer (1956) who examined the uppermost Edmonton (Scollard) and Paskapoo Formations as well as the Willow Creek and Porcupine Hills Formations of southern Alberta (Figure 7). The most striking feature of Paskapoo molluskan fauna noted by Tozer (1956) was the terrestrial element, which included at least ten species.

Two distinct molluskan faunas were found to occur within the Willow Creek Formation; a largely aquatic molluskan fauna and gastropods of a terrestrial habitat. Also noted was the lack of characteristic Fort Union Formation species in the lower Willow Creek and the Scollard Formations, thereby implying a Lancian age. The appearance of Fort Union species in the upper part of the Willow Creek correlated it with the lower Paskapoo Formation of Paleocene age. Mollusk fossils collected from the Porcupine Hills Formation also suggested a very strong correlation with the Paskapoo Formation. The major conclusion by Tozer (1956) was that the Paskapoo Formation was Paleocene in age.

OTHER PALEONTOLOGICAL ASPECTS

In a thorough examination of the Paskapoo Formation at the Joffre and Blindman localities, some rather rare paleontologic occurrences have been discovered. A variety of fossil insects have been recorded by Wighton (1982) and Kevan and Wighton (1981) from the Joffre Bridge locality, with Mitchell and Wighton (1979) and Wighton (1980) describing those from the Blindman locality. Wilson (1978) considers these insects from the Paskapoo in the context of other early Tertiary faunas. By far the most abundant insect fossils are the elytra of beetles (Coleoptera).

Russell (1928) reported fossils of the amiid fish *Stylomyleodon*, now known as *Kindleia* from the Paskapoo in the vicinity of Red Deer. Wilson (1980) stated that a diverse teleostean fauna is represented in the Paskapoo Formation at a large number of sites including Joffre Bridge. From the Smokey Tower locality, approximately 3 m below the plant layer of Christophel (1979), Wilson reports the remains of *Esox tiemani*, an elongate, narrow snouted pike. This fauna has also been found at Lovetteville (Foothills), Erickson's Landing, and the Roche Percee' sites. The remains of *Esox* from these sites are much older than had been previously known, and these Paleocene types more closely resemble those of the Eocene than late Cretaceous forms.

IV. PALYNOLOGY OF THE LATE CRETACEOUS TO PALEOCENE

EARLIER STUDIES

Palynology of the uppermost Cretaceous and Tertiary strata of the interior Plains of North America began with the pioneer work of Stanley (1965). This study of the Hell Creek and Fort Union Formations of South Dakota (Figure 11), had three major objectives: a) establish the type of microfossils present, b) infer botanical affinites, and c) establish a palynological zonation useful for correlation. Stanley (1965) had also hoped to identify the Cretaceous-Tertiary boundary. However, he did note the very close resemblance between his microflora and that found in Siberia.

Norton and Hall (1967, 1969) studied the microflora from the Hell Creek type-locality in Montana (Figure 11). Their intent was to delineate the Cretaceous-Tertiary boundary palynologically. They illustrated an Upper Cretaceous assemblage characterized by abundant *Aquilapollenites* spp. and *Wodehouseia spinata*, and a Paleocene assemblage distinguished by large numbers of tricolpate and tricolporate forms along with *Wodehouseia fimbriata*. Norton and Hall (1969) did not identify a major palynological break, but instead suggested a transition zone to mark the Cretaceous-Tertiary boundary.

Leffingwell (1971) in a major palynological study of the Lance and Fort Union Formations in the type-Lance area of Wyoming, identified three assemblage zones corresponding to two microfloral changes. He further interpreted the top of his lowermost Assemblage A to mark the Cretaceous-Tertiary boundary, which corresponded to the Lance-Fort Union boundary (Figure 11). A similar break had been illustrated by Stanley (1965) in his sections in South Dakota.

R.H. Tschudy (1971) compared assemblages from across the Cretaceous-Tertiary boundary from both the Rocky Mountains and a Mississippi Embayment locality in Kentucky. The Cretaceous assemblages of the Rocky Mountains and Kentucky localities were different because they belonged to two distinct paleofloral provinces

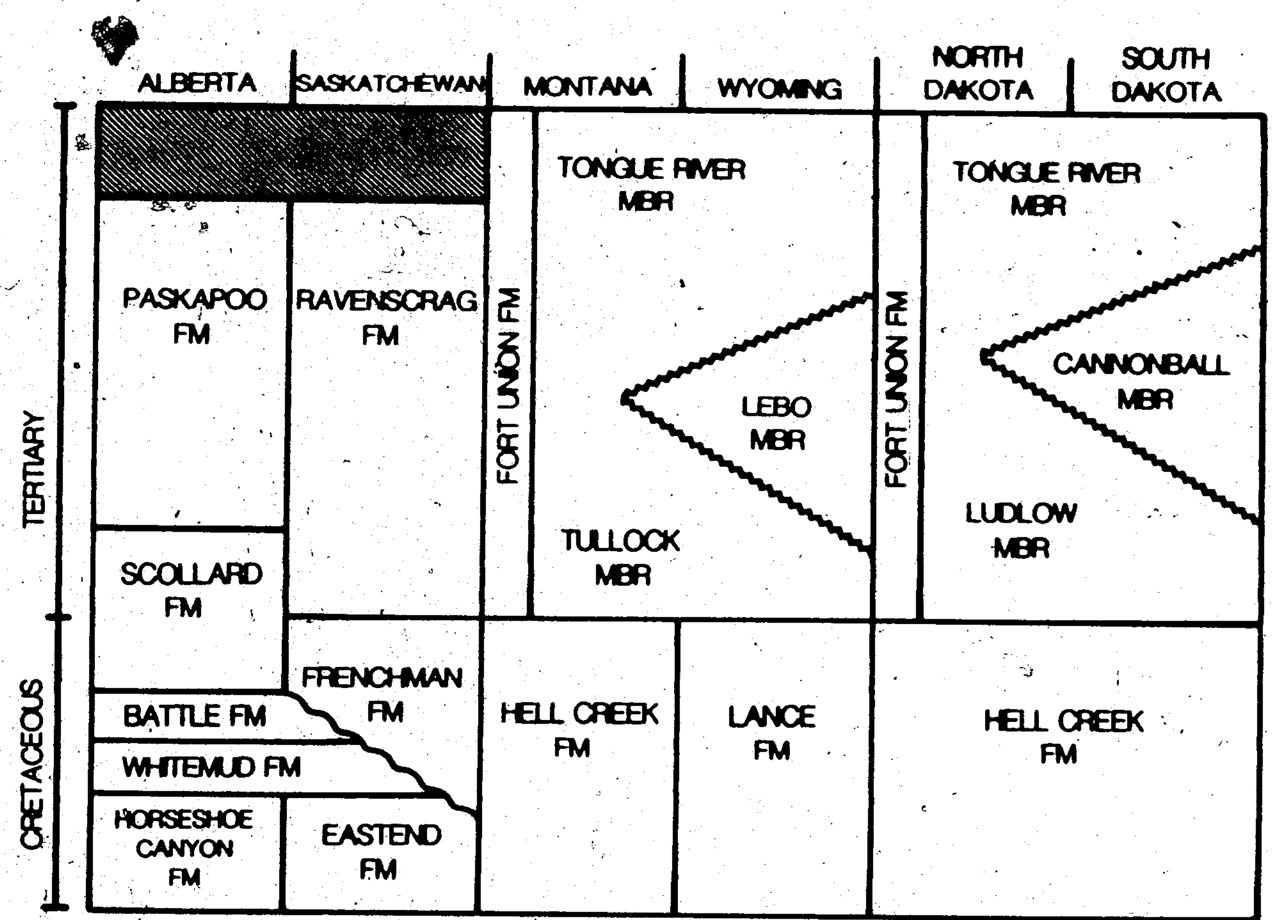

Figure 11. Uppermost Cretaceous and Paleocene correlatives of the western Interior Plains (modified from Russell and Singh, 1978).

(Aquilapollenites in the west, and Normapolles in the east) separated by the epeiric sea. According to R.H. Tschudy (1971) the floral change at the Cretaceous-Tertiary boundary resulted from the climatic changes caused by the withdrawl of the epeiric sea as a result of uplift of the Rocky Mountains.

The Paleocene strata of the Wind River Basin in Wyoming (Figure 11) were zoned by Nichols and Ott (1978) utilizing first appearances and extinctions of the *Momipites-Caryapollenites* palynofloral lineage. They noted that the lower Paleocene (P1-P3 Zones) was dominated by *Momipites* and the upper Paleocene (P4-P6 Zones) by *Caryapollenites*, with a corresponding decline in *Momipites*.

Palynology of the Paleocene strata of the Alberta Plains has not been a prime area of research, but in recent years a search for the Cretaceous-Tertiary boundary has provided some interest. The first worker to study the palynoflora from strata outcropping along the Red Deer River valley was Srivastava (a number of papers culminating in 1970). He concentrated basically on the upper Campanian-Maestrichtian strata of the Edmonton Group, zoning this interval into eight assemblages (Srivastava, 1970). Of [illegible]r interest was the identification of the *Wodehouseia spinata* Zone (VIII), an interval from the Battle Formation to the Nevis seam, and the termination of many angiosperm species at the top of this zone. Immediately above this was recognized a *Wodehouseia fimbriata* Zone (IX) which further exhibited a decrease in angiosperms and an increase in gymnosperms. This sequence of *W. spinata* and *W. fimbriata* was identical to that found by Stanley (1965) and Norton and Hall (1969).

The only study encompassing palynology of the Paskapoo Formation of the Alberta Plains was undertaken by Snead (1969) in an attempt to define the Cretaceous-Tertiary boundary, and to correlate from outcrop in the Red Deer River valley into the subsurface by means of assemblage zonation. Snead (1969) subdivided the uppermost Edmonton and lower Paskapoo strata into three zones based on stratigraphically restricted species, and confirmed a palynological break at the level of the Nevis seam. He did not identify this as the Cretaceous-Tertiary boundary, but instead interpreted a transition zone above the Nevis seam which he believed represented the boundary.

With angiosperm palynomorph data, Eliuk (1969) attempted to correlate the Entrance Conglomerate of the central Alberta Foothills to strata of the Alberta Plains, using the works of Srivastava and Snead (1969) to derive his correlations. Eliuk (1969) concluded that the Entrance Conglomerate was Maestrichtian in age and correlated with the upper Edmonton division. He believed that the Conglomerate did not mark the Cretaceous-Tertiary boundary, but that the boundary was contained in the 3500 feet of strata between the Entrance Conglomerate and the High Divide Ridge Conglomerate of the basal Paskapoo Formation (Figure 7).

Singh (in Russell and Singh 1978, and in Lerbekmo *et al.* 1979) examined in greater detail the strata in the immediate vicinity of the Nevis seam in the Red Deer River valley, hoping to accurately locate the Cretaceous-Tertiary boundary palynologically. Due to the presence of *Wodehouseia fimbriata*, a known Paleocene specimen within the Nevis-Ardley interval, Singh (in Russell and Singh, 1978) suggested placing the boundary at the top of the Nevis seam, in accordance with the similar palynological break identified by Snead (1969) and Srivastava (1970). However, the erroneous record of dinosaur remains above the Nevis (Sternberg, 1949) prompted Russell and Singh (1978) to move the boundary up to the base of the Ardley seam, stating that the palynological break preceded the extinction of the dinosaurs.

Lerbekmo (in Lerbekmo *et al.*, 1979) relocated Sternberg's (1949) original Tyrannosauroid find and re-measured the section, placing the *in-situ* occurrence as 10.5 m below the Nevis seam. It was therefore concluded that the dinosaur and palynofloral extinctions were nearly synchronous and part of a worldwide extinction. The Cretaceous-Tertiary boundary was shifted down to the top of the Nevis seam. The position of this boundary was then re-adjusted to the base of the Nevis by Sweet and Hills (1984) based on very detailed palynological sampling below and within the 35 cm seam.

Sweet (1978) examined the palynology of the Frenchman and Ravenscrag Formations of southern Saskatchewan (Figure 11). The major purpose of this study was to develop a biostratigraphic framework to assist in the correlation of individual coal seams within the several coal zones present. Sweet (1978) identified the Cretaceous-Tertiary boundary at the base of the Ferris coal zone of the Cypress Hills area, and further identified a second microfloral change between the Boundary and Estevan coal zones. Paleoecologically, Sweet (1978) suggested that the events represented by the palynomorph trends immediately adjacent to the Cretaceous-Tertiary boundary were the result of a critical change of climate following late Maestrichtian climatic deterioration. The gradual cooling was reflected by the shift from angiosperm to gymnosperm dominance in the latest Maestrichtian, then, as suggested by Tschudy (1971),

> "...the apparent simaltaneous extinction of accessory taxa already occurring in reduced numbers was the result of a critical point being reached within a continued climatic deterioration rather than a catastrophic event..."

Recently, Sweet (in Jerzykiewicz *et al.* 1984, and Jerzykiewicz and Sweet 1986a) has placed the Cretaceous-Tertiary boundary in the central Alberta Foothills at the base of the Mynheer seam, the lowermost coal seam of the Coalspur Formation (Figure 7). The boundary was identified by the well-documented shift from angiosperms to gymnosperms and corresponding extinctions. This boundary identification has led to the correlation of the Mynheer seam in the Foothills, with the Nevis seam in the Plains, and the Ferris seam in southern Saskatchewan.

In a paleoenvironmental study by Jerzykiewicz and Sweet (1986b), Sweet illustrated that palynological assemblages from the Willow Creek Formation in southern Alberta (Figure 7) were anomalously impoverished compared to assemblages of similar age from northerly localities. They interpreted the formation of caliche horizons, red beds, and the lack of good coal development to represent deposition in a semi-arid environment that was biologically stressed during the late Maestrichtian, but less so in early Paleocene times. The Cretaceous-Tertiary boundary was identified within the upper portion of the Willow Creek Formation, and a middle Paleocene age interpreted for the uppermost Porcupine Hills Formation (Figure 7).

V. THE *MOMIPITES-CARYAPOLLENITES* PALYNOFLORAL LINEAGE

Fossil pollen of the family Juglandaceae are common in strata of early Cenozoic age. The wide range of morphologic variations encountered in Paleocene pollen suggests that this family was undergoing rapid diversification at this time (Nichols and Ott, 1978). Their widespread distribution throughout the central Plains of North America provides the basis for biostratigraphic applications.

Wodehouse (1933) erected the genus *Momipites*. His specimens are believed to be congeneric with species of *Momipites* described subsequently, although the holotype has never been re-located (Nichols and Ott, 1978). In a comprehensive study of Juglandaceae, Whitehead (1965) delineated the major morphologic groups including one or more extant genera. Stone and Broom (1975) surveyed all genera, and re-affirmed Whitehead's morphologic groups and trends in evolution. Leopold and McGintie (1972) surveyed mega- and microfossils of *Pterocarya*, *Platycarya* and *Engelhardtia* of the Juglandaceae. They compared their Rocky Mountain forms to other Tertiary forms around the world.

Nichols (1973) examined the morphologies of triporate Juglandaceae, and distinguished seven different groups of *Momipites*. The genus *Momipites* was emended to accomodate fossil pollen similar to modern *Engelhardtia*, but exhibiting only fossil features. Nichols (1973) demonstrated that *Engelhardtia* may have been derived from *Momipites* on the basis of morphologic trends. No stratigraphic evidence was given by Nichols (1973) for phyletic lineages of *Momipites*, and neither Leffingwell (1971) nor Nichols (1973) identified the relationship between *Momipites* and *Caryapollenites* biostratigraphically. Subsequent detailed stratigraphic examination of Paleocene strata has identified and utilized the *Momipites-Caryapollenites* lineage (Nichols and Ott, 1978).

WYOMING ZONATION

Nichols and Ott (1978) have divided the Paleocene Fort Union Formation of the Wind River Basin of Wyoming into six palynostratigraphic zones (Figure 12). This zonation is based on the appearance levels and subsequent ranges of species in the *Momipites-Caryapollenites* phylogenetic lineage. Twelve species, seven *Momipites* and five *Caryapollenites*, their relative abundances, plus other stratigraphically important forms are utilized in this zonation (Figure 13).

Lower Paleocene Zones P1 to P3 are characterized by the appearances of the seven *Momipites* species, and the domination of *Momipites* over *Caryapollenites* in relative abundance. Conversely, upper Paleocene Zones P4 to P6 are characterized by the appearances of four *Caryapollenites* (*C. prodromus* appears in P3) and the shift to *Caryapollenites* dominance over *Momipites* (Figure 13). Also, in the upper Paleocene many lower Paleocene *Momipites* species terminate their upward ranges. Accessory forms such as *Aquilapollenites spinulosus* further characterize the P3 Zone, with *Pistillipollenites mcgregorii* and *Insulapollenites rugulatus* diagnostic of the P5 Zone.

This *Momipites-Caryapollenites* lineage has been interpreted as phylogenetic, based on subtle morphologic variations which appear in species from younger strata. Speciation within *Momipites* and *Caryapollenites* is based on three features:

1) size (modal diameter)
2) shape of the interporia (concave or convex sides)
3) structure of the exine at one pole.

M. leffingwellii, the ancestral form, is small (21 microns) with concave interporia and a well developed circumpolar ring. Younger species of *Momipites* are larger and exhibit a range of polar modification. Further, *Caryapollenites* differ from *Momipites* in the degree of heteropolarity, that is, the amount to which the pores have migrated into one hemisphere of the pollen grain (Figure 13). The degree of heteropolarity is an important specific characteristic.

<table>
<tr><th>AGE</th><th colspan="2">FORMATION</th><th>PALYNOMORPH ZONES</th></tr>
<tr><td>EOCENE</td><td colspan="2">WIND RIVER Fm.</td><td>E</td></tr>
<tr><td rowspan="6">PALEOCENE</td><td rowspan="6">FORT UNION Fm.</td><td rowspan="2">WALTMAN SH. Mbr. (Lacustrine)</td><td>P6</td></tr>
<tr><td>P5</td></tr>
<tr><td rowspan="4">LOWER UNNAMED Mbr. (Fluviatile)</td><td>P4</td></tr>
<tr><td>P3</td></tr>
<tr><td>P2</td></tr>
<tr><td>P1</td></tr>
<tr><td>CRET. (Maestrichtian)</td><td colspan="2">LANCE Fm.</td><td>K</td></tr>
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Figure 12. Paleocene zonation of the Wind River Basin, Wyoming (reproduced by permission of Nichols and Ott, 1978).

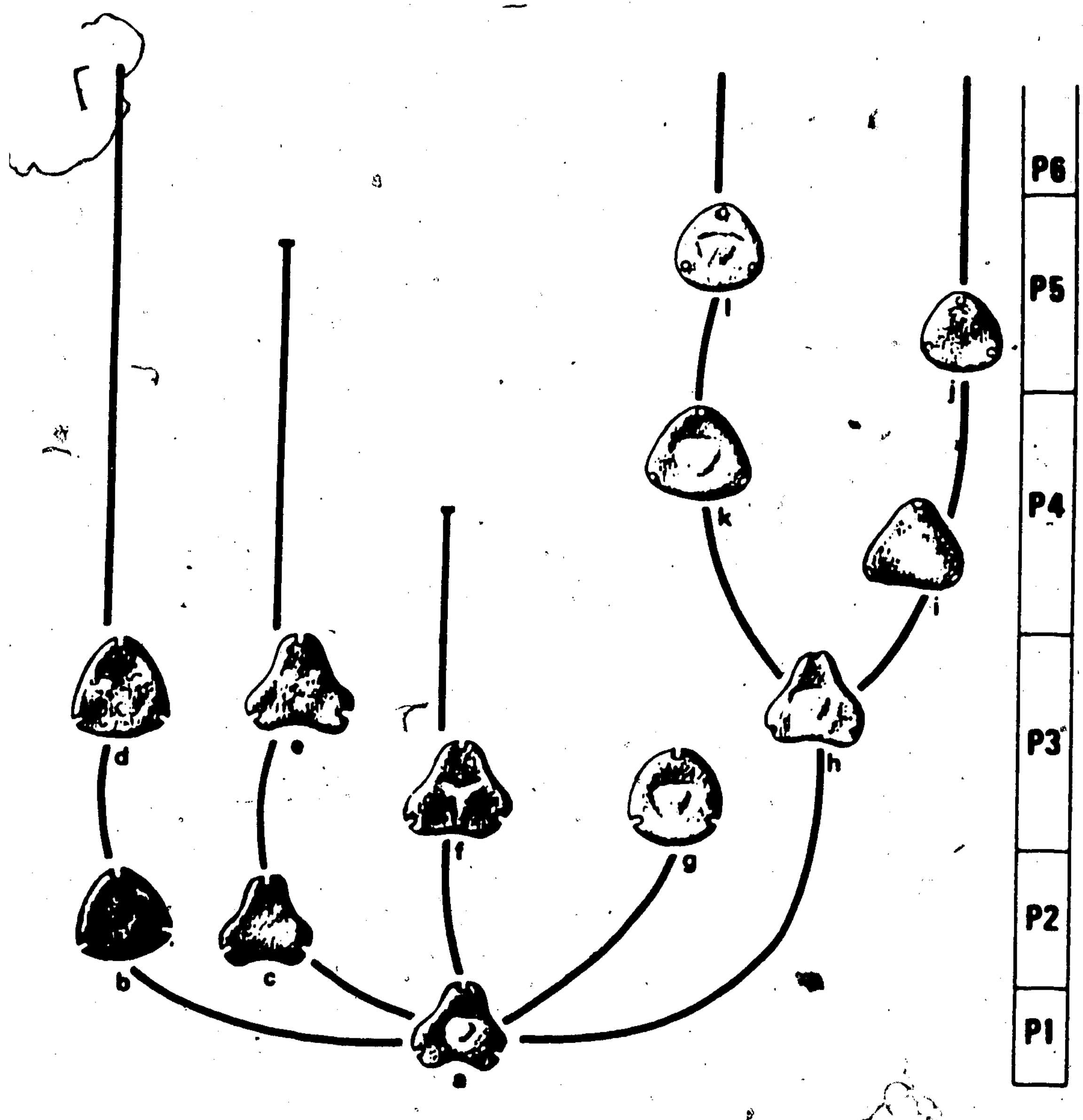


Figure 13. *Momipites-Caryapollenites* palynofloral lineage as determined from Paleocene strata of the Wind River Basin, Wyoming (reproduced by permission of Nichols and Ott, 1978)
a-M. leffingwellii b-M. wyomingensis c-M. waltmanensis d-M. ventifluminis e-M. triorbicularis f-M. actinus g-M. annellus h-C. prodromus i-C. imparalis j-C. inelegans k-C. wodehousei l-C. veripites

VI. PALEOCENE STRATIGRAPHIC PALYNOLOGY

ALBERTA ZONATION

Paleocene strata extend from the base of the Nevis seam (Cretaceous-Tertiary boundary) in the Scollard Formation to the top of the Paskapoo Formation. Uppermost Maestrichtian assemblages are dominated by diverse *Aquilapollenites* spp. Also common are *Tricolpites reticulatus*, *Leptopecopites pocockii*, and *Wodehouseia spinata*. This interval from the top of the Battle Formation to the Cretaceous-Tertiary boundary is known as the *Wodehouseia spinata* Zone (VIII) with a *Leptopecopites pocockii* Subzone (VIIIa) (Srivastava, 1970). The Cretaceous-Tertiary boundary within the sampled coreholes was identified by the extinction of these forms, and the shift to the low diversity early Paleocene assemblage.

The writer has been able to divide the Paleocene strata of the central Alberta Plains into six palynostratigraphic zones based on a modification of the Nichols and Ott (1978) *Momipites-Caryapollenites* palynofloral lineage (Figure 14). Although the following zonal nomenclature is that of Nichols and Ott (1978) (ie. P1, P2,...P6), it should be noted that these zones are interpreted for central Alberta Plains strata only. Reference to these zones should be confined to this geographic area. A thorough listing and discussion of all palynological occurrences from all localities is presented in Appendix A.

P1 Zone

The lowermost Paleocene P1 Zone is characterized by *Wodehouseia fimbriata* with no *Momipites* nor *Caryapollenites* species present (Figure 14). The extreme lowermost portion of this zone may be identified by the presence of *Wodehouseia spinata* while lacking other Maestrichtian forms, particularly diverse *Aquilapollenites* spp. This sequence of *W. spinata* to *W. fimbriata* has been well documented in the boundary interval, with these two species never occurring in the same horizon

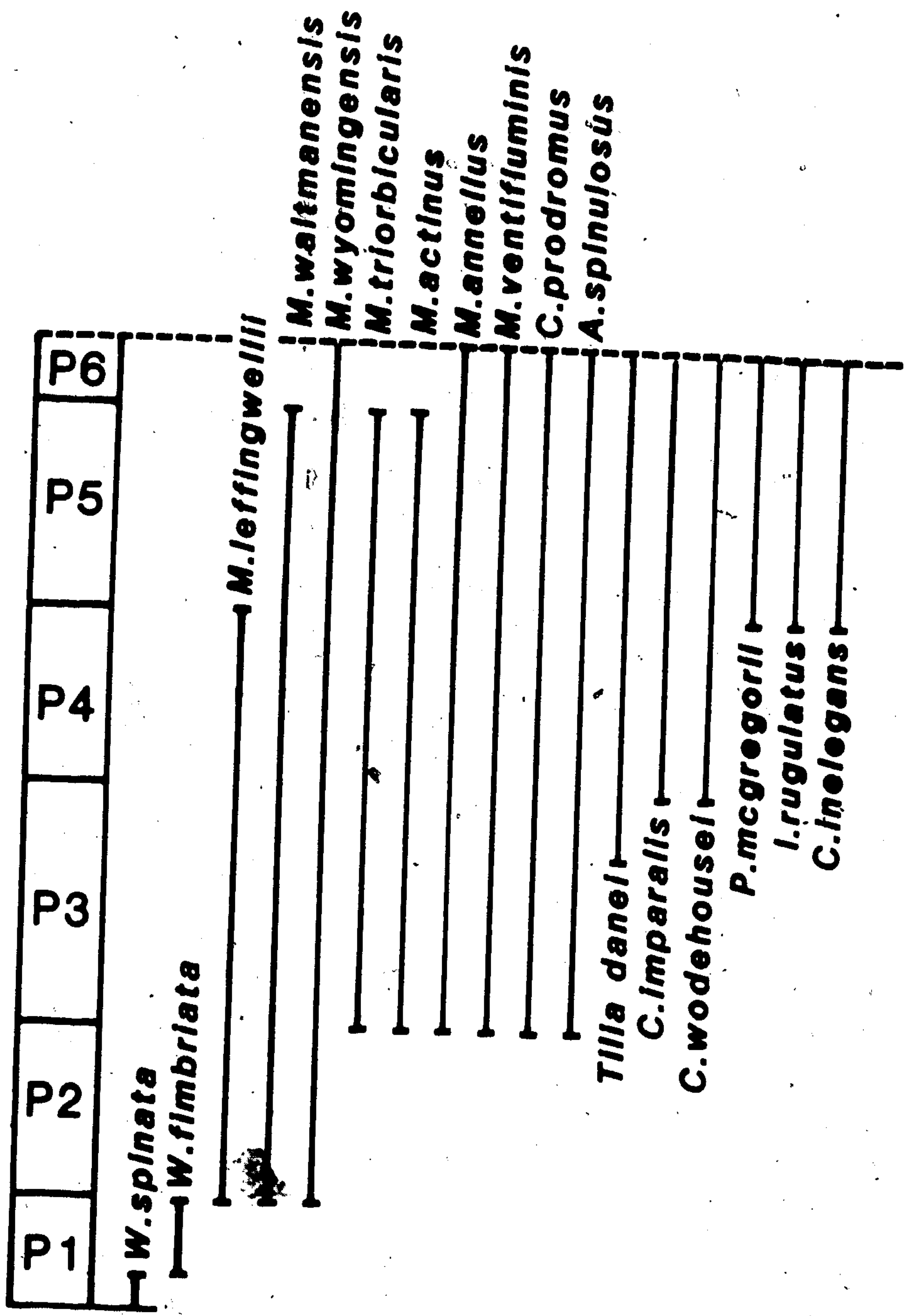


Figure 14. Ranges of stratigraphically important species of the central Alberta Plains, with corresponding zonation (*Alberta palynostratigraphic zones).

(Stanley 1961, Russell and Singh 1978) (Plate 5).

Stratigraphically, this zone extends from the base of the Nevis seam to the base of the Ardley seam (Figure 15). At this level, the range of *W. fimbriata* terminates.

P2 Zone

This zone is identified by the first appearances of *Momipites* in the forms *M. leffingwellii*, *M. waltmanensis*, and *M. wyomingensis* (Figure 14) (Plate 4). It is indeterminable as to which of these species appears first in the stratigraphic sequence. The first occurrence of P2 Zone *Momipites* succeeds the termination of the range of *W. fimbriata*. The P2 Zone is further characterized by the presence of *Retitrescolpites bathyreticulatus* and *R. anguloluminosus* (Plate 6). Although scarce within the samples from this study, they have been recorded as a common occurrence from Ardley equivalent strata at Wabamun-Highvale (west of Edmonton), and from equivalent strata outcropping in the Red Deer River valley (Russell and Singh, 1978). In addition, this zone may be distinguished by abundant *Kurtzipites* spp. and the subsequent termination of the range of *K. circularis*, which transcends the Cretaceous-Tertiary boundary but becomes extinct within upper P2 Zone strata (Plate 6).

The P2 Zone encompasses strata from the base of the Ardley seam to the base of the Paskapoo Formation (Figure 15). The first fine-grained sample above basal Paksapoo Formation sandstones normally exhibits a diverse P3 Zone assemblage, therefore the boundary between the P2 and P3 Zones is arbritrarily placed at the Scollard/Paskapoo contact.

P3 Zone

The P3 Zone assemblage displays many new forms, which include four *Momipites* species and the first appearance of *Caryapollenites*. Species of *Momipites* making their entrance are: *M. annellus*, *M. ventifluminis*, *M. triorbicularis*, and *M. actinus* (Plate 4). *Caryapollenites prodromus* is the oldest species of *Caryapollenites*, appearing in this interval (Plates 5). As well, the appearance of *Aquilapollenites spinulosus* is very characteristic of the P3 Zone (Figure 14), and is the only well documented species of *Aquilapollenites* from the middle Paleocene of the central North American Plains (B.D. Tschudy and Leopold, 1971). The appearance of *Tiliaepollenites danei* is diagnostic of upper P3 Zone strata (Figure 14), with the termination of the range of *Kurtzipites trispissatus* within this P3 Zone (Plate 6).

Stratigraphically, this zone encompasses an appreciable part of the Paskapoo Formation due to inclusion of the palynologically barren basal Paskapoo sandstones within the lower portion of this zone (Figure 15).

P4 Zone

Two more *Caryapollenites* species viz. *C. wodehousei* and *C. imparalis*, make their first appearances and characterize the P4 Zone (Figure 14) (Plate 5). Both of these species display increasing heteropolarity consistent with younger forms of *Caryapollenites*, with *C. wodehousei* displaying a circumpolar ring and *C. imparalis* lacking polar modification. The termination of the range of *Kurtzipites annulatus* within these strata is further indication of this zone (Plate 6). A full complement of lower Paleocene *Momipites* is still present.

There are no lithologic markers at the P3/P4 boundary as there are at the lower zonal boundaries. The P4 Zone must be identified on the basis of the first appearance of the two new *Caryapollenites* species. However, the interval containing the P3/P4 boundary is a much finer grained sequence above the basal Paskapoo

Formation sandstones, and is characterized by an increasing amount of argillaceous and carbonaceous strata (Figure 15).

P5 Zone

The upper Paleocene P5 Zone is distinguished by the appearances of *Caryapollenites inelegans*, *Pistillipollenites mcgregorii* and *Insulapollenites rugulatus* (Figure 14) (Plates 5, 6). *P. mcgregorii* is the most characteristic and easily recognizable of these P5 Zone species, and usually appears first in the stratigraphic record, followed by the other two species. In addition to these appearances, the P5 Zone is characterized by the overall assemblage domination by *Momipites wyomingensis* and *M. ventifluminis* (Plate 4).

M. leffingwellii, which first appeared in the P2 Zone, terminates within P4 Zone and is conspicuously absent from the P5 Zone assemblage (Figure 14). All other species of *Momipites* are present in this zone. *Caryapollenites inelegans* displays complete heteropolarity with all three pores having migrated into one hemisphere of the pollen grain. This species also lacks polar modification and is much more rounded in outline compared to older *Caryapollenites* species, which are sub-triangular in shape. This minor characteristic was also noted by Nichols and Ott (1978) in their identification of this lineage.

As with the previous zonal boundary, the P4/P5 boundary is not distinguished by any single lithologic marker. The P5 Zone must be identified by the first appearance of *Pistillipollenites mcgregorii*. The P5 Zone of the Paskapoo Formation includes abundant carbonaceous strata and coal. This zone includes all strata from the first occurrence of *P. mcgregorii* to the top of the Obed No. 2 coal seam at the Obed-Marsh locality (Figures 15 and 16). This comprises most of the Paskapoo Formation surface bedrock in the central Plains (Figure 17).

P6 Zone

In contrast to the distinction of the previous zones, the P6 Zone is characterized by the absence of three *Momipites* species, viz. *M. actinus*, *M. triorbicularis*, and *M. waltmanensis* (Plate 4). Similar to the P5 Zone however, the overall assemblage is dominated by *M. wyomingensis* and *M. ventifluminis*, which are also associated with a full complement of *Caryapollenites* species.

The P6 Zone is limited both geographically and stratigraphically. The P5/P6 boundary appears to coincide with the top of the Obed No. 2 seam, and therefore, the P6 Zone encompasses only those strata from this level to the top of the preserved Paskapoo Formation (Figure 16). Due to the limited geographic extent of the Obed-Marsh coal zone, the P6 Zone is likely to be restricted to this immediate area (Figure 17). There does not appear to be any further possible subdivision of this P6 Zone assemblage, nor is there any suggestion of Eocene age strata.

DIFFERENCES BETWEEN ALBERTA AND WYOMING PALYNOFLORAL ZONES

There are two major differences between the Alberta zonation and that of Wyoming. The first difference is the lack of *Momipites* spp. in the P1 zone of Alberta, and the second one is the paucity of *Caryapollenites* spp. in the upper Paleocene of Alberta.

According to Nichols and Ott (1978) the P1 Zone in Wyoming is characterized by the occurrence of *Momipites leffingwellii* followed by *M. wyomingensis* and *M. waltmanensis* in the P2 Zone. In the central Alberta Plains, these three species seemingly appear simaltaneously, and occur well above the Cretaceous-Tertiary boundary. The distinction of *M. leffingwellii* appearing first in the stratigraphic record does not seem to be valid in Alberta. Hence the P1 Zone in Alberta is based on *Wodehouseia fimbriata*, whose presence is restricted to the lowermost Paleocene strata (Figure 14).

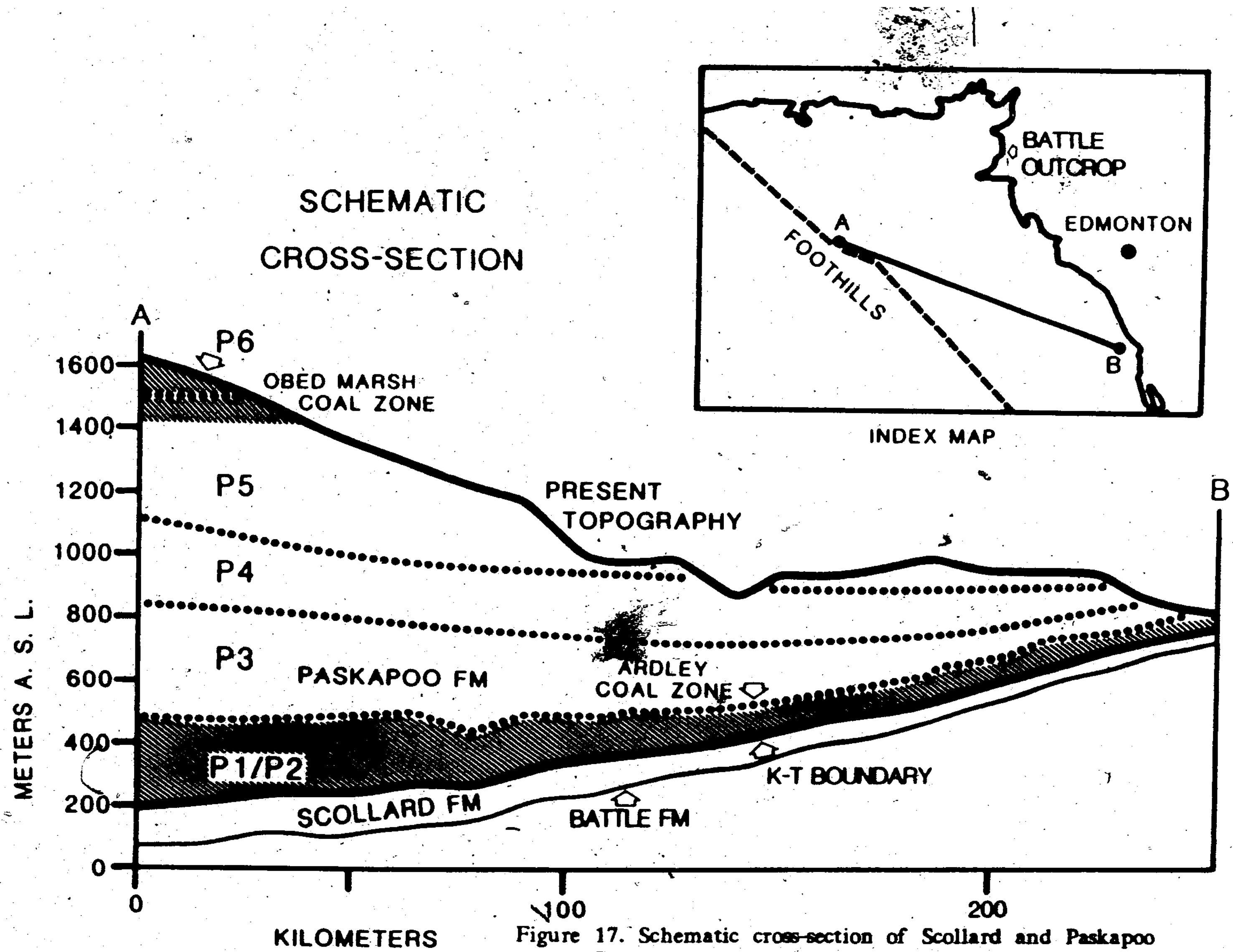


Figure 17. Schematic cross-section of Scollard and Paskapoo Formation strata of the Alberta Syncline, and nature of the Alberta P-Zones (modified from Richardson *et al.*, 1986).

In Wyoming, the upper Paleocene zones are distinguished by the shift to *Caryapollenites* dominance over *Momipites*, compared to the reverse for the lower Paleocene. In Alberta, *Momipites* dominates throughout the Paleocene, while *Caryapollenites* remains a subordinate element in the upper Paleocene. Within upper Paleocene Zones P5 and P6, *Momipites wyomingensis* and *M. ventifluminis* are dominant, with *Caryapollenites* comprising a small percentage of the overall assemblage.

The lack of P1 Zone *Momipites* in Alberta may be due to the presence of a pre-P1 zone in the lowermost Paleocene. Jacobson and Nichols (1982) have said:

> "...we note however that (Newman) and (Tschudy) (oral comm., 1980) stated that a lowermost Paleocene pre-P1 Zone exists in some locations. According to Newman and Tschudy, the zone is characterized by absence of species of the *Momipites-Caryapollenites* lineage..."

The localities which exhibit the pre-P1 Zone, are from the northern United States. This phenomenon likely represents the northward migration in the early Tertiary, of plants which produced *Momipites* pollen thus resulting in *Momipites* diachroneity from south to north. In Alberta, this is represented by a stratigraphic interval in the lowermost Paleocene which is devoid of *Momipites* spp. Hence the three species of *Momipites* appear simaltaneously in Alberta stratigraphically well above the Cretaceous-Tertiary boundary (Figure 14). The Wyoming P1 Zone designation of Nichols and Ott (1978) based on the sole occurrence of *Momipites leffingwellii* is not valid for northerly localities. The appearance of *M. leffingwellii* in conjunction with *M. wyomingensis* and *M. waltmanensis*, identifies the P2 Zone in Alberta, with the P1 Zone devoid of *Momipites spp.* This probably compares to the pre-P1 Zone of Newman and Tschudy quoted by Jacobson and Nichols (1982).

The later appearance of *Momipites* may also account for the lack of *Caryapollenites* in the upper Paleocene of Alberta. The migration northward and subsequent domination of the palynofloral assemblages by *Caryapollenites* perhaps did not occur until much later in Alberta, possibly Eocene time, which is not represented in the stratigraphic record of Alberta. In examining fossil leaf physiognomy, paleobotanists have determined that there was a distinct warming trend at the end of the Paleocene in the north-central United States Plains (Brown 1962, Hickey 1977, Wolfe and Upchurch 1986). This warming perhaps resulted in the flourishing of plants which produced *Caryapollenites* pollen and hence their abundance in the fossil record of this region. This warming may have been less in Alberta, and therefore *Momipites* dominance extended through the upper Paleocene.

Brown (1962) also stated that fossil plant assemblages collected from neighboring basins differed greatly, and that there was a distinct north-south climatic differentiation of the floras. However, although climatic differences were no doubt present between Alberta and Wyoming, determining these differences is beyond the scope of the present study.

Other minor modifications to the palynofloral lineage established in Wyoming include the extension of the range of *Momipites actinus* to the top of the P5 Zone (*M. actinus* is absent in the P5 Zone of Wyoming), and the termination of *Momipites waltmanensis* at the top of the P5 Zone in Alberta (*M. waltmanensis* is present throughout the upper Paleocene of Wyoming) (Figure 14). As well, conspicuous by its absence is *Caryapollenites veripites* from the Alberta record, whereas it is common in the upper Paleocene of Wyoming and characterizes the P6 Zone of that area.

In contrast to these differences, there are similarities in the occurrences of the palynofloras which do not seem to be affected by latitude. These include the diversity of *Momipites* spp., and the appearance of *Aquilapollenites spinulosus* and *Tiliaepollenites danei* in the P3 Zone, the diversification of *Caryapollenites* (*C. wodehousei* and *C. imparalis*) in the P4 Zone, and the appearance of *Pistillipollenites mcgregorii*, *Insulapollenites rugulatus* and *Caryapollenites inelegans* in the P5 Zone.

VII. STRATIGRAPHIC CORRELATIONS

ALBERTA PLAINS CORRELATIVES

The most complete palynological study of Scollard and Paskapoo Formation strata of the Red Deer area was undertaken by Snead (1969), who originally studied the palynology of CH-65-1 (Wizard Lake) and outcropping strata from the Red Deer River valley in search of the Cretaceous-Tertiary boundary (Figure 4). Snead (1969) recognized the floral change at the Nevis seam, but placed the Cretaceous-Tertiary boundary within a transition palynofloral assemblage above it.

Zone B of Snead (1969) encompasses the entire Ardley coal zone from the Nevis seam to the base of the Paskapoo Formation. This zone which contains abundant *Kurtzipites* spp. and *Myrtaceidites* spp., is equivalent to the P1 and P2 Zones of this study. Snead (1969) did not find *Wodehouseia fimbriata* in sample WL-30 immediately above the Nevis seam, which was recorded subsequently by Singh (in Russell and Singh, 1978) who re-examined Snead's microfloral slides.

Of interest was Snead's placement of the Zone B/C division at the contact between the Scollard and Paskapoo Formations. This is equivalent to the P2/P3 zonal boundary. Snead (1969) identified a distinct palynofloral assemblage corresponding to the Paskapoo Formation. Zone C included strata to the top of the Paskapoo Formation within CH-65-1, and this is equivalent to the P3 Zone.

Snead (1969) identified two species of *Momipites; M. inequalis* and *M. tenuipolus*. From the systematic descriptions and photographs, the specimen of *M. inequalis* described by Snead (1969) is actually *M. wyomingensis*. The range of Snead's species is consistent within the P2 and younger zones (Zones B and C of Snead, 1969). Also, the specimen of *M. tenuipolus* (Snead, 1969) may actually be *M. leffingwellii*. The specimen pictured displays concave interporia with an indistinct polar island. Nichols and Ott (1978) distinguish *M. tenuipolus* as displaying polar thinning rather than a distinct island with a circumpolar ring as in *M. leffingwellii*.

If the specimen displayed by Snead (1969) is *M. leffingwellii*, it's range is consistent within the P2 and P3 Zones (Zones B and C of Snead, 1969) of CH-65-1.

Snead (1969) also placed stratigraphic value on such genera as *Betulaceoipollenites*, *Carpinites*, and *Alnipollenites*. These genera have been shown to occur sporadically throughout the Maestrichtian and Paleocene, and their stratigraphic value therefore, is very limited. Also, species of *Kurtzipites* spp. which are described by Snead (1969) as terminating at the top of the P2 Zone (Zone B), have now been identified within strata of the P3 and P4 Zones.

Both Srivastava (1970) and Singh (in Russell and Singh, 1978) recognized that *Wodehouseia fimbriata* does not range into, or above the Ardley seam, and was limited to the interval between the Nevis and Ardley seams. Srivastava (1970) originally termed this interval the *W. fimbriata* Zone (IX), and this is equivalent to the P1 Zone.

Singh (in Russell and Singh, 1978) further recognized the importance of *Retitrescolpites anguloluminosus* and *R. bathyreticulatus* (described by Singh as *Tricolpites* rather than *Retitrescolpites*) in characterizing the Ardley seam and the uppermost Scollard Formation. Although these species have been reported as occurring sporadically in Maestrichtian strata, they reach a peak abundance in the Ardley seam and upper Ardley coal zone. Singh (in Russell and Singh, 1978) also placed stratigraphic significance on the species *Momipites tenuipolus* within the uppermost Scollard Formation, above the Ardley seam. This is not inconsistent with the first appearances of *Momipites* spp. in the P2 Zone, and retains the observation that the P1 Zone contains no *Momipites*.

ALBERTA FOOTHILLS CORRELATIVES

Sweet (in Jerzykiewicz and Sweet, 1986a) has studied the palynology of the Coalspur Formation in the central Alberta Foothills. The Cretaceous-Tertiary boundary has been identified at the base of the Mynheer seam, the lowermost coal seam of the Coalspur coal zone (Figure 18). This signifies that the Scollard Formation in the Plains is coeval with the Coalspur Formation in the Foothills. Sweet has also identified *Wodehouseia spinata* approximately one meter above the boundary iridium anomaly and synchronous palynofloral extinctions, coincident with occurrences of *Aquilapollenites reticulatus* and *A. immiser*. This established that the palynofloral changes related to the Cretaceous-Tertiary boundary in the Foothills sequence are consistent with those of the Alberta Plains and Saskatchewan. Sweet (in Lerbekmo *et al.*, in press) has recently encountered *Wodehouseia fimbriata* 1.15 m above the Mynheer seam, or 11.3 m above the boundary (Figure 18). This form enables one to correlate strata above the Mynheer seam to the P1 Zone in the Plains.

From the Coalspur Anticline (Figure 19), Sweet (in Jerzykiewicz and Sweet, 1986a) has identified the species *Momipites microfoveolatus* within the McPherson coal seam, approximately 165 m above the Cretaceous-Tertiary boundary (Figure 18). Sweet suggested a correlation of the McPherson seam to the P1 Zone of Nichols and Ott (1978) based on this lone occurrence of *M. microfoveolatus*. Nichols and Ott (1978) have distinguished *Momipites microfoveolatus* from *M. waltmanensis* on the basis of modal diameter, with *M. waltmanensis* being slightly larger. No specimens of *M. microfoveolatus* have been identified from the Plains, but in keeping with the finding that the P1 Zone is barren of *Momipites* spp., this occurrence of *M. microfoveolatus* likely represents the P2 Zone. The 165 m interval from the Cretaceous-Tertiary boundary to the McPherson seam is therefore interpreted as P1 Zone in age, and presumably devoid of *Momipites* spp.

Samples taken from the lowermost Paskapoo Formation, immediately above the

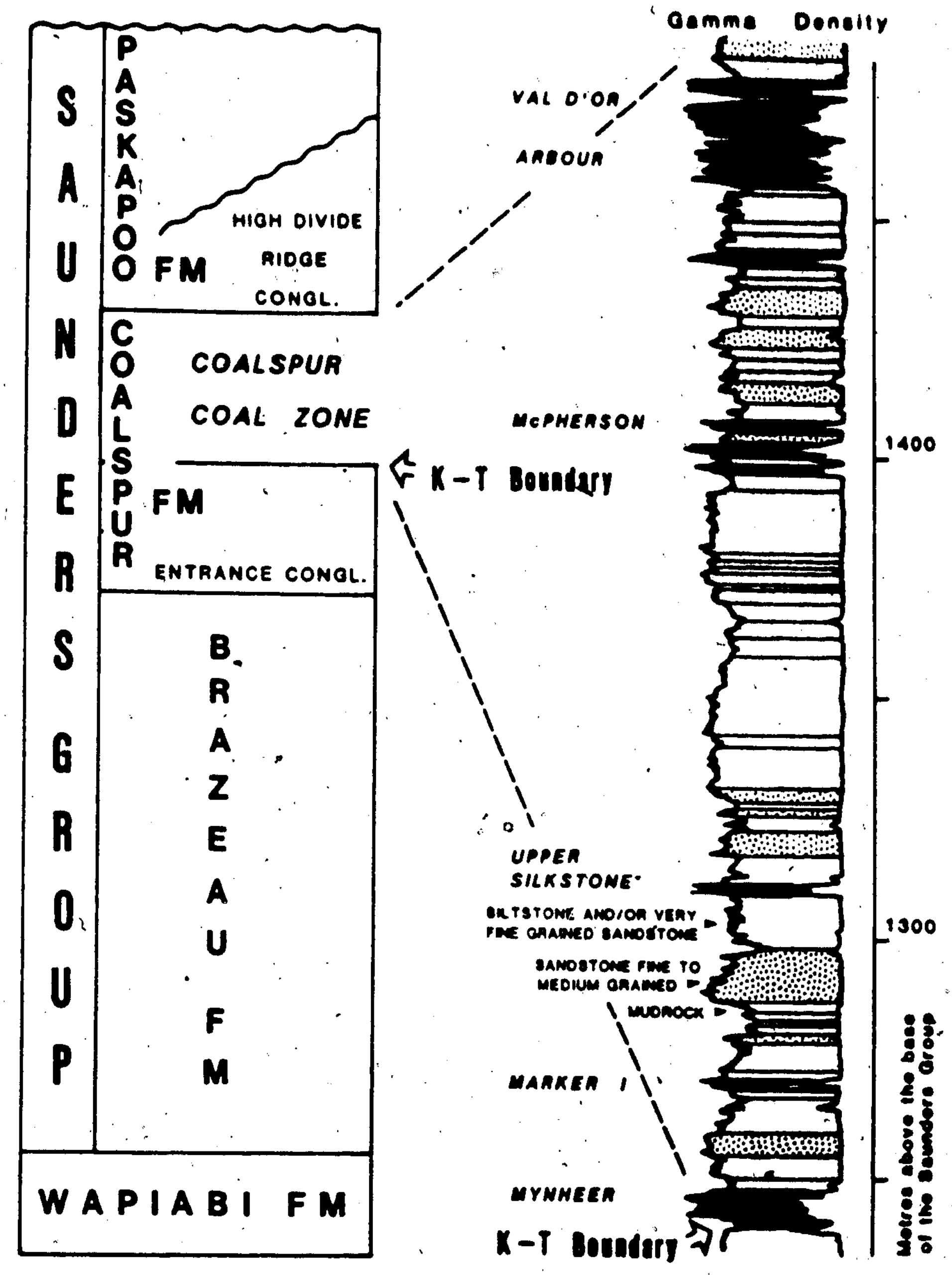


Figure 18. Detailed stratigraphy of the Coalspur Formation (central Alberta Foothills) (modified from Jerzykiewicz and Sweet, 1986a).

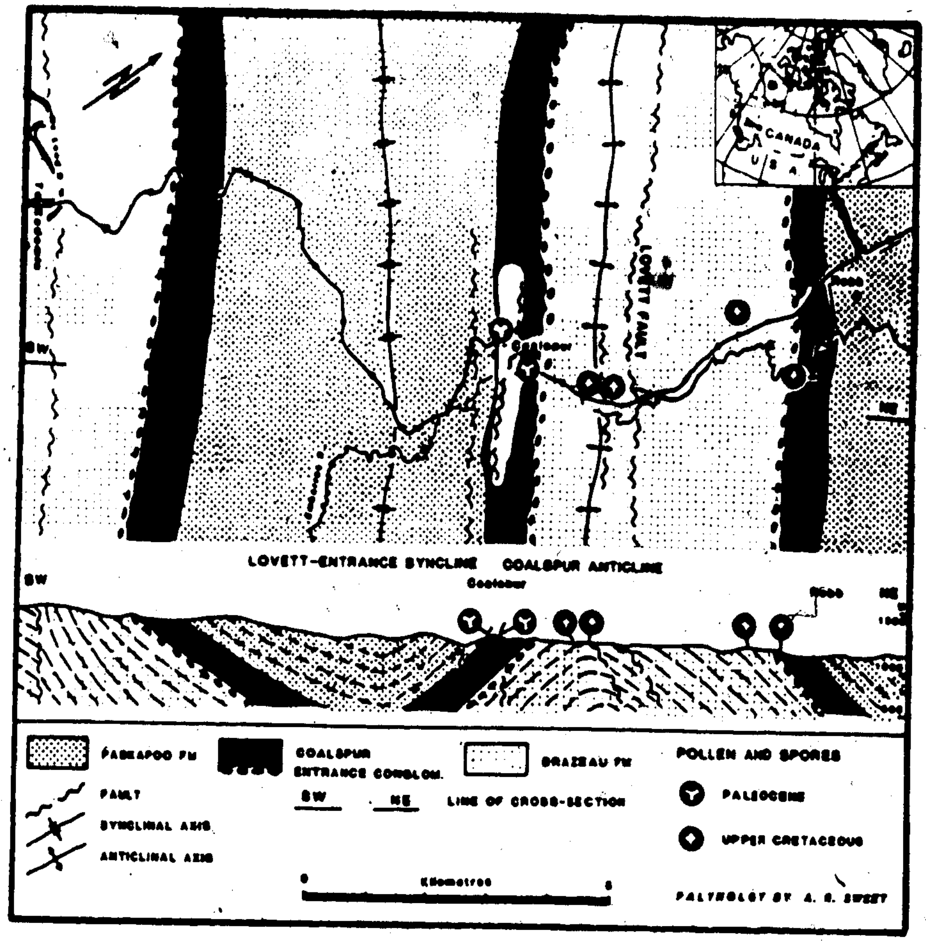


Figure 19. Detailed geologic map of the Coalspur area (modified from Jerzykiewicz and Langenberg, 1983).

Val d'Or seam (Figure 18) contained *M. microfoveolatus* and a lone specimen of *Aquilapollenites spinulosus*. Sweet (in Jerzykiewicz and Sweet, 1986a) suggested that due to the persistence of this lone species of *Momipites*, the entire Coalspur Formation and lowermost Paskapoo Formation were lower Paleocene P1 Zone in age. However, Sweet overlooked the importance of *A. spinulosus* in characterizing the P3 Zone as established by Nichols and Ott (1978), and also confirmed by this study. Although an abundance of *A. spinulosus* was not encountered as in other P3 assemblages, this appearance suggests an equivalence with P3 Zone for the lowermost Paskapoo strata in the Foothills, which would therefore be coeval with the basal Paskapoo Formation in the Plains.

In summation, the P1 Zone extends from the Cretaceous-Tertiary boundary at the base of the Mynheer seam to the base of the McPherson seam in the Coalspur Formation of the central Alberta Foothills. The McPherson seam itself belongs to P2 Zone based on the first appearance of a *Momipites* species *M. microfoveolatus* (Figure 18). The overlying Coalspur Formation also belongs to the P2 Zone. The basal Paskapoo Formation contains *Aquilapollenites spinulosus*, clearly indicative of the P3 Zone.

SOUTHERN ALBERTA CORRELATIVES

Sweet (in McIntyre *et al.* 1984, and Jerzykiewicz and Sweet 1986b) has examined the palynology from a number of sites in southern Alberta, from the Willow Creek and Porcupine Hills Formations (Figure 20). Sweet recognized that the diversity of Juglandaceous pollen in Alberta was much less than that of assemblages in Wyoming examined by Nichols and Ott (1978), but gave no explanation.

In McIntyre *et al.* (1984), from an outcrop of uppermost Porcupine Hills Formation near Cochrane (Figure 20), Sweet identified an assemblage consisting of *Momipites wyomingensis, M. waltmanensis* and *M. ventifluminis.* This diverse suite of *Momipites* spp. was interpreted by Sweet, as P3 Zone equivalent. From Big Hill Springs, northwest of Calgary, a similar assemblage was identified, including species of *Momipites annellus* and *Tiliaepollenites danei*. The presence of *T. danei* suggests an upper P3 Zone age, implying that the Big Hill Springs locality may be slightly younger than the Cochrane locality.

In the DeWinton Quarry, south of Calgary (Figure 20), no species of *Momipites* were found. Sweet suggested that this assemblage was typically that of the earliest Paleocene of the Scollard Formation in the central Alberta Plains, and therefore P1 Zone in age.

Sweet (in Jerzykiewicz and Sweet, 1986b) identified the Cretaceous-Tertiary boundary near the top of Member D of the Willow Creek Formation in southwestern Alberta (Figure 7). No species of *Momipites* were encountered in the upper part of Member D above the Cretaceous-Tertiary boundary, nor in the lowermost part of Member E; thus this interval belongs to the P1 Zone. Species of *Momipites wyomingensis* and *M. waltmanensis* were identified from the upper portion of Member E indicating a P2 Zone age, with the P1/P2 zonal boundary likely to be situated within the lower part of Member E.

From the lowermost Porcupine Hills Formation, Sweet identified only *M. waltmanensis* without any characteristic P3 Zone species. This level therefore belongs to the P2 Zone, and correlates the base of the Porcupine Hills Formation to uppermost Scollard Formation strata. Assemblages from the uppermost Porcupine Hills Formation, however, exhibit a diverse *Momipites* suite of *M. annellus*, *M. ventifluminis*, and *M. waltmanensis*, plus *Aquilapollenites spinulosus* and *Tiliaepollenites danei*. This suite is very characteristic of the upper P3 Zone.

From these correlations, it is evident that the uppermost Porcupine Hills Formation is older than the Paskapoo at the Blindman locality in the Red Deer River valley, contradicting Carrigy's (1971) interpretation (Jerzykiewicz and Sweet, 1986b).

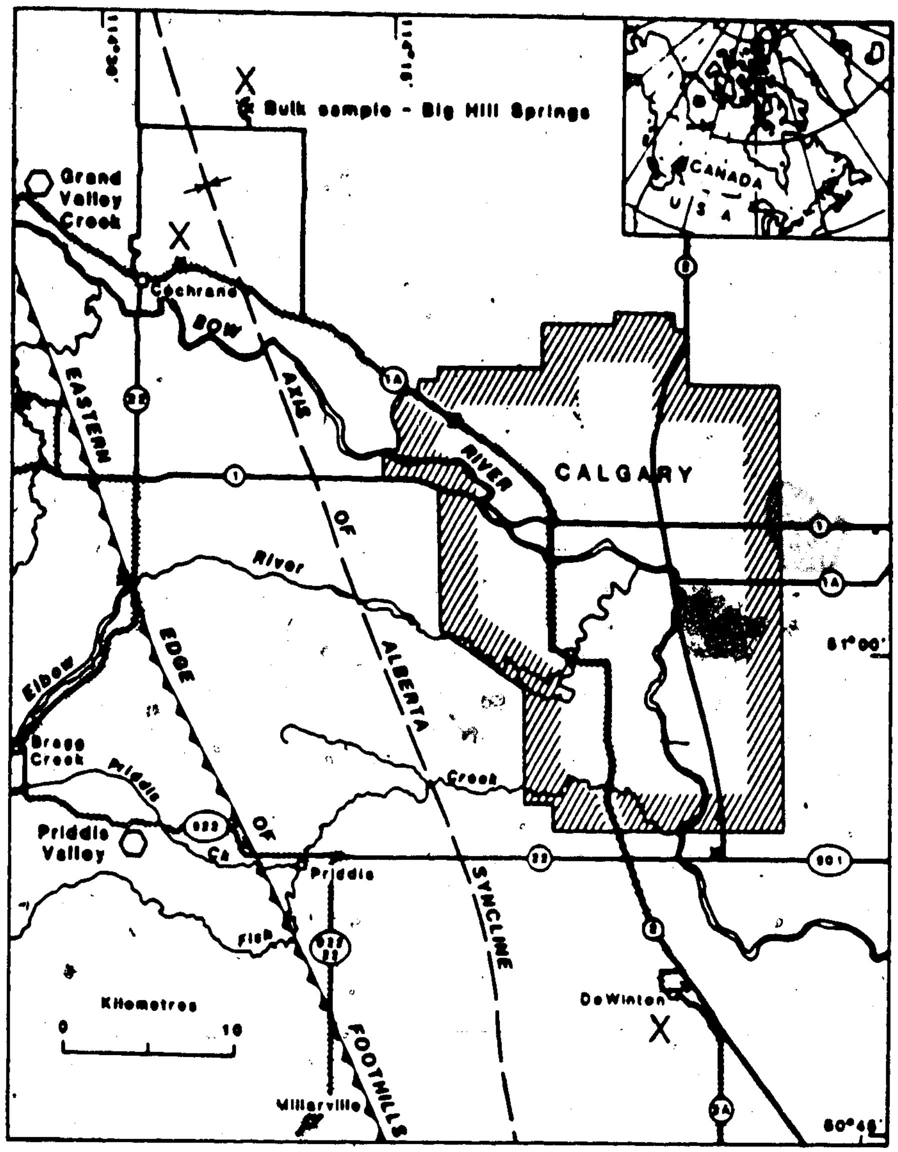


Figure 20. Map showing southern Alberta palynological sample localities. (X) (modified from McIntyre *et al.*, 1984).

RELATIONSHIP OF PALYNOFLORAL AND VERTEBRATE ZONES IN ALBERTA

The ages for the Alberta vertebrate sites have been derived from Krause (1978) and Fox (1987, pers. comm.); and the palynological interpretations are from this study and from Sweet (in McIntyre *et al.* 1984, and Jerzykiewicz and Sweet 1986b) (Figure 21).

Although Canyon Ski Quarry and Swan Hills have not been sampled for palynology, the vertebrate paleontology illustrates that they are of similar age to the Crestomere School section, and should display a P5 Zone assemblage containing *Pistillipollenites mcgregorii* (Figure 21).

SASKATCHEWAN CORRELATIVES

Sweet (1978) studied the palynology of the Frenchman and Ravenscrag Formations of southern Saskatchewan in order to aid in the identification and correlation of the numerous Paleocene coal zones present. In the Cypress Hills area (Figure 22), the Cretaceous-Tertiary boundary was identified at the base of the Ferris coal, the lowermost coal seam of the Ferris coal zone (Figure 23). Two distinct palynological zones were identified by Sweet (1978); Zone 1 from the uppermost Frenchman Formation which is Maestrichtian in age, and Zone 2 from the lowermost Ravenscrag Formation which is lowermost Paleocene in age. Zone 2 was characterized by an assemblage exhibiting a low diversity of angiosperm pollen, dominated by gymnosperms. Specimens of *Wodehouseia spinata* and *Aquilapollenites reticulatus* were recorded for the first time in western Canada, a short interval above the boundary. Stratigraphically higher, Zone 2 was further characterized by *Wodehouseia fimbriata*. Sweet (1978) equated this Zone 2 to the *W. fimbriata* zone (IX) of Srivastava (1970) and this is correlative to the P1 Zone.

In the Willowbunch-Estevan coal area (Figure 22), five distinct coal zones are present in upper Ravenscrag Formation strata (Figure 23). The palynofloral assemblages

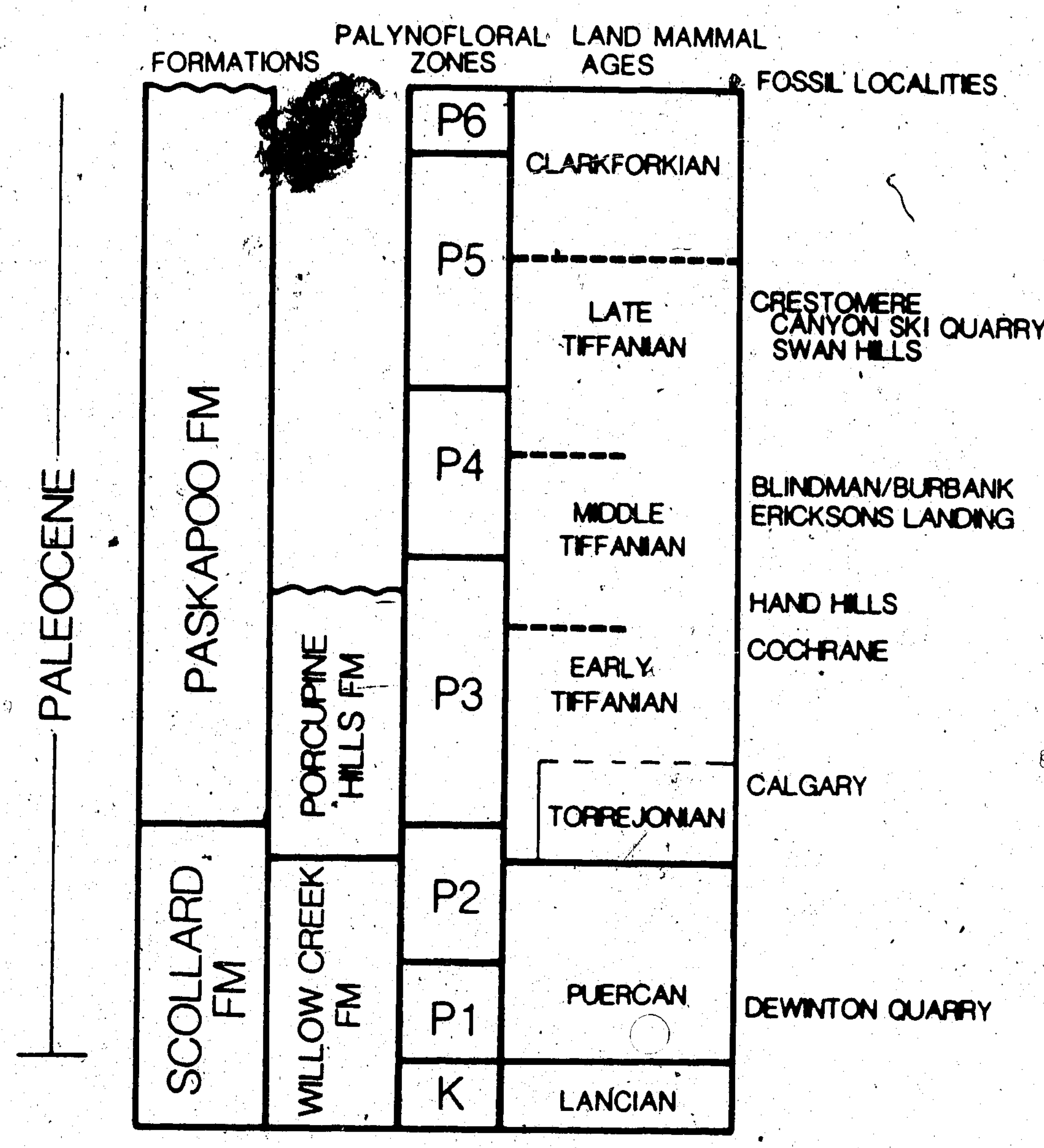


Figure 21. Relationship of palynofloral zones with Paleocene stages in Alberta, with corresponding fossil localities.

studied were dominated by Cupressaceae-Taxodiaceae pollen, and differentiation of the individual coal seams was difficult. Species such as *Aquilapollenites spinulosus* were identified in strata of the Boundary coal zone, with *Pistillipollenites. mcgregorii* present in strata above the Estevan coal zone (Figure 23). *Insulapollenites rugulatus* and *Tiliaepollenites danei* were identified throughout the entire sequence.

For the Boundary coal zone, the presence of *Aquilapollenites spinulosus* and *Tiliaepollenites danei* are indicative of at least a late P3 Zone age. However, the Boundary coal zone also contains *Insulapollenites rugulatus* which appears to be restricted to the upper Paleocene in central Alberta. Nichols and Ott (1978) had additionally characterized the P5 Zone of Wyoming by the presence of *I. rugulatus*; however, Leffingwell (1971) recorded this species from middle Paleocene strata of the Fort Union Formation. Possibly the range of this species may extend into older strata in southerly localities. It is likely however, that the Boundary coal zone belongs to P5 Zone but that species such as *Pistillipollenites mcgregorii* were not encountered. Strata above the Estevan coal zone are definitely P5 Zone correlatives based on the presence of *P. mcgregorii* (Figure 23). Of note, Sweet (1978) identified the species *Caryapollenites viridifluminipites* from these upper Paleocene coal zones. Nichols and Ott (1978) suggest that some specimens previously identified as *C. viridifluminipites* may actually be the species *Caryapollenites inelegans*, as the difference between these two species is very subtle. Even so, the advanced degree of heteropolarity exhibited by both of these species suggests an upper Paleocene, P4 to P5 Zone age for this entire interval from the Boundary through Short Creek coal zones (Figure 23). There are no strata assignable to P6 Zone, as a diverse *Momipites* assemblage including *M. triorbicularis* persists in all coal zones.

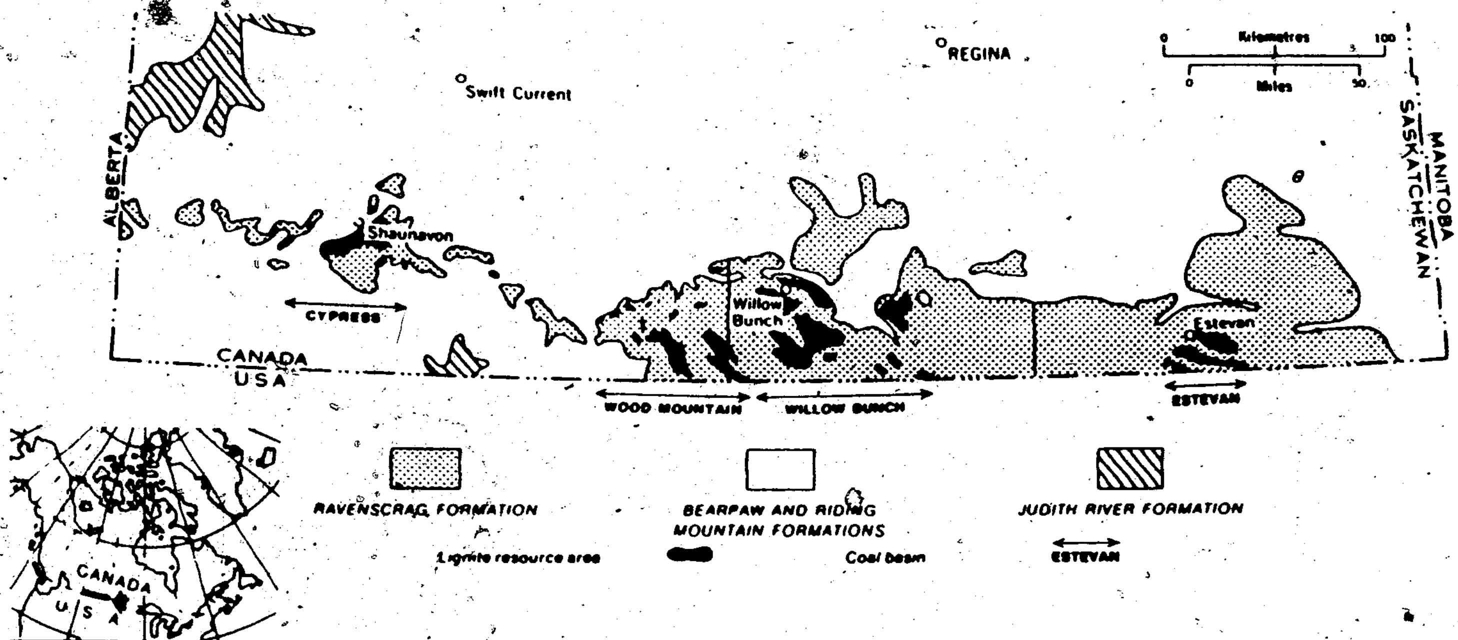
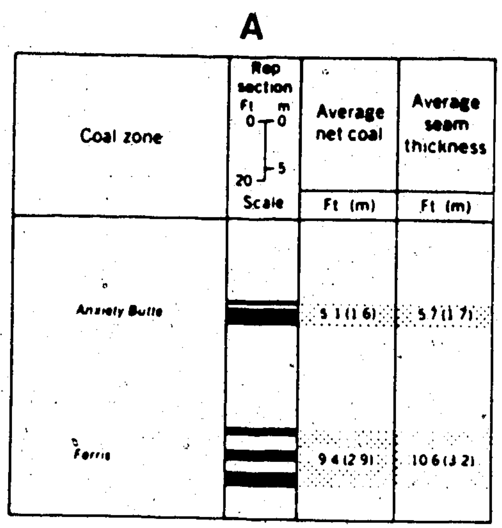


Figure 22. Map of southern Saskatchewan coal fields (modified from Whitaker *et al.*, 1978).



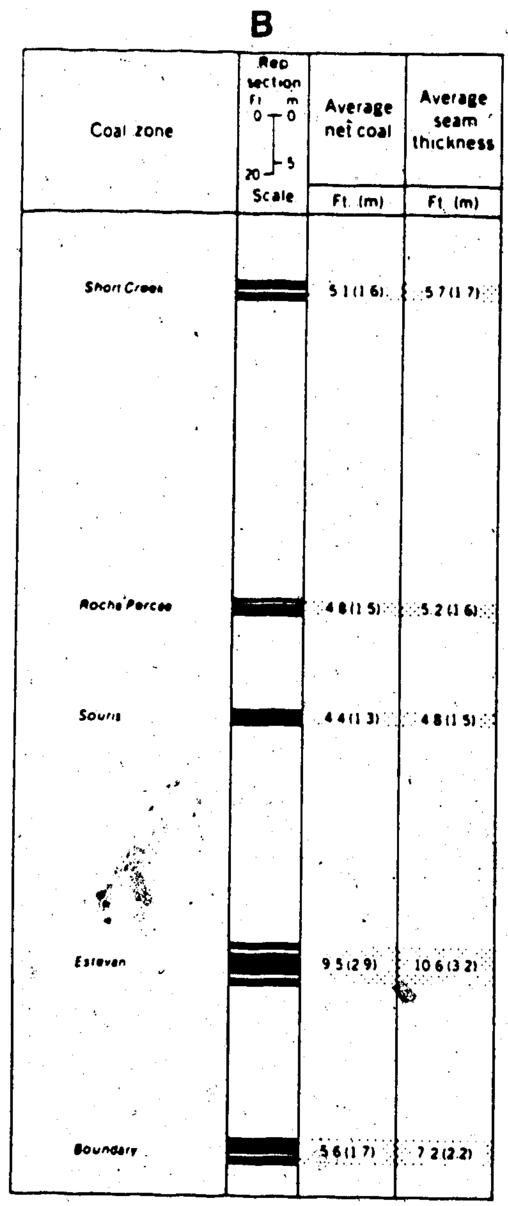


Figure 23. Coal zones of the Cypress (A) and Estevan (B) coal fields. (modified from Whitaker *et al.*, 1978).

UNITED STATES CORRELATIVES

Stanley (1965) identified a palynofloral break (Cretaceous-Tertiary boundary) at the top of the Hell Creek Formation and recognized the presence of *Wodehouseia spinata* and *W. fimbriata* in the boundary interval (Stanley, 1961). *W. spinata* was illustrated as terminating immediately at the top of the Hell Creek Formation, with *W. fimbriata* appearing in Zone 1 (lowermost Ludlow) and ranging into the base of Zone 2 of the lower Paleocene. This occurrence of *W. fimbriata* suggests a correlation of these strata to the P1 Zone.

The only species of *Momipites* (identified as *Engelhardtia*) identifed by Stanley (1965) was *M. microfoveolatus*. In the North Cave Hills and Crow Butte sections, this species occurs within the upper portion of Zone 1, and does not occur coincidentally with *Wodehouseia fimbriata*. In the Twin Butte section however, the ranges of these two species do overlap. This may not be unusual, however, because of the earlier first appearances of *Momipites* in more southerly localities. The occurrence of *W. fimbriata* at Twin Butte indicates P1 Zone, with its termination and the occurrence of *M. microfoveolatus* characterizing the P2 Zone. There is no evidence to suggest that any of Stanley's sections reach the level of the P3 Zone.

Norton and Hall (1969) confirmed the sequence of *Wodehouseia spinata* and *W. fimbriata* across the Cretaceous-Tertiary boundary, which was placed at the Hell Creek-Ludlow contact in Montana. They documented two species of *Momipites*, *M. parvus* and *M. circularis*. From their descriptions, it is evident that these two specimens are of the genus *Kurtzipites* and not *Momipites*. These specimens were originally identified as *Momipites* since they lacked the nexinous thickenings at the pores thought to be distinctive of *Kurtzipites*. Srivastava (1981) recognizing this, placed *M. circularis* into the genus *Kurtzipites* (*K. circularis*). This species thus ranges from the Hell Creek Formation (Maestrichtian) into the Paleocene Tullock Member of the Fort Union Formation ([illegible] Norton and Hall, 1969).

Specimens of *Retitrescolpites bathyreticulatus* and *R. anguloluminosus* from Montana (described as *Tricolpites* by Norton and Hall, 1969) occur through the Tullock Member and into the lower Lebo Member. In the Alberta Plains, these species are common in the P2 Zone, but are absent from the P3 zone. From these ranges, the Tullock Member and at least the lower portion of the Lebo Member are P1 and P2 Zone correlatives (Figure 11).

Leffingwell (1971) divided the Paleocene Fort Union Formation of Wyoming into two palynofloral zones with a lower major palynofloral change taking place at the Cretaceous-Tertiary boundary (Figure 24). Assemblage B of Leffingwell (1971) was interpreted as being lower Paleocene in age encompassing strata of the Tullock and the lower portion of the Lebo Member. This assemblage was characterized by *Wodehouseia spinata* in the lowermost portion, transcending the extinction of *Aquilapollenites* spp. Assemblage B was further characterized by the marked increase in *Kurtzipites* spp. abundance. The P1 Zone is likely equivalent to the short interval from the base of the Fort Union Formation to the level of the R coal (Figure 24). Above this, the palynofloral assemblage contained *Momipites tenuipolus, Retitrescolpites anguloluminosus, R. bathyreticulatus*, with abundant *Kurtzipites* spp. which is distinctly P2 Zone in age.

The boundary between Leffingwell's (1971) B[1] and C Assemblage correlates with the P2/P3 zonal boundary, and is located at the level of the K coal in the Fort Union Formation (Figure 24). Assemblage C was characterized by the appearance of diverse *Momipites* spp., and therefore, at least the lower part of this assemblage is P3 Zone equivalent. Conspicuous by its absence from Leffingwell's (1971) assemblages is *Aquilapollenites spinulosus* which is thought to be common in middle Paleocene strata throughout the United States and Canada. Also, *Insulapollenites rugulatus* was illustrated as occurring in the lower part of Assem[illegible]h is different from Nichols and Ott (1978), who document this species [illegible]ement of the P5

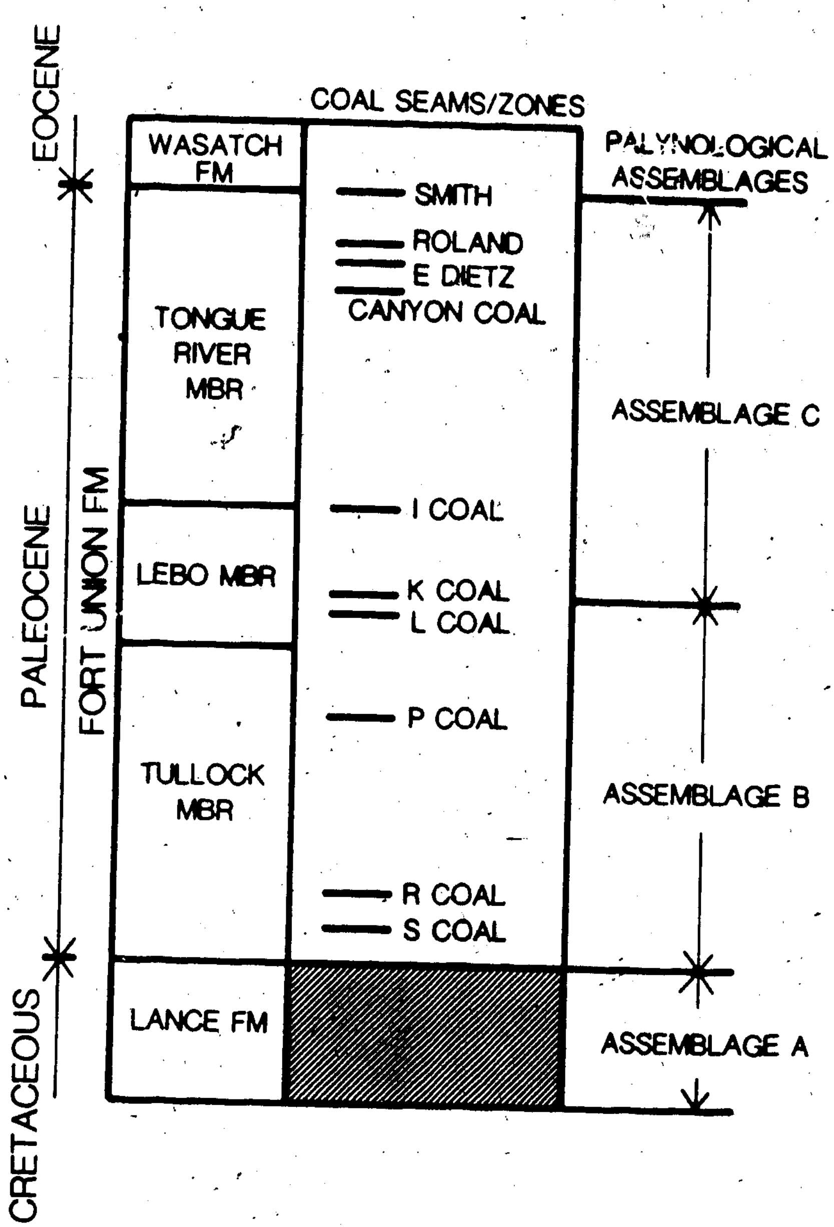


Figure 24. Coal seams of the Fort Union Formation and palynological assemblages of Leffingwell (1971) (stratigraphy after Leffingwell, 1971).

Zone.

From the Gillette area coals, Leffingwell (1971) identified *Caryapollenites veripites* and *C. viridifluminipites.* As stated previously, Nichols and Ott (1978) suspect that some specimens of *C. viridifluminipites* identified by Leffingwell (1971) may be *Caryapollenites inelegans,* and therefore indicative of the P5 Zone. In the upper Gillette coals (Roland coal), *C. veripites* becomes dominant in the overall assemblage which can be correlated with the P6 Zone of Nichols and Ott (1978). Also at this level, many species of *Momipites* terminate their upward ranges, or become greatly reduced in number. Nichols and Ott (1978) stated, however, that P6 Zone strata are likely present only in the western part of Wyoming, and therefore may not be present in Leffingwell's study area.

Boundaries between the P3 and P4 Zones, and P4 and P5 Zones are difficult to discern from Leffingwell's (1971) distributions, but may correspond to the I coal and Canyon coal, respectively (Figure 24).

VIII. SUMMARY AND CONCLUSIONS

The *Momipites-Caryapollenites* palynofloral lineage has proven to be extremely useful in zoning the Paleocene strata throughout the western interior of North America. From the initial work of Nichols and Ott (1978) in the Wind River Basin in Wyoming, modifications of the lineage established by them have been used in zoning North American Paleocene strata. One such modification has been found useful for the central Alberta Plains. Division of the Paleocene strata of the Scollard and Paskapoo Formations into six zones is based on the ranges of species of *Momipites*, *Caryapollenites*, and other stratigraphically important species.

The P1 Zone, extending from the base of the Nevis seam (Cretaceous-Tertiary boundary) to the Ardley seam is characterized by *Wodehouseia fimbriata*. P2 Zone, from the Ardley seam to the top of the Scollard Formation is identified by the first appearances of three *Momipites* species. The base of the P3 Zone is placed at the base of the palynologically barren basal Paksapoo Formation sandstones. The first recoverable sample (approximately 15 m above the base of the formation) contains diverse *Momipites*, the first *Caryapollenites* species, *Aquilapollenites spinulosus* and *Tiliaepollenites danei*. P4 and P5 Zones display a diversification of *Caryapollenites* with the P5 Zone further characterized by *Pistillipollenites mcgregorii* and *Insulapollenites rugulatus*. The base of the P6 Zone is defined by the termination of the upward ranges of three *Momipites* species (*M. waltmanensis*, *M. triorbicularis*, and *M. actinus*), following the termination of *Momipites leffingwellii* at the base of the P5 Zone.

In contrast to the P1 Zone of Wyoming, the Alberta P1 Zone lacks *Momipites*. The presence of this interval devoid of *Momipites* in Alberta, originally identified by Newman and Tschudy (Jacobson and Nichols, 1982) from the northern United States, may be a reflection of climatic differences between Wyoming and Alberta, immediately following the terminal Cretaceous event. The climatic difference also undoubtedly played a role in the paucity of *Caryapollenites* specimens in the upper Paleocene of Alberta.

This *Momipites-Caryapollenites* palynofloral lineage has also allowed for detailed correlations throughout Alberta. Comparisons with the palynostratigraphic findings of Sweet (in Jerzykiewicz and Sweet, 1986a) in the central Alberta Foothills indicate that the Coalspur Formation (Foothills) is coeval with the Scollard Formation (Plains), and that the basal Paskapoo strata in both regions, are also approximately coeval. Southern Alberta palynostratigraphy by Sweet (in Jerzykiewicz and Sweet, 1986b) shows that the lower Porcupine Hills Formation is correlative to the upper Scollard Formation, and that the uppermost Porcupine Hills is older than the youngest Paskapoo of the Red Deer River valley.

Utilization of a *Momipites-Caryapollenites* palynofloral lineage in this study has enabled construction of a framework for Paleocene zonation in central Alberta. A complete description of all the palynoflora will further enhance this framework and help in delineating the paleoecological setting during this time.

IX. SYSTEMATIC PALYNOLOGY

Division: ANTHOPHYTA

Class: DICOTYLEDONAE

Family: JUGLANDACEAE

Genus: *Momipites* Wodehouse, 1933 emend. Nichols, 1973

1933 *Momipites* Wodehouse, p. 511.

1937 *Engelhardtiapollenites* Raatz, p. 20 (*nom. nud.*).

1950 *Engelhardtioidites* Potonie', Thomson and Thiergart, p. 51.

1953 *Triatriopollenites* Thomson and Pflug, p. 76 (*partim*).

1960 *Engelhardtioidites* Potonie', Thomson and Thiergart ex Potonie', p. 118.

1971 *Maceopolipollenites* Leffingwell, p. 29.

1973 *Momipites* Wodehouse emend. Nichols, p. 106.

Type species: *Momipites coryloides* Wodehouse, 1933

Momipites leffingwellii Nichols and Ott, 1978

Plate 4, Figures 1, 2

1971 *Momipites tenuipolus auct. non* Anderson - Leffingwell, p. 31, pl. 7, fig. 4.

1978 *Momipites leffingwellii* Nichols and Ott, p. 103, pl. 1, figs. 27-30.

Description: Triporate pollen, oblate, amb angular to semi-lobate with straight to concave sides and well rounded corners. Pores atriate, exopores circular to meridionally elongate, 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at equators, endexine not extending to apertures but ending at the endopores to form the atria, ektexine thickening slightly at the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine thinned at one pole in a crcumpolar ring surrounding a polar island of exine of normal thickness, circumpolar ring 1 to 3 microns wide, varying in shape from circular to rounded triangular.

Size: Diameter 17.4 (21.6) 25.3 microns

Specimens measured 24

Discussion: Anderson's (1960) specimen of *M. tenuipolus* differs in shape and polar structure from *M. leffingwellii*. However, some illustrated specimens of Anderson (1960) have concave sides and display both polar thinning as well as a poorly defined island. The specimens assigned to *M. tenuipolus* by Leffingwell (1971) belong to *M. leffingwellii*. This species belongs to the Annellus Group of *Momipites* of Nichols and Ott (1978).

Occurrence: Zones P2 to P4, Scollard and Paskapoo Formations (Paleocene) central Alberta Plains (this study). Assemblage B, Tullock and Lebo Members, Fort Union Formation (Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Zones P1 to P3, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Momipites wyomingensis Nichols and Ott, 1978

Plate 4, Figures 5, 6

1969 *Momipites inequalis auct. non* Anderson - Snead, p. 38, pl. 6, fig. 15.

1978 *Momipites wyomingensis* Nichols and Ott, p. 100, pl. 1, figs. 1-4.

Description: Triporate pollen, oblate, amb semi-angular with convex interporia. Pores atriate, exopores circular to meridionally elongate, 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at the equator, endexine not extending to apertures but ending at the endopores to form the atria, ektexine thickening slightly towards the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine of even thickness at both poles, lacking any structural modification.

Size: Diameter 20.2 (24.3) 26.9 microns

Specimens measured 48

Discussion: This species displays the simplest morphology, having convex interporia and lacking structure at the poles. It resembles *M. coryloides* Wodehouse, 1933, from the Eocene and modern *Engelhardtia* and *Alfaroa*, but is smaller than the Eocene form and larger than the modern species. It is similar to Anderson's (1960) *M. inequalis* which differs in having unequal sides and a more angular amb. Snead's (1969) illustrated specimen of *M. inequalis* is *M. wyomingensis*.

Occurrence: Zones P2 to P6, Scollard and Paskapoo Formations (Paleocene) central Alberta Plains (this study). Assemblages B and C, Scollard and Paskapoo Formations (Paleocene) central Alberta Plains (Snead, 1969). P3 Zone, Porcupine Hills Formation (Paleocene) Big Hill Springs/Cochrane, southern Alberta Plains (McIntyre *et al.*, 1984). Members D and E, Willow Creek and Porcupine Hills Formations (lower to middle Paleocene) southern Alberta Plains (Jerzykiewicz and Sweet, 1986b). Lance Formation (upper Maestrichtian) Wyoming (Farabee and Canright, 1986). Zones P2 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978)

Momipites waltmanensis Nichols and Ott, 1978

Plate 4, Figures 3, 4

1978 *Momipites waltmanensis* Nichols and Ott, p. 102, pl. 2, figs. 5-8.

Description: Triporate pollen, oblate, amb angular to semi-lobate with straight to concave interporia and well rounded corners. Pores atriate, exopores circular to meridionally elongate, 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at the equator, endexine not extending to apertures but ending at the endopores to form the atria, ektexine thickening slightly towards the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine of even thickness at poles, lacking any structural modification.

Size: Diameter 18.7 (21.3) 25.1 microns

Specimens measured 49

Discussion: This species is characterized by concave interporia and a lack of structural modification, making it distinct from other species of *Momipites*.

According to Nichols and Ott (1978) *Momipites microfoveolatus* (Stanley) Nichols, 1973, differs from *M. waltmanensis* in having a smaller size and foveolate sculpture. However, the size range of *M. microfoveolatus* (15-22 microns) clearly falls within the dimensions of *M. waltmanensis* (16-25 microns) recorded by Nichols and Ott (1978), and the foveolate sculpture on Stanley's (1965) specimens could be due to corrosion. Moreover, it is difficult to discern from Stanley's (1965) photographs as to whether the sculpture is foveolate or granulate. Until the holotype of *M. microfoveolatus* is restudied, the question of synonymy with *M. waltmanensis* will remain uncertain. *M. waltmanensis* belongs to the Coryloides Group of *Momipites* (Nichols, 1973).

Occurrence: Zones P2 to P5, Scollard and Paskapoo Formations (Paleocene) central Alberta Plains (this study). P3 Zone, Porcupine Hills Formation (Paleocene) Cochrane, southern Alberta Plains (McIntyre *et al.*, 1984). Members D and E, Willow Creek and Porcupine Hills Formations (lower to middle Paleocene) southern Alberta Plains (Jerzykiewicz and Sweet, 1986b). Zones P2 to P6, Fort Union Formation (Paleocene), Wind River Basin, Wyoming (Nichols and Ott, 1978).

Momipites ventifluminis Nichols and Ott, 1978

Plate 4, Figures 7, 8

1978 *Momipites ventifluminis* Nichols and Ott, p. 102, pl. 1, figs. 9-14.

Description: Triporate pollen, oblate, amb semi-angular with convex interporia. Pores atriate, exopores circular to meridionally elongate 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at the equator, endexine not extending to apertures but ending at the endopores to form the atria, ektexine thickening slightly towards the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine thinned on one hemisphere forming three circular spots approximately 3 to 4 microns in diameter, located on the interporial radii about the pole.

Size: Diameter 23.3 (26.2) 28.2 microns

Specimens measured 30

Discussion: The three circular spots around one pole and convex interporia are the most distinguishing chracteristics of *M. ventifluminis*. It differs from *M. rotundus* (Leffingwell) Nichols, 1973, which is larger (24-34 microns) and from *M. triorbicularis* which has concave to straight interporia.

Frederiksen and Christopher (1978) have transferred *M. ventifluminis* to the genus *Plicatopollis*. However, this species lacks the plicae associated with the thinned areas, characteristic of the genus *Plicatopollis*, and the author agress with Nichols and Ott (1978) who have retained *M. ventifluminis* in the genus *Momipites*.

Occurrence: Zones P3 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). P3 Zone, Porcupine Hills Formation (Paleocene) Big Hill Springs/Cochrane, southern Alberta Plains (McIntyre *et al.*, 1984). P3 Zone, Porcupine Hills Formation (Paleocene) southern Alberta Plains (Jerzykiewicz and Sweet, 1986b). Zones P3 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Momipites annellus Nichols and Ott, 1978

Plate 4, Figures 9, 10

1978 *Momipites annellus* Nichols and Ott, p. 103, pl. 1, figs. 22-25.

Description: Triporate pollen, oblate, amb semi-angular with convex interporia. Pores atriate, exopores circular to meridionally elongate, 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at the equator, endexine not extending to apertures, but ending at the endopores to form the atria, ektexine slightly thickened towards the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine thinned at one pole in a circumpolar ring surrounding a polar island of exine of normal thickness, circumpolar ring approximately 1 to 3 microns wide.

Size: Diameter 24.1 (26.9) 28.4 microns

Specimens measured 35

Discussion: This species closely resembles *M. tenuipolus* (Anderson, 1960), which however displays an irregular, thin polar area, but never a true well-defined polar island of normal exine thickness (Nichols and Ott, 1978). *M. annellus* differs from *M. amplus* (Leffingwell) Nichols, 1973, which is much larger (28.7 to 37.3 microns), and from *M. leffingwellii* which is smaller and has straight to concave sides. *M. marylandicus* (Groot and Groot) Nichols, 1973, differs in being much smaller. *M. annellus* belongs to the Annellus Group of *Momipites* (Nichols and Ott, 1978).

Occurrence: Zones P3 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). P3 Zone, Porcupine Hills Formation (Paleocene) Big Hill Springs, southern Alberta Plains (McIntyre *et al.*, 1984). Zones P3 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Momipites triorbicularis (Leffingwell) Nichols, 1973

Plate 4, Figures 11, 12

1971 *Maceopolipollenites triorbicularis* Leffingwell, p. 30, pl. 7, figs. 5a-b.

1973 *Momipites triorbicularis* Nichols, p. 107, pl. 1, figs. 15-17.

Descripiton: Triporate pollen, oblate, amb angular to semi-lobate with straight to concave sides and well-rounded corners. Pores atriate, exopores circular to meridionally elongate, 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at equators, endexine not extending to the apertures but ending at the endopores to form the atria, ektexine thickening slightly towards the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine thinned on one hemisphere forming three circular spots 3 to 4 microns in diameter that are located on the interporial radii about the pole.

Size: Diameter 20.5 (23.5) 26.1 microns

Specimens measured 18

Discussion: *M. triorbicularis* differs from both *M. ventifluminis* and *M. rotundus* (Leffingwell) Nichols, 1973, in being smaller and having concave interporia. It is most similar to *M. waltmanensis* but differs markedly in the development of the three polar thin spots.

Occurrences: Zones P3 to P5, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Assemblage C, Lebo and Tongue River Members, Fort Union Formation (Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Zones P3 to P5, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Momipites actinus Nichols and Ott, 1978

Plate 4, Figures 13, 14

1978 *Momipites actinus* Nichols and Ott, p. 103, pl. 1, figs. 18-21.

Description: Triporate pollen, oblate, amb angular to semi-lobate with straight to concave interporia and well-rounded corners. Pores atriate, exopores circular to meridionally elongate, 1 to 2 microns in diameter, endopores 6 to 10 microns in diameter. Exine 1 micron thick at the equator, endexine not extending to the apertures but ending at the endopores to form the atria, ektexine thickening slightly towards the exopores. Surface with fine, evenly spaced granules (finely granulate). Exine thinned at one pole forming a triradiate area that resembles a trilete mark, with rays directed along the interporial radii.

Size: Diameter 23.0 (26.4) 30.0 microns

Specimens measured 28

Discussion: This species differs from *M. leboensis* (Leffingwell) Nichols, 1973, which is larger (27 to 31 microns) with convex interporia. It resembles *M. triletipollenites* (Rouse) Nichols, 1973, which also has concave interporia but differs in being smaller (20 to 23 microns). *M. actinus* is distinct from *M. triradiatus* Nichols, 1973, the latter having a thickened triradiate structure with rays directed towards the pores rather than along the interporial radii. Nichols and Ott (1978) remark upon the unique taxonomic character of *M. actinus* in that no convex counterpart is present in the Wind River assemblage.

Occurrence: Zones P3 to P5, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Zones P3 to P4, Fort Union Formation (Paleocene), Wind River Basin, Wyoming (Nichols and Ott, 1978).

Genus *Caryapollenites* Raatz ex Potonie', 1960 emend. Krutzsch, 1961

1934 *Caryae? pollenites* Potonie' and Venitz, p. 21 (*nom. nud.*).

1937 *Caryapollenites* Raatz, p. 19 (*nom. nud.*).

1960 *Caryapollenites* Raatz ex Potonie', p. 123.

1961 *Caryapollenites* Potonie' emend. Krutzsch, p. 310.

Type species: *Caryapollenites simplex* (Potonie') Raatz, 1937

Caryapollenites prodromus Nichols and Ott, 1978

Plate 5, Figures 1, 2

1978 *Caryapollenites prodromus* Nichols and Ott, p. 105, pl. 2, figs. 1-3.

Description: Triporate pollen, oblate, subangular with straight to slightly concave or convex sides, and well-rounded corners. At least one pore located off the equator. Pores atriate, exopores circular to meridionally elongate, 2 microns in diameter, endopores 10 microns in diameter. Exine 1 to 2 microns thick at the equator, endexine not extending to apertures but ending at the endopores to form the atria.

Surface with fine, wid[illegible]y spaced granules (finely granulate). Exine at one pole thinned in a circumpolar ring surrounding a polar isl[illegible]d of exine of normal thickness, circumpolar ring 2 to 4 microns wide ranging in outline from circular to rounded triangular.

Size: Diameter 23.0 (27.3) 31.7 microns

Specimens measured 50

Discussion: This species departs the most from the morphology of modern *Carya*. According to Nichols and Ott (1978) [illegible] an intermediate form in the morphologic continuum extending from [illegible] *Caryapollenites* back to *Momipites*. *C. prodromus* most resembles *M. leffing*[illegible] *annellus*, however it is larger than [illegible]*ellii*, and more importantly differs in that the pores are not wholly [illegible] position. This aperture positioning is a very weak expression of the he[illegible]arity exhibited by younger species of *Caryapollenites*.

Although Nichols and Ott (1978) describe *C. prodromus* as displaying straight to slightly concave interporia, during the present study a few identical specimens were found with slightly convex interporia, which have been included in this species. It seems that the m[illegible] important characteristic of this species is the displaceme[illegible] of at least one pore from the equator so that it lies in one hemisphere displaying a weak heteropo[illegible]rity. Great care must be taken in identifying this weak heteropolarity, and distinguishing this species from *M. annellus*. The observer must decide as to whether the heteropolarity is real, or if it is a preservational feature.

Occurrence: Zones P3 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Zones P3 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Caryapollenites imparalis Nichols and Ott, 1978

Plate 5, Figure 3

1978 *Caryapollenites imparalis* Nichols and Ott, p. 105, pl. 2, figs. 4-6.

Description: Triporate pollen, oblate, subangular with straight to convex sides and well-rounded corners. Two or more pores (usually only two) located off the equator. Pores atriate, exopores circular to meridionally elongate, 2 microns in diameter, endopores 10 microns in diameter. Exine 1 to 2 microns thick, endexine not extending to the apertures but ending at the endopores to form the atria. Surface with fine, widely spaced granules (finely granulate). Exine of even thickness at both poles.

Size: Diameter 25.1 (27.5) 31.2 microns

Specimens measured 50

Discussion: This species is characterized by the subequatorial position of the two pores and the lack of polar modification. The two subequatorial pores are not completely in one hemisphere, but the amb is broken by indentations at the pore positions. *C. imparalis* differs from *C. prodromus* in having more pronounced heteropolarity and lacking polar modification.

Occurrence: Zones P4 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Zones P4 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Caryapollenites wodehousei Nichols and Ott, 1978

Plate 5; Figures 4, 5

1978 *Caryapollenites wodehousei* Nichols and Ott, p. 106, pl. 2, figs. 9-11.

Description: Triporate pollen, oblate, subangular with straight to convex sides and well-rounded corners. Two or more (usually only two) pores located off the equator, outline not entire, but at least one pore indenting the equatorial margin. Pores atriate, exopores circular to meridionally elongate, 2 microns in diameter, endopores 10 microns in diameter. Exine 1 to 2 microns thick, endexine not extending to apertures but ending at endopores to form the atria. Surface with fine, widley spaced granules (finely granulate). Exine thinned at one pole in a circumpolar ring surrounding a polar island of exine of normal thickness, circumpolar ring 2 to 4 microns wide, varying in outline from circular to rounded triangular.

Size: Diameter 25.1 (29.3) 32.5 microns

Specimens measured: 18

Discussion: This species is similar to *C. prodromus* with respect to polar modification, but differs in the degree of heteropolarity. It resembles *C. imparalis*, which however differs in lacking polar modification. The pores of *C. wodehousei* are displaced, but not completely into one hemisphere. One pore is on the equator, another one lies partly in one hemisphere displaying a notched amb, and the third pore is completely in one hemisphere. *M. amplus* (Lefffingwell) Nichols, 1973, is similar in size and shape, but differs in having the pores on the equator.

Occurrence: Zones P4 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Zones P4 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

Caryapollenites inelegans Nichols and Ott, 1978

Plate 4, Figures 6, 7

1978 *Caryapollenites inelegans* Nichols and Ott, p. 105, pl. 2, figs. 7, 8.

Description: Triporate pollen, oblate, amb well rounded triangular to almost circular and unbroken by apertures. All pores located entirely in one hemisphere. Pores atriate although the atria may be obscure in polar view. Exopores circular, 2 to 3 microns in diameter, endopores oval and equatorially elongate, 10 microns in greatest diameter. Exine 1 to 2 microns thick, endexine not extending to the apertures but ending at the endopores to form the atria. Surface with fine, widely spaced granules (finely granulate). Exine of even thickness at both poles, lacking polar modification.

Size: Diameter 25.3 (29.1) 33.0 microns

Specimens measured 10

Discussion: This species is characterized by complete heteropolarity (pores are located entirely in one hemisphere) and the lack of polar modification. The amb is entire without indentations at the pore positions. This factor distinguishes it from the species *C. imparalis*. The specimen assigned to *C. viridifluminipites* (Wodehouse) Wilson and Webster, 1946, and illustrated by Leffingwell (1971, pl. 6, fig. 4) exhibits weak polar modification but not a true circumpolar ring. Besides, *C. viridifluminipites* is considerably larger (36 to 39 microns) than Leffingwell's specimen. Nichols and Ott (1978) suspect that this specimen as well as others illustrated by Wilson and Webster (1946, fig. 13) may belong to *C. inelegans*.

Occurrence: Zones P5 and P6, Paskapoo Formation (Paleocene) central Alberta Plains. (this study). Zones P5 and P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming. Nichols and Ott (1978)

Family: TILIACEAE

Genus: *Tiliaepollenites* Potonie', 1931 ex Potonie' and Venitz, 1934

1931 *Tiliaepollenites* Potonie', p. 556 (*nom. nud.*).

1934 *Tiliaepollenites* Potonie' ex Potonie' and Venitz, p. 37.

1937 *Tiliapollenites* Raatz, p. 27.

1953 *Intratriporopollenites* Thomson and Pflug, p. 87.

Type species: *Tiliaepollenites instructus* Potonie', 1931 ex Potonie' and Venitz, 1934

Tiliaepollenites danei (Anderson) n. comb.

Plate 6, Figures 9, 10

1960 *Tilia danei* Anderson, p. 23, pl. 7, figs. 10, 11.

Description: Triporate pollen, circular in equatorial outline. Pores longitudinally elongate with thickened margins. Endexine curving inwards at the pores and slightly thickened. Exine thin, 0.5 microns in thickness and increasing to 1 micron at the pores. Ornamentation finely reticulate.

Size: Diameter 23.8 (26.1) 28.2 microns

Specimens measured : 50

Discussion: The thin exine, small size and very fine reticulate ornamentation are diagnostic of *Tiliaepollenites.*

Occurrence: Zones P3 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Zone C, Paskapoo Formation (Paleocene) central Alberta Plains (Snead, 1969). Zone P3, Porcupine Hills Formation (Paleocene) southern Alberta Plains (McIntyre *et al.*, 1984). Ravenscrag Formation (middle to upper Paleocene) southern Saskatchewan (Sweet, 1978). Nacimiento Formation (lowermost Palecoene) San Juan Basin, New Mexico (Anderson, 1960).

Family: GENTIANACEAE

Genus: *Pistillipollenites* Rouse, 1962

1962 *Pistillipollenites* Rouse, p. 206.

Type species: *Pistillipollenites mcgregorii* Rouse, 1962

Pistillipollenites mcgregorii Rouse, 1962

Plate 6, Figures 11, 12

1962 *Pistillipollenites mcgregorii* Rouse, p. 206, pl. 1, figs. 8-1

Description: Triporate pollen, circular to broadly subtriangular in outline. Pores may be elongated meridionally. True colpi not developed but may be represented by depressed weak exinal areas, usually bordered by gemmae. Exine 2 to 3 microns thick, with ornamentation obscuring the distinction of ektexine and endexine. Outer surface of exine (excluding gemmae) varies from smooth, to finely reticulate to punctate. Ornamentation consists of gemmae varying in number, size varying from 1 to 6 microns, gemmae are dome-shaped with a constricted base appearing to sit in a slight depression.

Size: Diameter 21.0 (24.5) 30.0 microns

Specimens measured 50

Discussion: The gemmate ornamentation is very characteristic of this species. A detailed description of *P. mcgregorii* has been given by Rouse and Srivastava (1970). Elsik (1968) proposed an emendation of the genus to include tricolpoidate and tricolpoidorate pollen, however this was not accepted by Rouse and Srivastava (1970). *Pistillipollenites* was restricted only to triporate specimens.

Occurrence: Zones P5 and P6, [illegible] Formation (Paleocene) central Alberta Plains (this study). Ravenscrag Formation (upper Paleocene) southern Saskatchewan (Sweet, 1978). Burrard Formation (mid-Eocene) Vancouver, British Columbia (Rouse, 1962). Kitsilano Formation (Eocene) southern British Columbia (Hopkins, 1969). Eureka Sound and Beaufort Formations (upper Paleocene and Eocene) Canadian Arctic (Doernkamp *et al.*, 1976). Zones P5 and P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978). Rockdale Lignite (upper Paleocene) Texas (Elsik, 1968). Elko Formation (Eocene) Nevada (Wingate, 1983). Yakut Province (Eocene) Siberia, USSR (Kulkova, 1968). European occurrences (see Krutzsch and Vanhoorne, 1971)

ANGIOSPERM POLLEN OF UNCERTAIN FAMILIAL AFFINITY

Genus *Retitrescolpites* Sah, 1967

1967 *Retitrescolpites* Sah, p. 56.

1969 *Albertipollis* Srivastava, p. 54.

Type species: *Retitrescolpites typicus* Sah, 1967

Retitrescolpites bathyreticulatus (Stanley) n. comb.

Plate 6, Figure 4

1965 *Tricolpites bathyreticulatus* Stanley, p. 320, pl. 47, figs. 18-23.

Description: Tricolpate pollen, oblate, circular in polar view with colpi gaping. Endexine 0.5 to 1 micron thick. Ektexine reticulate with large irregularly shaped lumina up to 3 microns in diameter. Muri retipilate with capitate pila, muri low 0.5 microns high. Colpi straight and gaping, furrow margin smooth.

Size: Diameter 23.0 (25.6) 28.2 microns

Specimens measured 5

Discussion: This species can be easily distinguished from *R. anguloluminosus* (Anderson) Frederiksen, 1979, which has high membranous muri.

Occurrence: P2 Zone, Scollard Formation (Paleocene) central Alberta Plains (this study). Scollard Formation (lower Paleocene) Red Deer River valley, central Alberta Plains (Russell and Singh, 1978). Tullock and Cannonball Members, Fort Union Formation (Paleocene) South Dakota (Stanley, 1965). Tullock and Lebo Members, Fort Union Formation (Paleocene) Montana (Norton and Hall, 1969). Tullock and Lebo Members, Fort Union Formation (Paleocene) Montana (Oltz [illegible]

Retitrescolpites anguloluminosus (Anderson) Frederiksen, 1979

Plate 6, Figure 5

1960 *Tricolpites anguloluminosus* Anderson, p. 26, pl. [illegible] figs. 15-17, pl. 8, figs. 17, 18.

1979 *Retitrescolpites anguloluminosus* (Anderson) Frederiksen, p. 139, pl. 1, fig. 13.

Descrption: Tricolpate pollen, spherical, colpi gaping and reaching one-half to two-thirds the distance to the pole. Exine reticulate with about 2 micron wide lumina and more than 1 micron high, membranous, narrow muri. Lumina angular, typically pentagonal and not opening into the furrows. Furrows bordered by muri which form a margo. Lumina sometimes increasing in size near the furrow.

Size: Diameter 23.0 (25.1) 27.4 microns

Specimens measured 4

Discussion: This species can be distinguished from *R. bathyreticulatus* by its high, membranous muri and angular, uniformly shaped lumina. According to Norton and Hall (1969), *R. anguloluminosus* differs from *R. bathyreticulatus* in having muri which are not retipilate.

Occurrence: Zone P2, Scollard Formation (Paleocene) central Alberta Plains (this study). Scollard Formation (lower Paleocene) Red Deer River valley, central Alberta Plains (Russell and Singh, 1978). Tullock and Lebo Members, Fort Union Formation (Paleocene) Montana (Norton and Hall, 1969). Tullock and Lebo Members, Fort Union Formation (Paleocene) Montana (Oltz, 1969). Assemblage B; Tullock and Lebo Members, Fort Union Formation (Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Ojo Alamo and Nacimiento Formations (lowermost Paleocene) San Juan Basin, New Mexico (Anderson, 1960). Moreno Formation (uppermost Maestrichtian) San Joaquin Valley, California (Chmura, 1973). Upper Moreno Formation (lowermost Paleocene) California (Drugg, 1967).

Genus *Insulapollenites* Leffingwell, 1971

1971 *Insulapollenites* Leffingwell, p. 48.

Type species *Insulapollenites rugulatus* Leffingwell, 1971

Insulapollenites rugulatus Leffingwell, 1971

Plate 6, Figure 6

1962 Unclassified pollen Groot and Groot, p. 170, pl. 31, figs. 10, 11.

1971 *Insulapollenites rugulatus* Leffingwell, p. 48, pl. 9, figs. 11, 12.

Description: Parasyncolpate pollen, oblate, triangular in polar view with rounded apices. Colpi bifurcating near the poles and at the angles of the amb to form islands, polar islands triangular and 10 microns in diameter, islands at the angles of the amb diamond-shaped. Exine 1.5 microns thick in the equatorial interapical areas, 1 micron thick at the angle of the amb. Sculpture coarsely rugulate in the interapical areas, becoming reticulate to very fine reticulate within 3 to 5 microns from the colpi. Equatorial islands very finely reticulate, one polar island very finely reticulate, the opposite island smooth to scabrate.

Size: Diameter 25.1 (29.6) 36.6 microns

Specimens measured 4

Discussion: This species seems very characteristic of uppermost Paleocene strata based on this study, and that of Nichols and Ott (1978), although it is usually not very abundant. However, according to Leffingwell (1971, pls. 1, 2), *Insulapollenites rugulatus* makes its entrance at the base of Assemblage C (middle of Lebo Member), which is most likely of middle Paleocene age in the Powder River Basin.

The natural affinity of *Insulapollenites* may be with Sapindaceae of Myrtaceae which produce morphologically similar pollen.

Occurrence: Zones P5 and P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Ravenscrag Formation (upper Paleocene) southern Saskatchewan (Sweet, 1978). Assemblage C, Lebo and Tongue River Members, Fort Union Formation (Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Zones P5 and P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978). Brightseat Formation (upper Paleocene) Maryland (Groot and Groot, 1962).

Genus *Wodehouseia* Stanley, 1961

1961 *Wodehouseia* Stanley, p. 156.

1961 *Kryshtofoviana* Samoilovitch in Samoilovitch and Mtchedlishvili, p. 232.

1961 *Regina* Samoilovitch in Samoilovitch and Mtchedlishvili, p. 240.

1961 *Deplexipollis* Chlonova, p. 81.

Type Species: *Wodehouseia spinata* Stanley, 1961

Wodehouseia spinata Stanley, 1961

Plate 5, Figure 8

1961 *Wodehouseia spinata* Stanley, p. 157, pl. 1, figs. 1-12.

1961 *Kryshtofoviana vera* Samoilovitch in Samoilovitch and Mtchedlishvili, p. 233, pl. 75, figs. 1a-d, 2, 3a-c.

1961 *Deplexipollis occulatus* Chlonova, p. 81, pl. 13, figs. 96, 96a.

Description: Tetraporate pollen, bilaterally symmetrical. Equatorial pollen profile circumscribing longest pollen axis, oblate to suboblate. Apertures binigeminate, two pores on each surface, elliptical, 2 x 5 microns in size, inset approximately one-third of, and at right angles to the longest pollen axis. Wall double layered, composed of endexine which forms a central body, and stratified ektexine which forms a carinate flange. Sculpture of ektexine microreticulate with internal rod-like thickenings and external spines distributed along, and restricted to the flange. Equatorial region micropunctate. Central body microreticulate with the exception of 10 or 11 large spines, approximately 11 microns long randomly distributed on each surface.

Size: Length of central body 33.3 (39.3) 46.1 microns

Width of central body 15.9 (20.0) 28.2 microns

Overall length 38.4 (47.5) 55.3 microns

Overall width 30.5 (35.6) 39.2 microns

Specimens measured 25

Discussion: Wiggins (1976) defined binigeminate aperture in referring to an aperture, pore or colpus that occurs as two pairs on any given pollen grain. This term was introduced particularly for the genus *Wodehouseia*.

Stanley (1961) instituted *Wodehouseia* for tetraporate palynomorphs possessing a flange, with grana and spinae for ornamentation. Stanley (1961) suggested that the genus may have zoological rather than botanical affinities. Chlonova (1961) suggested an affinity of *W. spinata* with *Impatiens* (*Balsaminaceae*) or *Jollydora* (*Connaraceae*). Samoilovitch (1961) suggested a relationship of *Wodehouseia* to the genera *Justicia*, *Adhatoda*, or *Beloperone* (*Acanthaceae*). Superficially these genera are similar to *Wodehouseia*, however Leffingwell *et al.* (1970) demonstrated fundamental differences in the wall structure which precluded any relationship to these taxa. According to Leffingwell *et al.* (1970) the plants that produced *Wodehouseia* pollen became extinct, but were definitely of angiospermous origin. This deduction was based on the exine structue, which involved a tectum consisting of a finely reticulate or punctate sexine on the flange and micropunctate on the body. At present, the botanical affinity of this genus is interpreted only as angiospermous (Farabee and Canright, 1986).

Srivastava (1970) utilized *W. spinata* in zoning the upper Edmonton Group of the Red Deer River valley. Leffingwell (1971) was the first to recognize that this species ranges a short interval above the Cretaceous-Tertiary boundary. *Wodehouseia* is greatly diversified and abundant in the Maestrichtian strata of more northerly localities (Wiggins, 1976), and also occurs in the Paleocene, but in much less numbers. No specimens of *Wodehouseia* have been identified from localities southwest of Colorado (Newman 1965).

Occurrence: Basal P1 Zone, Scollard Formation (Maestrichtian and basal Paleocene) central Alberta Plains (this study). Scollard Formation (Maestrichtian) Red Deer River valley, central Alberta Plains (Srivastava 1966 to 1970; Snead 1969; Russell and Singh 1978, Lerbekmo *et al.* 1979). Scollard Formation (Maestrichtian and basal Paleocene) Red Deer River valley, central Alberta Plains (Sweet and Hills, 1984). Coalspur Formation (Maestrichtian and basal Paleocene) central Alberta Foothills (Lerbekmo *et al.*, in press). Frenchman and Ravenscrag Formations (Maestrichtian and basal Paleocene) southern Saskatchewan (Sweet 1978, Jarzen 1982). Northwest Territories and Yukon, Canada (Maestrichtian) (Rouse and Srivastava 1972, Hopkins 1973, McIntyre 1974). Kanguk and Eureka Sound Formations (Maestrichtian and basal Paleocene) Canadian Arctic (Doernkamp *et al*, 1976). Eureka Sound Formation (upper Maestrichtian) Ellef Ringnes Island, Canadian Arctic (Felix and Burbridge, 1973). Hell Creek Formation (Maestrichtian) South Dakota (Stanley 1961, 1965), Montana (Norton and Hall 1967, 1969; Oltz, 1969). Lance and Fort Union Formations (Maestrichtian and basal Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Lance Formation (Maestrichtian) Wyoming (Farabee and Canright, 1986). Kemp Clay and Kincaid Formations (Maestrichtian and basal Danian) Texas (Evitt, 1973). Siberia (Maestrichtian and Paleocene) U.S.S.R. (Samoilovitch and Mtchedlishvili 1961, Chlonova 1961, Bratzeva 1965, 1967).

Wodehouseia fimbriata Stanley 1961

Plate 6, Figure 9

1961 *Wodehouseia fimbriata* Stanley, p. 160, pl. 2, figs. 1-8.

Description: Tetraporate pollen, bilaterally symmetrical. Equatorial profile circumscribing longest pollen axis, suboblate. Apertures binigeminate, two pores on each surface, elliptical, 4 x 8 microns in size, inset approximately one-third of, and at right angles to, the longest pollen axis. Wall double layered, composed of endexine which forms a constricted or "dumbbell" shaped central body, and stratified ektexine which forms a carinate flange. Sculpture of ektexine punctatireticulate with elongate spines, but reinforced with hair-like fimbriae.

Size: Length of central body 43.5 (45.3) 49.9 microns

Width of central body 12.0 (19.1) 22.3 microns

Overall length 60.2 (69.6) 79.9 microns

Overall width 44.0 (59.0) 74.2 microns

Specimens measured 6

Discussion: *W. fimbriata* is readily distinguishable from *W. spinata* by the presence of fimbriae on the flange, by the absence of spines on both surfaces of the body, and it's larger size.

Wiggins (1976) in his complete review of *Wodehouseia* from Alaska did not find *W. fimbriata*, but instead identified *W. fimbriata subsp. constricta* Wiggins, 1976, and *W. excelsa* (Samoilovitch) Wiggins, 1976. *W. fimbriata* differs from *W. excelsa* in which the flange is adequately supported by elongate spine columns, and from *W. fimbriata subsp. constricta* which has constricted flange at the longitudinal ends.

It seems that all occurrences of *W. fimbriata* from the northern U.S. and Canada are restricted to the lowermost Paleocene. Srivastava's (1969, p. 1310) report of *W. fimbriata* in the Maestrichtian from central Alberta is erroneous as he recorded it from strata above the Nevis seam. However, he did recognize the importance of this species immediately above the Cretaceous-Tertiary boundary (Srivastava, 1970).

Occurrence: P1 Zone (Scollard Formation) central Alberta Plains (this study). Scollard Formation (basal Paleocene) Red Deer River valley, central Alberta Plains (Srivastava 1970). Scollard Formation (basal Paleocene) Red Deer River valley, central Alberta Plains (Russell and Singh 1978, Lerbekmo *et al.* 1979). Coalspur Formation (basal Paleocene) central Alberta Foothills (Lerbekmo *et al.*, in press). Ravenscrag Formation (basal Paleocene) southern Saskatchewan (Jarzen, 1982). Eureka Sound Formation (basal Paleocene) Canadian Arctic (Doernkamp *et al.*, 1976). Fort Union Formation (basal Paleocene) South Dakota (Stanley 1961, 1965). Siberia (Maestrichtian to Paleocene), U.S.S.R. (Samoilovitch and Mtchedlishvili, 1961).

Genus: *Kurtzipites* Anderson, 1960 emend. Leffingwell, 1971

1960 *Kurtzipites* Anderson, p. 24.

1965 *Aenigmapollis* Stanley, p. 311.

1969 *Coriaripites* Srivastava, p. 49.

1970 *Aquilapollenites* (*Fibulapollis*) Chlonova in Kedves and Kiraly, p. 67.

1971 *Kurtzipites* Anderson emend. Leffingwell, p. 50.

Type Species: *Kurtzipites trispissatus* Anderson, 1960

Kurtzipites trispissatus Anderson, 1960

Plate 6, Figure 2

1960 *Kurtzipites trispissatus* Anderson, p. 25, [illegible], figs. 15-17.

1965 *Aenigmapollis polyformis* Stanley, p. 312, pl. 46, figs. 22-25.

1966 *Aquilapollenites minutus* Srivastava, p. 542, pl. 10, figs. 2, 3.

1969 *Coriaripites aliens* Srivastava, p. 50, pl. 1, fig. 1.

Description: Brevitricolporate pollen, oblate, subtriangular, sides convex and apices slightly protruded. Colpi short on narrowly rounded corners, length from colpi tip to equator about one-quarter of amb radius. Pores atriate. Nexine smooth and thickened at polar extremities of colpi, forming dark spots about 4 microns in diameter. Sexine very thin, tectate. Sculpture appears finely granulate in transmitted light but is revealed as finely spinulose under SEM (Srivastava, 1981, pl. 2, figs. 1-6).

Size: Diameter 19.2 (23.3) 26.1 microns

Specimens measured 50

Discussion: This species is characterized by circular, dark spots at the polar extremities of short colpi.

Srivastava (1981) revised the genus *Kurtzipites*, placing *Coriaripites* Srivastava, *Fibulapollis* Chlonova and *Aenigmapollis* Stanley into synonymy with *Kurtzipites*. Certain specimens described as *Porocolpopollenites* of Elsik (1968) from the Paleocene in Texas may also be assignable to *Kurtzipites* (Farabee and Canright, 1986).

Occurrence: Zones P1 to P3, Scollard and Paskapoo Formations (Paleocene) central Alberta Plains (this study). Horseshoe Canyon, Whitemud and Scollard Formations (Campanian to Maestrichtian) Red Deer River valley, central Alberta Plains (Srivastava 1967, 1969, 1970). Zones A and B, Scollard Formation (Maestrichtian to Paleocene) central Alberta Plains (Snead, 1969). Coalspur Formation (Maestrichtian to Paleocene) central Alberta Foothills (Jerzykiewicz and Sweet, 1986a). Frenchman and Ravenscrag Formations (Maestrichtian to Paleocene) Morgan Creek, southern Saskatchewan (Jarzen, 1977). Assemblages A and B, Lance Formation, Lebo and Tullock Members, Fort Union Formation (Maestrichtian to Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Lance and Fort Union Formations (Maestrichtian to Paleocene) South Dakota (Stanley, 1965). Hell Creek and Fort Union Formations (Maestrichtian to Paleocene) Montana (Norton and Hall, 1969). Hell Creek Formation and Tullock Member, Fort Union Formation (Maestrichtian to Paleocene) Montana (Oltz, 1969). Ojo Alamo Formation (Maestrichtian to Paleocene) San Juan Basin, New Mexico (Anderson, 1960). Kemp Clay and Kincaid Formations (Maeestrichtian to Paleocene) Texas (Evitt, 1973).

Kurtzipites annulatus Norton, 1969

Plate 6, Figure 3

1969 *Kurtzipites annulatus* Norton in Norton and Hall, p. 39, pl. 5, fig. 13.

1969 *Kurtzipites* sp. Snead, p. 52, pl. 5, figs. 15, 16.

1971 *Kurtzipites* sp. Leffingwell, p. 51, pl. 10, figs. 6, 7.

1971 *Kurtzipites* cf. *K. trispassatus* (Anderson) - R.H. Tschudy, p. 86, pl. 4, fig. 20.

1977 *Kurtzipites* sp. Jarzen, p. 48, pl. 1, fig. 12.

Description: Brevitricolporate pollen, oblate, amb subtraingular, with convex sides. Colpi short on narrowly rounded corners, length from colpi tip to amb one-quarter of amb radius. Pores atriate. Nexine thickened completely around the equatorial pore, sexine very thin. Sculpture finely granulate.

Size: Diameter 20.2 (23.6) 28.7 microns

Specimens measured 50

Discussion: This species is distinct from other forms of *Kurtzipites* in that the nexinous thickenings completely surround the pore, unlike *K. trispassatus* in which the thickenings are in the form of a dark spot at the polar extremity of short colpi.

Occurrence: Zones P1 to P3, Scollard and Paskapoo Formations (Paleocene) central Albera Plains (this study). Zone B, Scollard Formation (Maestrichtian to Paleocene) central Alberta Plains (Snead, 1969). Frenchman and Ravenscrag Formations (Maestrichtian to Paleocene) Morgan Creek, southern Saskatchewan (Jarzen, 1977). Frenchman Formation (Maestrichtian) southern Saskatchewan (Sweet, 1978). Ravenscrag Formation (Paleocene) southern Saskatchewan (Jarzen, 1982). Assemblages A and B, Lance Formation, Lebo and Tullock Members, Fort Union Formation (Maestrichtian to Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Lance Formation (Maestrichtian) Wyoming (Farabee and Canright, 1986). Hell Creek and Fort Union Formations (Maestrichtian to Paleocene) Montana (Norton and Hall 1969, R.H. Tschudy 1971). Hell Creek Formation and Tullock Member, Fort Union

Formation (Maestrichtian to Paleocene) Montana (Oltz, 1969).

Kurtzipites circularis (Norton) Srivastava, 1981

Plate [illegible] Figure 1

1969 *Momipites circularis* Norton in Norton and Hall, p. 37, pl. 5, fig. 8.

1971 *Kurtzipites simplex* Leffingwell, p. 51, pl. 10, figs. 2-4b.

1981 *Kurtzipites circularis* (Norton) Srivastava, p. 874.

Description: Brevitricolporate pollen, oblate, subtri[illegible] convex sides. Colpi short on narrowly rounded corners, length from colpi tips to equator one-quarter to one-half amb radius. Pores atriate. Nexine of even thickness, sexine very thin. Sculpture finely granulate.

Size: Diameter 20.0 (23.3) 26.4 microns

Specimens measured 29

Discussion: *K. circularis* is distinct from other forms of *Kurtzipites* in the absence of nexinous thickenings at the polar extremities of the colpi.

Occurrence: Zones P1 and P2, Scollard Formation (Paleocene) central Alberta Plains (this study). Assemblages A and B, Lance Formation, Tullock and Lebo Members, Fort Union Formation (Maestrichtian to Paleocene) Powder River Basin, Wyoming (Leffingwell, 1971). Hell Creek and Fort Union Formations (Maestrichtian to Paleocene) Montana (Norton and Hall, 1969). Hell Creek Formation, Tullock and Lebo Members, Fort Union Formation (Maestrichtian to Paleocene) Montana (Oltz, 1969).

Genus *Aquilapollenites* Rouse, 1957 emend. Funkhouser, 1961

1957 *Aquilapollenites* Rouse, p. 370.

1958 *Pentapollenites* Krutzsch, p. 520.

1961 *Aquilapollenites* Rouse emend. Funkhouser, p. 193.

1961 Triprojectacites Mtchedlishvili in Samoilovitch *et al.*, p. 203. (Supergroup)

1961 *Triprojectus* Mtchedlishvili in Samoilovitch *et al.*, p. 204.

1961 *Aquilapollenites* Rouse emend. Mtchedlishvili in Samoilovitch *et al.*, p. 209.

1961 *Integricorpus* Mtchedlishvili in Samoilovitch *et al.*, p. 217.

1961 *Mancicorpus* Mtchedlishvili in Samoilovitch *et al.*, p. 218.

1961 *Parviprojectus* Mtchedlishvili in Samoilovitch *et al.*, p. 225.

1961 *Projectaporites* Mtchedlishvili in Samoilovitch *et al.*, p. 227.

1961 *Triceropollis* Chlonova, p. 85.

1961 *Translucentipollis*, Chlonova p. 89.

1961 *Accuratipollis* Chlonova, p. 91.

1961 *Taurocephalus* Simpson, p. 440.

1968b *Aquilapollenites* Rouse emend. Funkhouser restr. Srivastava, p. 668.

1968b *Mancicorpus* Mtchedlishvili in Samoilovitch *et al.* emend. Srivastava, p. 695.

Type species: *Aquilapollenites quadrilobus* Rouse, 1957

Aquilapollenites spinulosus Funkhouser, 1961

Plate 6, Figures 7, 8

1961 *Aquilapollenites spinulosus* Funkhouser, p. 194, pl. 1, figs. 4-6.

Description: Isopolar, tridemicolpate. Body with three equatorial protrusions and two polar protrusions, diameter of polar protrusions approximately equal to the diameter of polar protrusions. Demicolpi located within the concavities between the equatorial and polar protrusions with smooth, narrow, thickened bands paralleling each demicolpi. Remainder of body covered with randomly spaced spinules 0.5 to 1 micron long, and

1 to 2 microns apart, spinules on the equatorial protrusions curving back towards the poles.

Size: Overall length 26.1 (35.1) 41.0 microns

Width of polar protrusions 9.5 (11.8) 15.1 microns

Length of equatorial protrusions 12.5 (16.3) 21.0 microns

Width of equatorial protrusions 7.7 (9.5) 12.8 microns

Width of body 12.5 (15.4) 18.1 microns

Specimens measured 25

Discussion: The proposed subdivision of *Aquilapollenites* by Mchedlishvili (in Samoilovitch *et al.*, 1961) and Srivastava (1968) are not acceptable for two reasons: a) the genera are not clearly distinct from each other and b) *Aquilapollenites* would be deprived of it's type species (B.D. Tschudy and Leopold, 1971). *Mancicorpus* would usurp the type species *A. quadrilobus*.

A. spinulosus differs from *A. attenuatus* in having shorter equatorial protrusions, no punctae, and the spinules are not grouped into definite areas. There is a question also, as to whether *Aquilapollenites* should be defined as tricolpate, or tridemicolpate. Certain species clearly show the colpi extending about the polar protrusion wheras other species do not show this feature precisely. A polar view of the specimen is necessary to distinguish this fact.

A. spinulosus is the only well-documented species of *Aquilapollenites* from the middle Paleocene of the western interior of North America.

Occurrence: Zones P3 to P6, Paskapoo Formation (Paleocene) central Alberta Plains (this study). Zone C, Paskapoo Formation (Paleocene) central Alberta Plains (Snead, 1969). Paskapoo Formation (Paleocene) Red Deer River valley, central Alberta Plains (Russell and Singh, 1978). Porcupine Hills Formation (Paleocene) southern Alberta Plains (McIntyre *et al.*, 1984). P3 Zone, Porcupine Hills Formation (Paleocene) southern Alberta Plains (Jerzykiewicz and Sweet, 1986b). Paskapoo Formation

(Paleocene) central Alberta Foothills (Jerzykiewicz and Sweet, 1986a). Ravenscrag Formation (Paleocene) southern Saskatchewan (Sweet, 1978). Fort Union Formation (Paleocene) Wyoming (Funkhouser, 1961). Sentinental Butte Member, Fort Union Formation (Paleocene) North Dakota; Tongue River Member, Fort Union Formation (Paleocene) North Dakota; Coalmount Formation (Paleocene) Colorado; Hell Creek Formation (Maestrichtian) Montana (Tschudy and Leopold, 1971). Zones P3 to P6, Fort Union Formation (Paleocene) Wind River Basin, Wyoming (Nichols and Ott, 1978).

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PLATE 4

(All figures X1000)

Figures 1 and 2) *Momipites leffingwellii* Nichols and Ott — p. 67
(Fig. 1 CH-4-82, 56.2 m, 36.0 X 97.2)
(Fig. 2 CH-3-82, 81.3 m, 24.3 X 108.6)

Figures 3 and 4) *Momipites waltmanensis* Nichols and Ott — p. 69
(Fig. 3 CH-2-82, 81.7 m, 44.5 X 105.6)
(Fig. 4 CH-2-82, 24.3 m, 39.5 X 103.3)

Figures 5 and 6) *Momipites wyomingensis* Nichols and Ott — p. 68
(Fig. 5 OS-1-6, 20.8 X 97.0)
(Fig. 6 OS-1-2, 10.8 X 100.6)

Figures 7 and 8) *Momipites ventifluminis* Nichols and Ott — p. 70
(Fig. 7 ON-2-2 (10-30 micron fraction), 13.7 X 101.0)
(Fig. 8 OS-1-7, 43.6 X 97.4)

Figures 9 and 10) *Momipites annellus* Nichols and Ott — p. 71
(Fig. 9 CH-3-82, 124.6 m, 36.7 X 96.9)
(Fig. 10 J-LC-5, 32.3 X 97.3)

Figures 11 and 12) *Momipites triorbicularis* (Leffingwell) Nichols and Ott — p. 72
(Fig. 11 CH-2-82, 27.0 m, 22.0 X 109.0)
(Fig. 12 CH-3-82, 132.3 m, 29.3 X 108.9)

Figures 13 and 14) *Momipites actinus* Nichols and Ott — p. 73
(Fig. 13 CH-3-82, 124.6 m, 10.6 X 105.1)
(Fig. 14 J-LC-4, 36.8 X 104.7)

PLATE

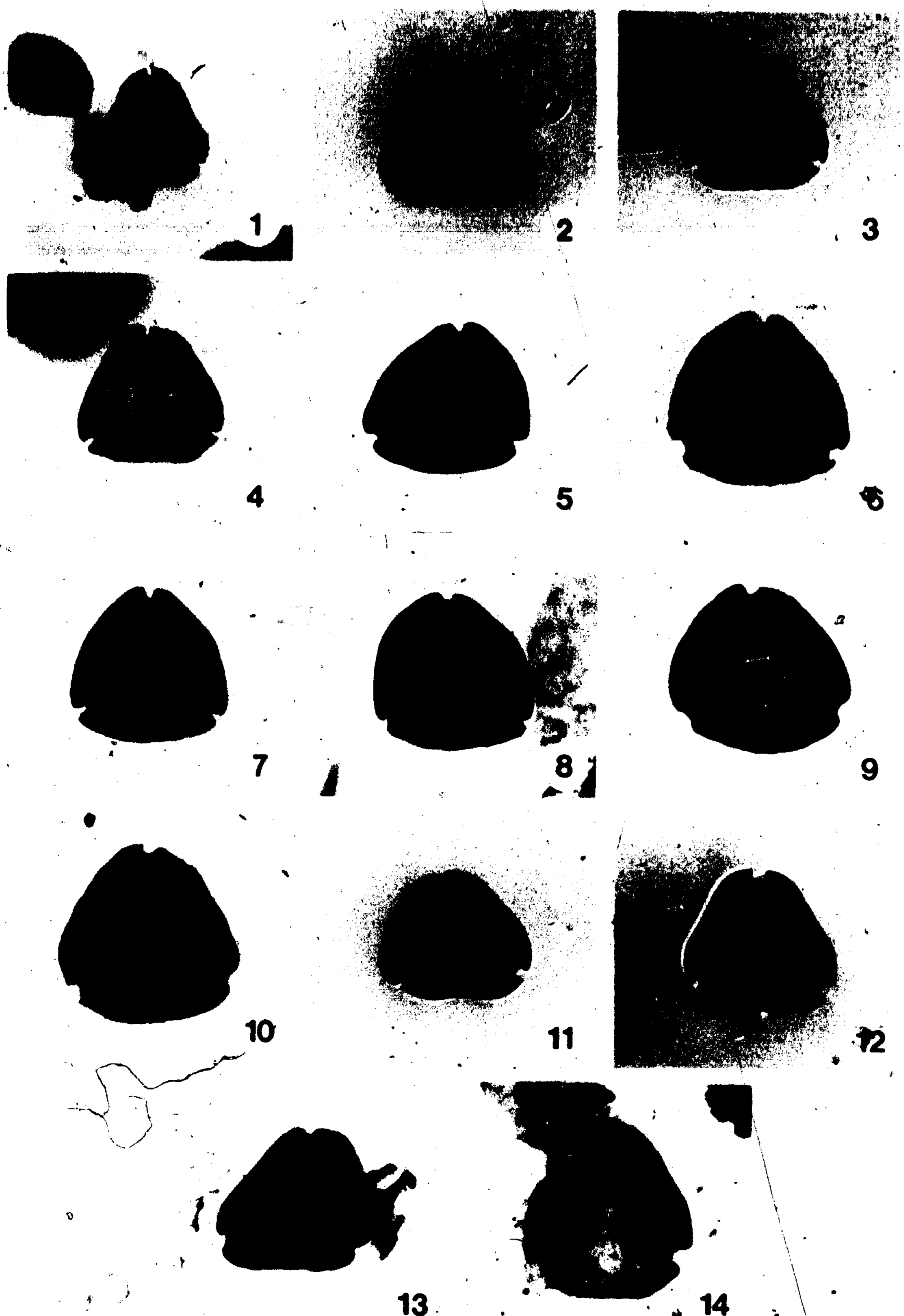


PLATE 5

(All figures X1000)

Figures 1 and 2) *Caryapollenites prodromus* Nichols and Ott p. 74
(Fig. 1 ON-2-4, 26.4 X 102.7)
(Fig. 2 CH-4-82, 56.2 m, 10.9 X 106.1)

Figure 3) *Caryapollenites imparalis* Nichols and Ott p. 76
(Fig. 3 CH-3-82, 62.25 m, 43.7 X 106.9)

Figures 4 and 5) *Caryapollenites wodehousei* Nichols and Ott p. 76
(Fig. 4 CH-3-82, 132.6 m, 7.0 X 103.0)
(Fig. 5 CH-2-82, 27.0 m, 33.0 X 108.0)

Figures 6 and 7) *Caryapollenites inelegans* Nichols and Ott p. 77
(Fig. 6 OS-1-2, 36.0 X 97.2)
(Fig. 7 ON-2-2 (10-30 micron fraction), 47.0 X 102.9)

Figure 8) *Wodehouseia spinata* Stanley p. 84
(Fig. 8 CH-4-82, 112.2 m, 44.1 X 97.1)

Figure 9) *Wodehouseia fimbriata* Stanley p. 86
(Fig. 9 AR(1)-2, 27.8 X 96.0, specimen courtesy C. Singh)

PLATE 5

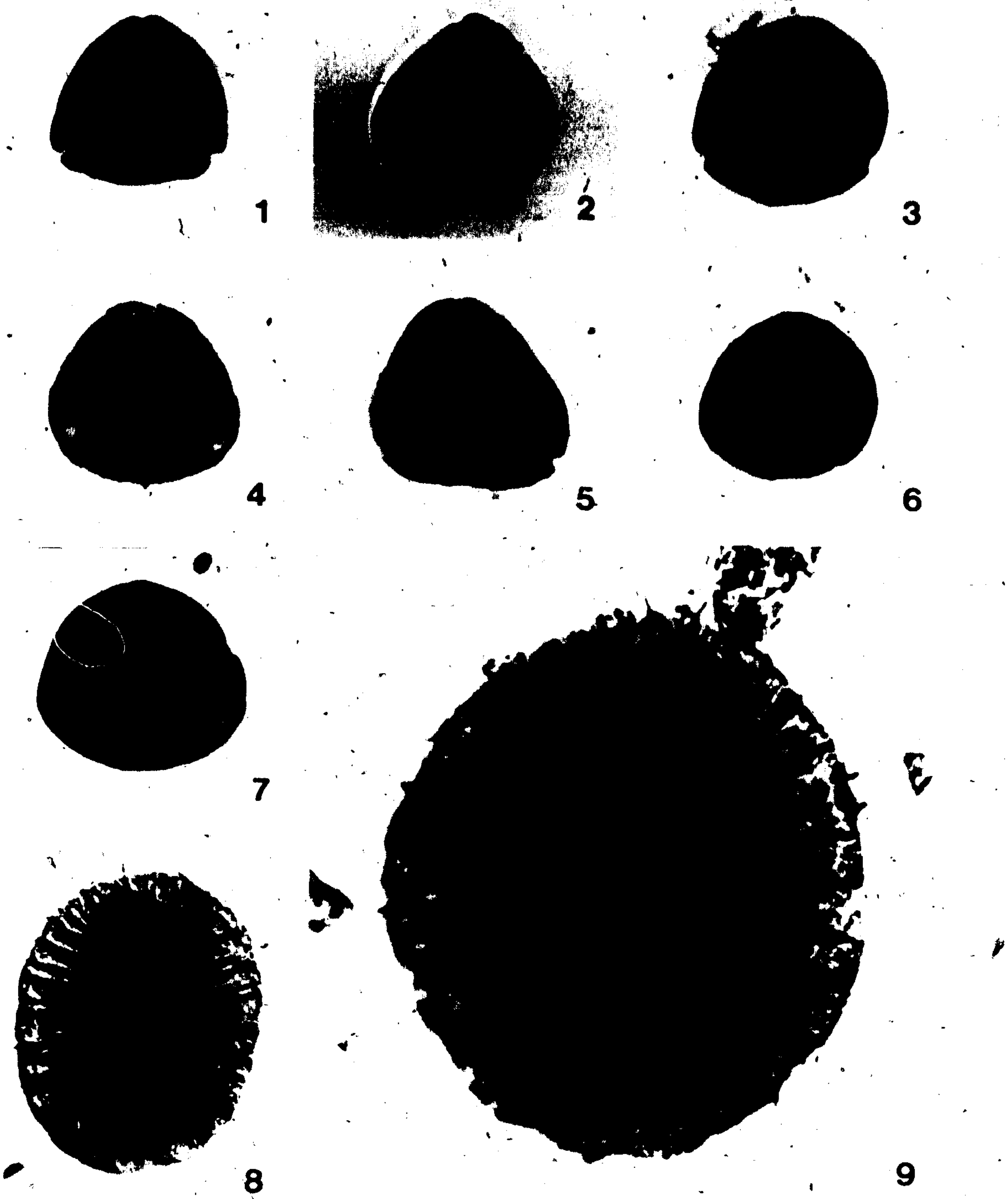


PLATE 6

(All figures X1000)

Figure 1) *Kurtzipites circularis* (Norton and Hall) Srivastava — p. 91
(Fig. 1 CH-3-82, 221.0 m, 32.6 X 99.3)

Figure 2) *Kurtzipites trispissatus* Anderson — p. 88
(Fig. 2 CH-2-82, 140.9 m, 27.5 X 99.7)

Figure 3) *Kurtzipites annulatus* Norton and Hall — p. 90
(Fig. 3 CH-2-82, 140.9 m, 39.4 X 97.8)

Figure 4) *Retitrescolpites bathyreticulatus* (Stanley) n. comb. — p. 81
(Fig. 4 HV-19, 42.25 m, 22.3 X 95.8, specimen courtesy C. Singh)

Figure 5) *Retitrescolpites anguloluminosus* (Anderson) Frederiksen — p. 82
(Fig. 5 HV-19, 42.25 m, 4.9 X 94.1, specimen courtesy C. Singh)

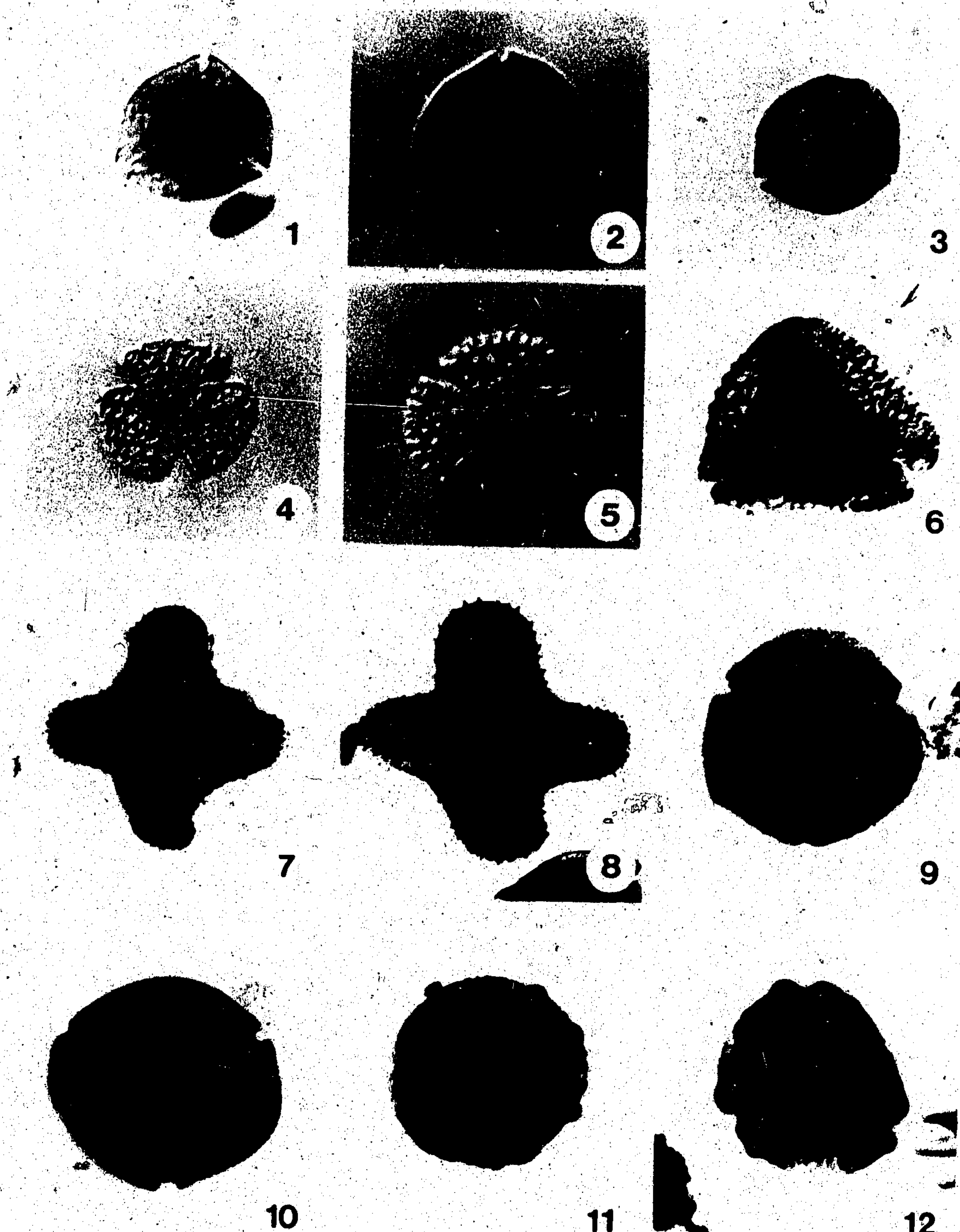
Figure 6) *Insulapollenites rugulatus* Leffingwell — p. 83
(Fig. 6 CR-1-1, 10.2 X 104.7)

Figures 7 and 8) *Aquilapollenites spinulosus* Funkhouser — p. 92
(Fig. 7 CH-3-82, 96.15 m, 26.7 X 105.0)
(Fig. 8 CH-3-82, 96.15 m, 25.7 X 96.9)

Figures 9 and 10) *Tiliaepollenites danei* (Anderson) n. comb. — p. 78
(Fig. 9 J-LC-5, 46.2 X 99.1)
(Fig. 10 CH-3-82, 96.15 m, 33.8 X 93.0)

Figures 11 and 12) *Pistillipollenites mcgregorii* Rouse — p. 79
(Fig. 11 076-54, 356 ft, 16.4 X 95.4)
(Fig. 12 CH-3-82, 63.75 m, 5.4 X 102.6)

PLATE 6



APPENDIX A

DETAILED ANALYSES OF SAMPLED LOCALITIES

PLAINS COREHOLES (Tables 1 to 4, Figure 15)

CH-2-82 (Haynes) (Table 1, Figure 15)

The Cretaceous-Tertiary boundary within CH-2-82 (Haynes) occurs in the interval from 157.5 m to 158.1 m. Specimens of *Aquilapollenites* spp. are abundant at 158.1 m but are absent at 157.5 m, with common *Wodehouseia spinata* at 157.0 m. The coal at this level is therefore interpreted as the Nevis seam on this basis, with the boundary located at it's base (Sweet and Hills, 1984). This distribution in CH-2-82 confirms the [illegible] of *W. spinata* for a short interval above the extinction of *Aquilapollenites* sp. (Leffingwell 1971, Sweet and Hills 1984). Sweet and Hills (1984) have also identified *A. reticulatus* as occurring coincident with *W. spinata* for this short interval above the boundary.

The P1 Zone extends from the Cretaceous-Tertiary boundary to the base of the Ardley seam identified at a depth of 143.0 m. This coal seam can be identified by the distinctive sequence of coal and bentonitic partings (Campbell, 1967). This P1 Zone is characterized by *Wodehouseia fimbriata*. *Momipites wyomingensis* first appears at 137.5 m indicating the P2 Zone. This zone continues up to the base of the Paskapoo Formation which is identified as the first thick sandstone unit above the Ardley seam (Gibson, 1977). The Scollard/Paskapoo contact is placed at 109.0 m. The first available palynology sample above the basal Paskapoo sandstone is at 81.7 m, thus there is an interval of 27 m of sandstone with no palynological control.

The P4 Zone is first represented in CH-2-82 by the appearance of *Tiliaepollenites danei* at 28.0 m (uppermost P3 Zone), then at 27.0 m by the presence of *C. imparalis*. This P4 Zone assemblage continues to the top of the core.

CH-3-82 (Lacombe) (Table 2, Figure 15)

In CH-3-82 (Lacombe), the Nevis seam is identified at a depth of 244.8 m based on the extinction of *Aquilapollenites* spp.. The Ardley seam is identified at 233.65 m. *Momipites wyomingensis* first appears at 221.0 m indicating the P2 Zone, in which the upper Ardley coals are very well developed, as in CH-2-82.

An unusual situation is encountered in defining the Scollard/Paskapoo contact in CH-3-82. A channel sandstone sequence is present from a depth of 205 m to 186 m, capped by a small coal seam, and the question arises as to whether this is a basal Paskapoo sandstone, or a Scollard channel (a channel sandstone interbedded with Ardley coals). This situation illustrates the difficulties in applying the outcrop nomenclature of Gibson (1977) to the subsurface. If the coal at 186.0 m is interpreted to be an Ardley coal, then the sandstone is in the Scollard Formation. Otherwise, by definition, this lower sandstone is basal Paskapoo Formation. The palynology of this coal, unfortunately, is equivocal as it does not display any characteristic P2 nor P3 Zone species; there are no species of *Momipites*, nor is *Aquilapollenites spinulosus* present. Therefore, the base of the Paskapoo Formation is placed at the base of this lower sandstone unit. Above the second sandstone sequence in CH-3-82, a diverse P3 Zone assemblage is present at 150.4 m. Following this at 132.6 m, *Caryapollenites imparalis* and *C. wodehousei* appear, characteristic of the P4 Zone. These uppermost P3 and P4 Zones are represented by a much finer grained interval above the basal Paskapoo sandstones. This finer grained interval is characterized by small fining upward sequences capped by carbonaceous beds.

In CH-3-82, the appearance of *Pistillipollenites mcgregorii* at a depth of 72.7 m, corresponding with the termination of the range of *Momipites leffingwellii*, distinguishes the P5 Zone. This P5 Zone assemblage is present to the top of the core, with the continued diversity of *Momipites* spp. illustrating that the P6 Zone is not encountered. Therefore, within CH-3-82, a complete P1 through P5 zonation is present.

CH-4-82 (Clive) (Table 3, Figure 15)

The situation present in CH-4-82 (Clive) is anomalous in that the interval from the top of the Battle Formation to the Ardley seam is reduced and the Nevis seam is not present. This interval in this core is only 17 m, even less than that recorded by Lerbekmo and Coulter (1985) for a similar situation at their Wood Lake section. Within this interval, there is no coal nor carbonaceous shale, instead three small sand sequences are present. From the palynology, the sample at 112.5 m is Maestrichtian due to the occurrence of diverse *Aquilapollenites*. The sample at 109.8 m contains *Wodehouseia spinata*, the 109.6 m sample is barren, and at 108.0 m, *W. fimbriata* is present indicative of the P1 Zone. The Cretaceous-Tertiary boundary thus lies in the interval from 112.5 m to 108.0 m. Since 109.8 m contains *W. spinata* but lacks *Aquilapollenites*, it is interpreted as Paleocene, and the boundary placed at the base of the sandstone sequence at 112.5 m. This series of channel sandstones is likely to have eroded away the Nevis seam, replacing this interval with smaller sandstone units, an explanation invoked by Lerbekmo and Coulter (1985).

The Ardley seam is identified at 108.7 m. The P2 Zone is further identified by the appearances of *Momipites wyomingensis* and *M. waltmanensis* at depths of 87.5 m and 85.6 m respectively. The contact between the Scollard and Paskapoo Formations is placed at 85.0 m. A P3 Zone assemblage is present at 57.8 m. There are only 75 m of Paleocene strata present within CH-4-82, and the Paskapoo Formation is predominantly sandstone and no younger than P3 zone in age.

CH-65-1 (Wizard Lake) (Table 4, Figure 15)

*(It should be noted that the original geophysical log of the Wizard Lake corehole was unavailable, and therefore the litholog from Snead (1969) was employed to illustrate the sample levels).

In CH-65-1 (Wizard Lake) the Nevis seam is at the sample depth of WL-31. The Nevis seam in CH-2-82 and CH-65-1 is thicker than usual. Normally, this seam is on the scale of that encounterd in CH-3-82, or it may be no more than a carbonaceous shale bed. The Ardley seam however is thin, a situation noted by Holter *et al.* (1975) for the Ardley seam northward away from the Red Deer River valley. The P2 Zone is identified at sample WL-18 by the presence of *Momipites leffingwellii*. This zone is also characterized by abundant *Kurtzipites* spp., and an occurrence of *Retitrescolpites anguloluminosus*. A P3 Zone assemblage is present in sample WL-8, and the presence of *Tiliaepollenites danei* in sample WL-2 from the very top of the core indicates an upper P3 Zone age. No species of *Caryapollenites* were identified.

PLAINS OUTCROPS (Tables 5 to 7, Figure 25)

The five outcrop localities studied for palynology in this report range in age from upper P3 at Hand Hills, to lower P5 at Crestomere. A detailed palynological account of each locality follows.

The Hand Hills are an outlier of Paskapoo Formation located northeast of Drumheller. This area is isolated from other outcrop, making correlations rather difficult. Fortunately, the Battle Formation is exposed near the base of this outlier, and a thick coal seam above the Battle has been tentatively correlated as the Ardley seam (Allan and Sanderson 1945, Campbell 1967, Gibson 1977, Lerbekmo 1985). A palynological sample from a road exposure near the top of the Hand Hills, above the coal seam, yielded an assemblage of diverse *Momipites* spp. and *Tiliaepollenites* *danei* (Table 5). No specimens of *Caryapollenites* were identified, therefore these uppermost strata of the Hand Hills are interpreted as upper P3 Zone in age. These strata correlate approximately to a level equivalent to the uppermost strata within CH-65-1 (Wizard Lake) (Figure 15).

Outcrop at the Joffre Bridge locality is well-known for its mammal and megafloral fossil remains (Stockey and Crane, 1985). A location just upstream from the Joffre Bridge is believed to be Erickson's Landing, a site studied for its vertebrate fossils by Brown (1914). Higher stratigraphically (approximately 20 m), is a prolific fossil leaf layer. A fortuitous roadside exposure provided access to these beds for palynological examination. Due to the small stratigraphic separation between these two fossiliferous levels, no differentiation in the palynofloral assemblages was identified (Figure 25).

The assemblage from Joffre is comprised of diverse *Momipites* spp., *Caryapollenites wodehousei, C. imparalis. Tiliaepollenites danei* and *Kurtzipites annulatus* which is indicative of a P4 Zone age (Table 5). The presence of *K. annulatus* is diagnostic in that this species persists into lower P4 Zone assemblages but terminates by upper P4 time.

The Delburne road outcrop, to the south of Joffre Bridge, is about 100 m higher topographically, yet displays a similar palynological assemblage to that of the Joffre locality, excluding *Kurtzipites annulatus* (Table 5). This suggests, at least, an upper P4 Zone age for this locality. The Delburne site is one of the highest topographically in the general area. Over the stratigraphic interval of approximately 100 m from Joffre to Delburne, a greater differentiation in palynofloral assemblages might be expected. However, poor recovery and the lack of suitable sediments for palynology has hampered the recognition of possibly younger strata. This assemblage is therefore of P4 Zone age or younger.

The Blindman and Burbank localities are well-known for their megafloral and vertebrate fossils (Stockey and Crane 1984, Fox 1984a, b). These exposures are located upstream from the Joffre Bridge, on the Red Deer River at the confluence of the Blindman and Red Deer rivers. This locality exhibits an assemblage similar to the assemblage identified from Delburne, suggesting upper P4 Zone (Table 6).

The Crestomere School locality, west of Ponoka, is the farthest west and youngest of the central Plains outcrop localities studied. The palynofloral asemblage contains *Pistillipollenites mcgregorii* and *Insulapollenites rugulatus*, which are characteristic of the P5 Zone (Table 7). Also, there is a full suite of *Momipites* spp. with the exception of *M. leffingwellii*, which further confirms P5, but excludes a P6 Zone age. This locality is therefore younger than Blindman/Burbank, and is correlative to the uppermost strata present in CH-3-82 (Figure 15).

The ages of these outcrop localities is further evidence for the erosion of upper Paskapoo Formation strata to the east, leaving only older strata downstream along the Red Deer River valley. This has also been illustrated by mammal paleontology (Krause, 1978) as has been discussed earlier.

OBED-MARSH (Tables 8 to 10, Figures 16 and 26)

All outcrop localities in the Obed-Marsh area exhibit similar palynofloral assemblages. These include the four road cut exposures along the access corridor (Figure 5) (Table 8), and the two exposures of the Obed No. 1 and No. 2 seams at the active minesite (Tables 9 and 10).

The palynofloral assemblage consists of a complete suite of *Caryapollenites* spp. and *Momipites* spp. (except *M. leffingwellii*), with *Pistillipollenites mcgregorii* and *Insulapollenites rugulatus*. The dominant species are *Momipites wyomingensis* and *M. ventifluminis*, which seems to be characterisitic of the P5 Zone assemblage from Obed-Marsh. This assemblage persists downward to the lower road exposure, which also contains *P. mcgregorii* (Figure 26). According to topographic maps, this road exposure (OM-2.5) is approximately 150 m below the level of the Obed No. 1 coal seam at the minesite. This implies a minimum thickness of 150 m for P5 Zone strata in the western central Plains adjacent to the disturbed belt.

The two coreholes from the Obed Block have allowed for the examination of all five coal seams within the Obed-Marsh coal zone (Tables 11 and 12) (Figure 16). Placement of the P5/P6 zonal boundary at the top of Obed No. 2 coal seam is based upon the absence of *Momipites triorbicularis*, *M. waltmanensis* and *M. actinus* from the P6 Zone. These species are present in the assemblages within the Obed No. 2 seam, but appear to terminate simaltaneously at the top of this coal seam. Due to the very limited geographic extent of strata above the Obed No. 2 seam, P6 Zone strata are likely restricted to the immediate vicinity of Obed-Marsh block, adjacent to the Foothills. Basis for further division of the P6 Zone assemblage is not evident, and no P6 Zone strata have been identified elsewhere (eastwards) in the Plains (Figure 17).

From well-log data in the Obed-Marsh area, the uppermost coal seam of the Coalspur Formation, the Val d'Or, has been identified in the subsurface adjacent to the Foothills. According to these data, approximately 700 m of Paskapoo Formation strata are present between the top of the Val d'Or seam and the Obed No. 1 seam. Including the 280 m of Paleocene strata in the Coalspur Formation (Jerzykiewicz, 1985) and the 135 m within the Obed-Marsh coal zone (Union Oil, 1979), the total thickness of Paleocene strata adjacent to the disturbed belt is aproximately 1115 m, encompasing a complete P1 through P5, and a [illegible] partial P6 zonation. This is in contrast to only 200 m of P1 through P4 and partial P5 Zone strata present in CH-3-82 in the Red Deer River valley.

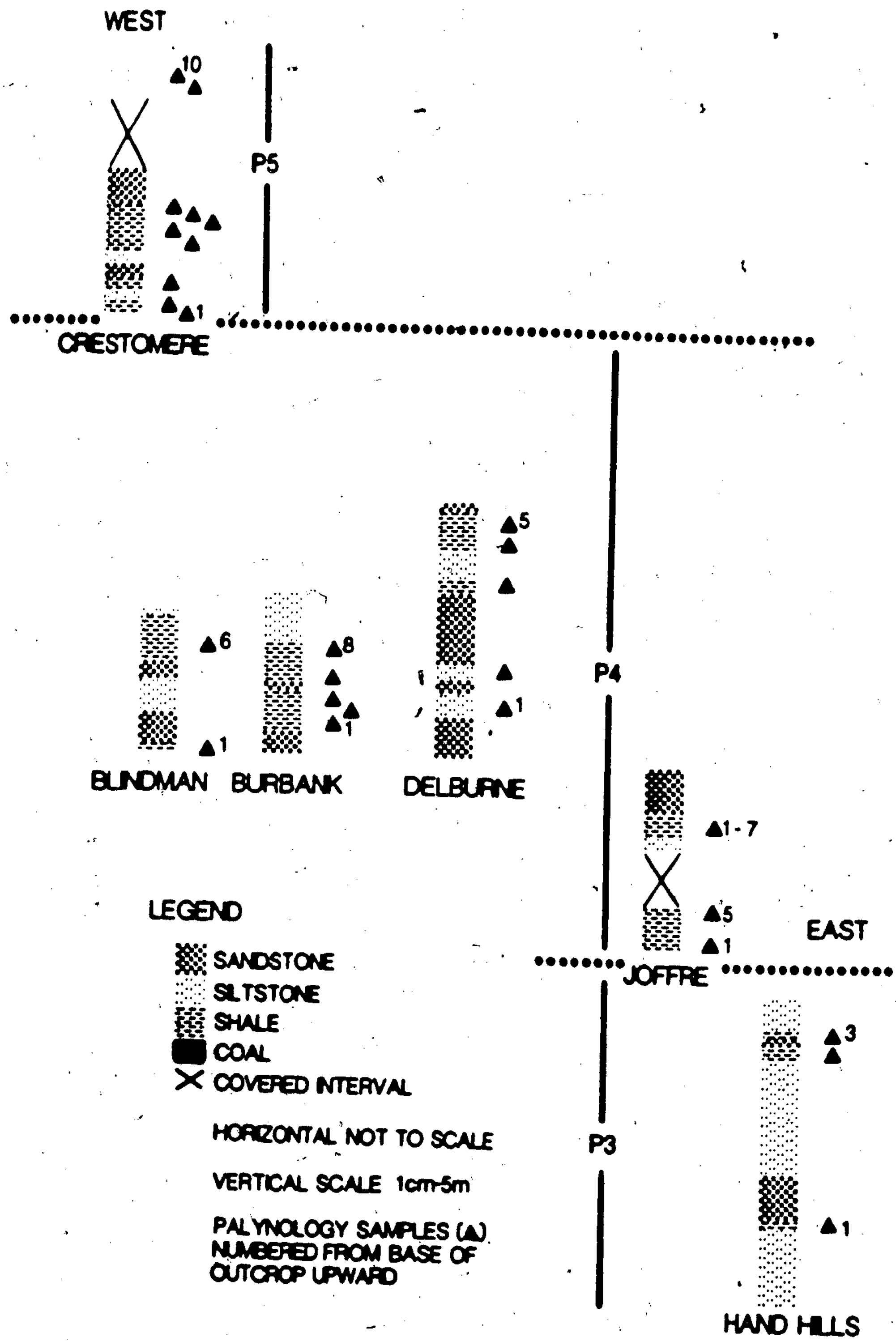


Figure 25. Stratigraphy of Red Deer-Lacombe outcrop localities (an exact correlation between the Blindman/Burbank and Delburne localities is not implied).

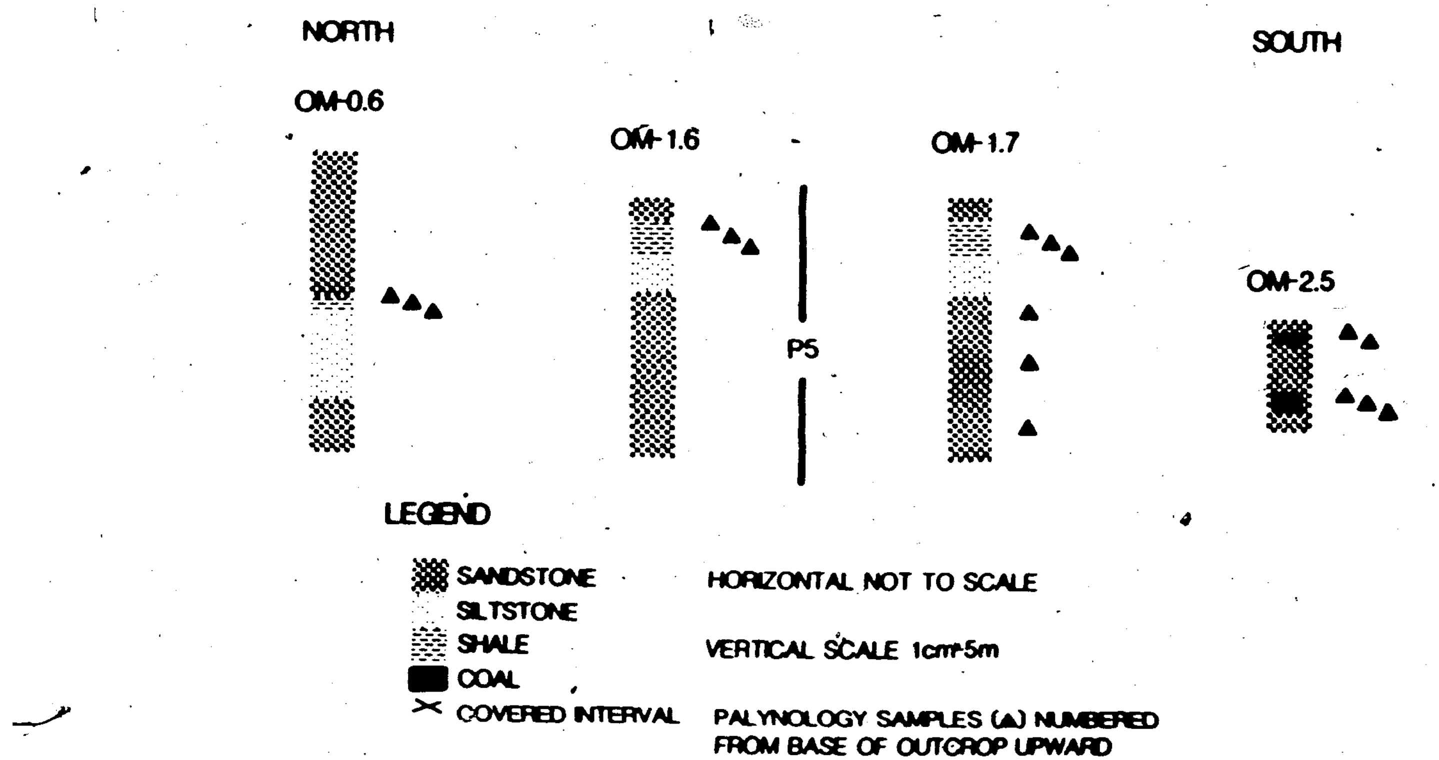


Figure 26. Stratigraphy of Obed-Marsh access corridor outcrops.

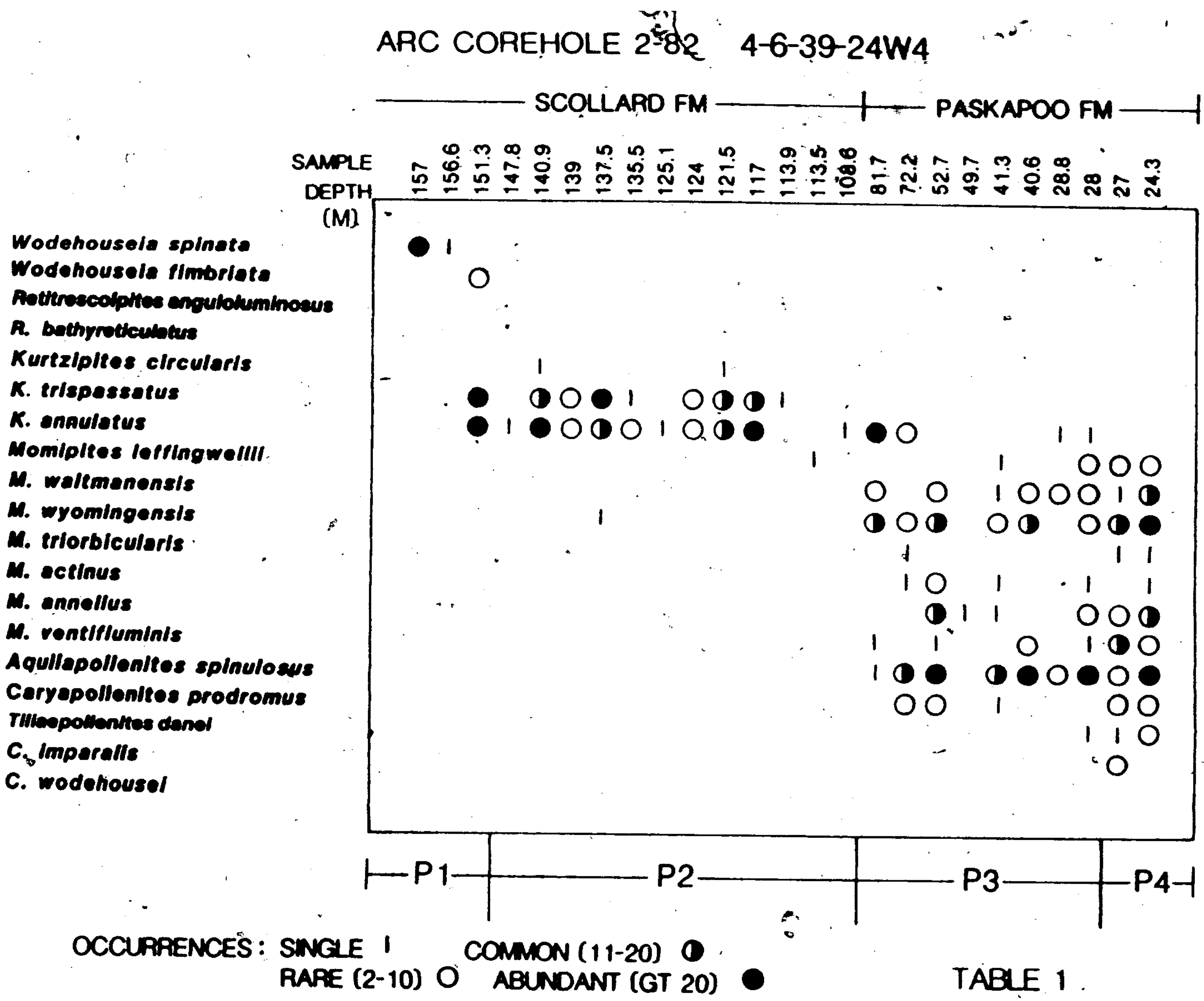

ARC COREHOLE 2-82 4-6-39-24W4
SCOLLARD FM
PASKAPOO FM
SAMPLE DEPTH (M)
157
156.6
151.3
147.8
140.9
139
137.5
135.5
125.1
124
121.5
117
113.9
113.5
108.6
81.7
72.2
52.7
49.7
41.3
40.6
28.8
28
27
24.3
Wodehouseia spinata
Wodehouseia fimbriata
Retitrescolpites anguloluminosus
R. bathyreticulatus
Kurtzipites circularis
K. trispassatus
K. annulatus
Momipites leffingwellii
M. waltmanensis
M. wyomingensis
M. triorbicularis
M. actinus
M. annellus
M. ventifluminis
Aquilapollenites spinulosus
Caryapollenites prodromus
Tiliaepollenites danei
C. imperalis
C. wodehousei
P1
P2
P3
P4
OCCURRENCES: SINGLE
RARE (2-10)
COMMON (11-20)
ABUNDANT (GT 20)

TABLE 1

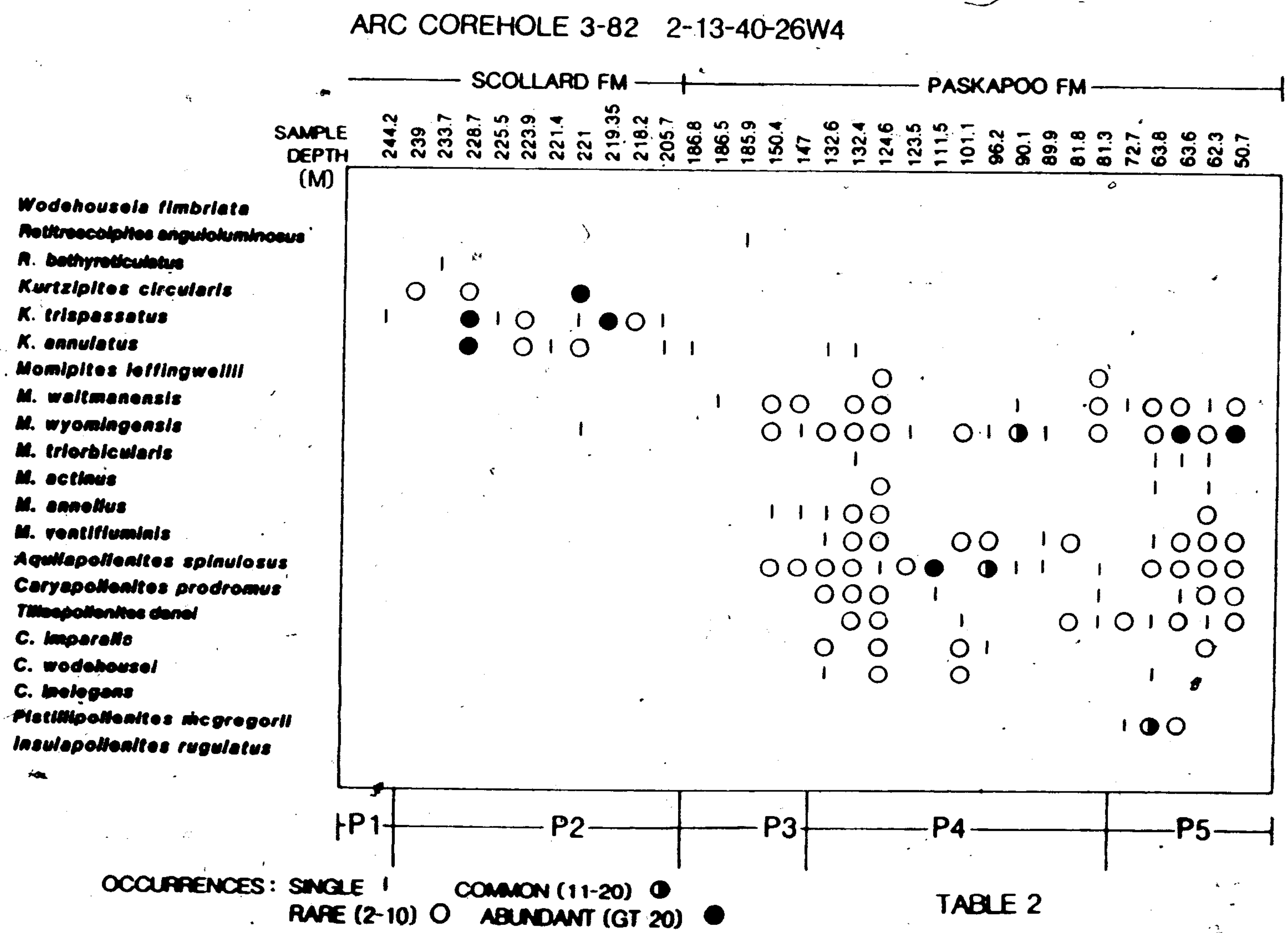

ARC COREHOLE 3-82 2-13-40-26W4
SCOLLARD FM
PASKAPOO FM
SAMPLE DEPTH (M)
244.2
239
233.7
228.7
225.5
223.9
221.4
221
219.35
218.2
205.7
186.8
186.5
185.9
150.4
147
132.6
132.4
124.6
123.5
111.5
101.1
96.2
90.1
89.9
81.8
81.3
72.7
63.8
63.6
62.3
50.7
Wodehouseia fimbriata
Retitrescolpites anguloluminosus
R. bathyreticulatus
Kurtzipites circularis
K. trispassatus
K. annulatus
Momipites leffingwellii
M. waltmanensis
M. wyomingensis
M. triorbicularis
M. actinus
M. annellus
M. ventifluminis
Aquilapollenites spinulosus
Caryapollenites prodromus
Tiliaepollenites danei
C. imperalis
C. wodehousei
C. inelegans
Pistillipollenites mcgregorii
Insulapollenites rugulatus
P1
P2
P3
P4
P5
OCCURRENCES: SINGLE I
RARE (2-10) O
COMMON (11-20)
ABUNDANT (GT 20)

TABLE 2

ARC COREHOLE 4-82 1-29-41-24W4

— SCOLLARD FM ——| PASKAPOO FM

SAMPLE DEPTH (M)	109.8	109	108	101.9	90.8	87.5	87.2	85.6	61.8	57.8	56.2
Wodehouseia spinata	O										
Wodehouseia fimbriata			I								
Retitrescolpites anguloluminosus											
R. bathyreticulatus											
Kurtzipites circularis							I	I			
K. trispassatus	O			I	I				I		O
K. annulatus	I	O			O	O	I		O		O
Momipites leffingwellii											O
M. waltmanensis								O			O
M. wyomingensis						I					O
M. triorbicularis											
M. actinus											
M. annellus											O
M. ventifluminis											
Aquilapollenites spinulosus										●	O
Caryapollenites prodromus										O	O

|P1——|—— P2 ——|—P3—|

OCCURRENCES: SINGLE I   COMMON (11-20) ◑   RARE (2-10) O   ABUNDANT (GT 20) ●

TABLE 3

ARC COREHOLE 65-1
WIZARD LAKE 4-8-48-27W4

— SCOLLARD FM —| PASKAPOO FM

SAMPLE NO	WL-30	26	25	22	18	15	14	8	5	4	2	1
Wodehouseia fimbriata	I											
Retitrescolpites anguloluminosus	○		I									
R. bathyreticulatus	I											
Kurtzipites circularis			○	I	○							
K. trispassatus		I	○	●	○							
K. annulatus	○	○	○	●	●							
Momipites leffingwellii					I	I				I		
M. waltmanensis					I		○	○	I	○		I
M. wyomingensis						I	○	◐	●	○	○	○
M. triorbicularis												
M. actinus									I			
M. annellus								○	○	○		
M. ventifluminis								○	◐	I		
Aquilapollenites spinulosus								●	○	◐	I	
Caryapollenites prodromus									○	I		
Tiliaepollenites danei											○	
	P1	P2						P3				

OCCURRENCES : SINGLE I COMMON (11-20) ◐
RARE (2-10) ○ ABUNDANT (GT 20) ●

TABLE 4

	JOFFRE UPPER CUT						JOFFRE LOWER CUT			DELBURNE		HAND HILLS
SAMPLE NO	1	2	3	4	6	7	3	4	5	1	4	3
K. annulatus		○	I	○	I				I	I		
Momipites leffingwellii		I		I			I	○				
M. waltmanensis	I	○	○	I	I	○		○				○
M. wyomingensis	○	○		○	I	○		○	I	○	I	●
M. triorbicularis	I											○
M. actinus								I	○			I
M. annellus								●	I			○
M. ventifluminis		I						I	I			
Aquilapollenites spinulosus		○	●	○		○						○
Caryapollenites prodromus		I						●	○			
Tiliaepollenites danei	◐	○	○	○				I	I	I		○
C. imparalis		○				I		○				
C. wodehousei				I				I				
C. inelegans												
Pistillipollenites mcgregorii												
Insulapollenites rugulatus												

——————————————— P4 —— P3 —

OCCURRENCES: SINGLE I   COMMON (11-20) ◐
RARE (2-10) ○   ABUNDANT (GT 20) ●

TABLE 5

	BLINDMAN				[illegible]RBANK						
SAMPLE NO	2	3	4	5	1	2	4	5	6	7	8
K. annulatus											
Momipites leffingwellii								O			
M. waltmanensis	O	I		O				O	O	I	
M. wyomingensis	O	O		O	I		O	O	O	I	I
M. triorbicularis	I							O	O		
M. actinus	I			O							
M. annellus				O				I	I		
M. ventifluminis	O							◐	O		
Aquilapollenites spinulosus	O			O	I	I		●			I
Caryapollenites prodromus	O	I		O				O	O		
Tiliaepollenites danei		O		O				O	O		
C. imparalis		I	O	I					I		
C. wodehousei									I		
C. inelegans											
Pistillipollenites mcgregorii											
Insulapollenites rugulatus											

P4

OCCURRENCES: SINGLE I COMMON (11-20) ◐
RARE (2-10) O ABUNDANT (GT 20) ●

TABLE 6

CRESTOMERE

SAMPLE NO	1	2	4	7	8	9	10
Momipites leffingwellii							
M. waltmanensis			O				
M. wyomingensis	O		O	O	O	I	
M. triorbicularis				I			
M. actinus							
M. annellus			O				
M. ventifluminis				O	O	I	
Aquilapollenites spinulosus							
Caryapollenites prodromus							
Tiliaepollenites danei			I		I	I	
C. imperalis	I		I		I		
C. wodehousei							
C. inelegans							
Platillipollenites mcgregorii	●	O					O
Insulapollenites rugulatus	I						

P5

OCCURRENCES: SINGLE I COMMON (11-20) ◑
RARE (2-10) O ABUNDANT (GT 20) ●

TABLE 7

OBED-MARSH
ACCESS CORRIDOR OUTCROP

	OM-0.6			OM-1.6			OM-1.7				OM-2.5				
SAMPLE NO	1	2	3	1	2	3	3	4	5	6	1	2	3	4	5
Momipites leffingwellii															
M. waltmanensis				I	O	O		O	O			I	I		
M. wyomingensis	●	O	O	O	●	●	O	O	O	O	●	●	●	●	
M. triorbicularis											O		I		
M. actinus			I		I						I		O		
M. annellus						I				I			O		
M. ventrifluminis	I	O	O								O		O		
Aquilapollenites spinul[illegible]		O	O				I	I							I
Caryapollenites prodrom[illegible]				I	I	O							I		
Tiliaepollenites danei				I	I	O					O	O	I	O	
C. imparalis				O	O	O				I	◑	O	O	O	
C. wodehousei															
C. inelegans												I		I	
Pistillipollenites mcgregorii											O	I		O	
Insulapollenites rugulatus															

——————————— P5 ———

OCCURRENCES: SINGLE I COMMON (11-20) ◑
RARE (2-10) O ABUNDANT (GT 20) ●

TABLE 8

OBED MINE SECTION
ON-1

SAMPLE NO	2	3	4	5	6	7	8	9	11	12
Momipites leffingwellii										
M. waltmanensis			I	I			I			
M. wyomingensis	●	O	●	●	●	●	O	O	O	O
M. triorbicularis					I					
M. actinus				I	I	I				
M. annellus		I	I		I					
M. ventifluminis		I	O	◑	●	●			I	
Aquilapollenites spinulosus										
Caryapollenites prodromus		I	I	I	O	O			I	
Tiliaepollenites danei			I	O	O	I				
C. imparalis	O	O	O	O	◑	◑				
C. wodehousei					I	O				
C. inelegans	I			I		O				
Platillipollenites mcgregorii										
Insulapollenites rugulatus				I						

P5

OCCURRENCES: SINGLE I COMMON (11-20) ◑
RARE (2-10) O ABUNDANT (GT 20) ●

TABLE 9

OBED MINE SECTION
ON-2

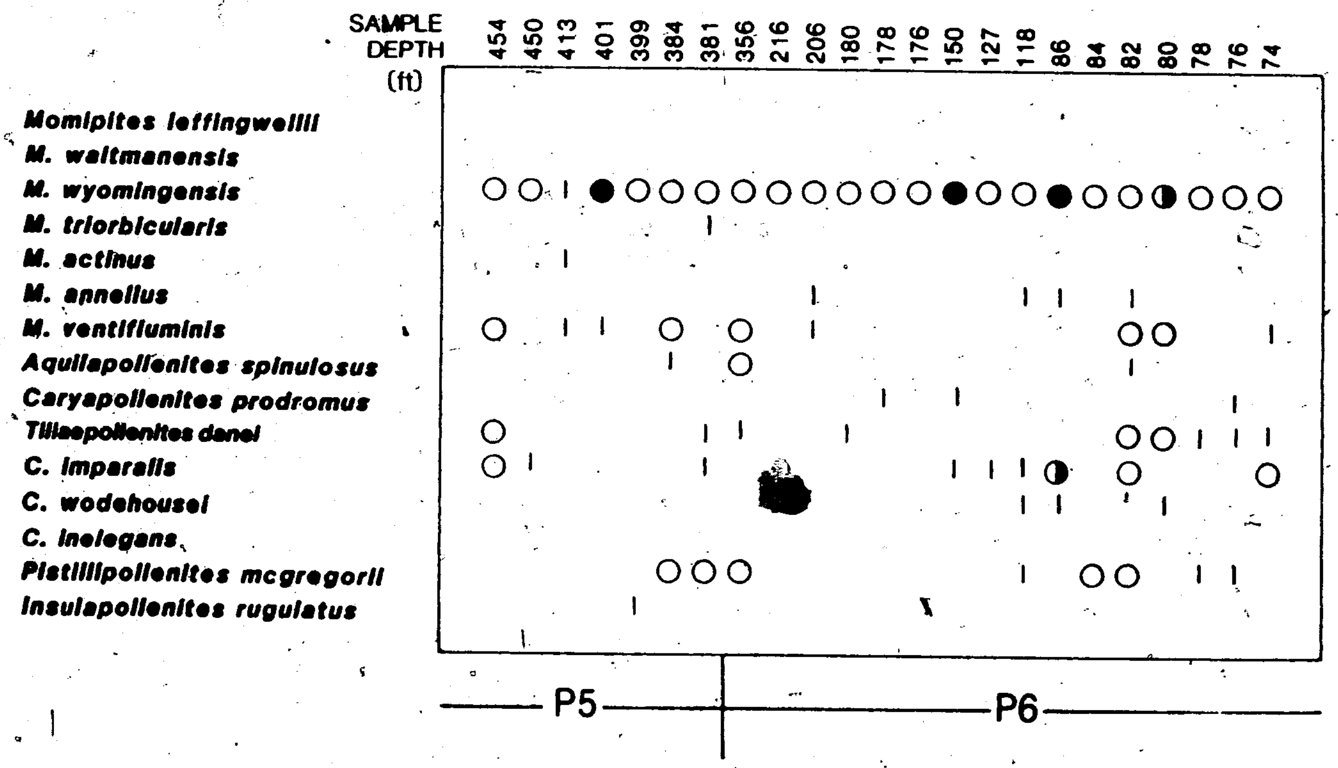
SAMPLE NO	1	2	3	4	5	6	8	9	10	11	12
Momipites leffingwellii											
M. waltmanensis	I	I								I	
M. wyomingensis	○	●	◑	●	○	○	◑		◑	●	●
M. triorbicularis			○								
M. actinus		I			I						I
M. annellus	I				I		I				I
M. ventifluminis	I	●	●	●	○	◑	●	I	○	I	●
Aquilapollenites spinulosus			I							I	
Caryapollenites prodromus	I	○			I	I					
Tiliaepollenites danei		○				I	I				○
C. imparalis	○	●	●	◑	I	○	○		○	○	●
C. wodehousei			I				I		I		
C. inelegans		I	I								
Platillipollenites mcgregorii											
Insulapollenites rugulatus											

P5

OCCURRENCES: SINGLE I   COMMON (11-20) ◑
RARE (2-10) ○   ABUNDANT (GT 20) ●

TABLE 10

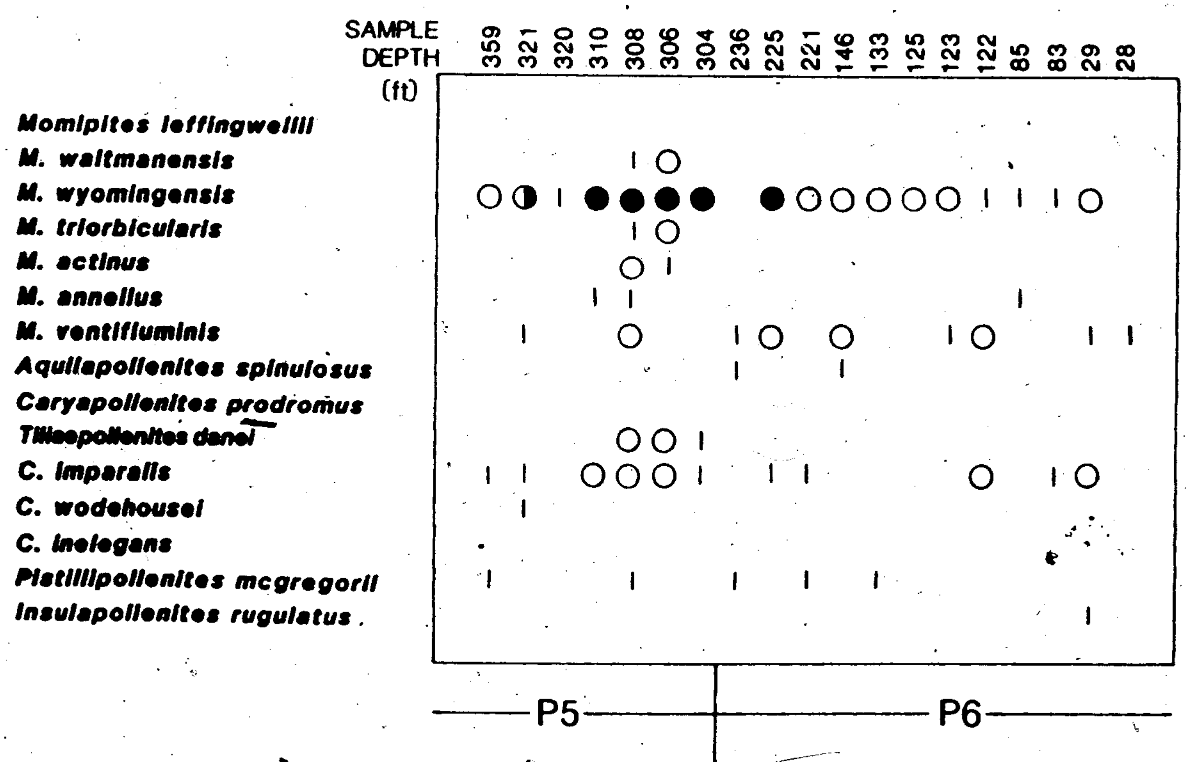
OBED COREHOLE 76-54 7-8-53-24W5



OCCURRENCES: SINGLE I COMMON (11-20) ◐
RARE (2-10) ○ ABUNDANT (GT 20) ●

TABLE 11

OBED COREHOLE 76-21 12-15-53-24W5



OCCURRENCES: SINGLE I COMMON (11-20) ◑ RARE (2-10) O ABUNDANT (GT 20) ●

TABLE 12

APPENDIX B

ACCESS TO SAMPLED LOCALITIES

PLAINS COREHOLES (Figure 15)

The three coreholes dated 1982, were the product of the Alberta Research Council, Coal Geology Group Drilling Program. These three cores are housed in their entirety at the Alberta Research Council, Mineral Core Research Facility in Edmonton, and are available for investigation. Cores are the property of the Alberta Research Council, Geological Survey, and all inquiries regarding these cores should be directed to this Group.

Each core is accompanied by a complete suite of geophysical logs. Upon describing these cores, depths were re-adjusted with respect to the geophysical logs, and therefore the palynology sample depths shown in Figure 15 may not precisely correspond to the sampled lithology. Accuracy has been emphasized with respect to depth of the sample rather than the lithology from which the sample was taken.

For the Wizard Lake core (65-1), neither the original core nor geophysical logs were available. Therefore Snead's (1969) original sample designations were retained, and the original litholog used.

PLAINS OUTCROP (Figure 25)

Hand Hills (LSD 1-21-30-17W4, Map Sheet 82 P/9, Elevation 3375 ft) (Plate 7)

The Hand Hills are an outlier of Paskapoo Formation immediately northeast of Drumheller. These hills are clearly visible to the east of Highway 56 on the way to Drumheller.

The exact location of the sampled section is north on the gravel road from Delia towards Hand Hills. Near the top, just before the television tower, a sharp left turn onto a hidden gravel road leads down the northwest side of Hand Hills. The section is on the west side of the road and is very easy to spot. The entire section is approximately 25 m thick. This is presumably the same location discussed by Fox (1987) with respect to fossil mammals.

Joffre Bridge (LSD 16-12-38-26W4, Map Sheet 83 A/5, Elevation 2750 ft) (Plate 9)

A fortuitous road exposure, provided for the International Organization of Paleobotany Conference in the Fall of 1984, allowed access to both the fossil leaf locality and strata equivalent to Erickson's Landing mammal site. This leaf horizon is presently under investigation by Ruth Stockey (Department of Botany, University of Alberta); however, the lower exposure (mammal horizon) is small.

This road exposure is on Highway 11 east from Red Deer toward the Joffre Bridge. The exposure is on the south side of the highway, approximately half a kilometer west of the bridge as the road begins to drop into the Red Deer River valley. The exact location of Erickson's Landing (Brown, 1914) is clearly visible just upstream of the bridge, on the north side of the river, directly north of this road exposure.

Delburne (LSD 4-3-38-26W4, Map Sheet 83 A/4, Elevation 3250 ft) (Plate 8)

This is a roadcut on secondary Highway 595 from Red Deer to Delburne, although the town of Delburne itself is 30 km east of this exposure. The road exposure is on the north side of the highway, approximately 11 km east of Red Deer. This is the only such exposure in the area, and is therefore very easily spotted. Unfortunately, the lithologies present in this exposure are very poor for palynology. On the basis of elevation, this locality should be much younger than Joffre Bridge, yet there is very little differentiation in the palynofloral assemblages.

Burbank (LSD 12-18-37-26W4, Map Sheet 83 A/5, Elevation 2725 ft) (Plate 11)

This outcrop is in the bank of the Red Deer River, approximately 0.5 km downstream from the confluence of the Blindman and Red Deer rivers. To access this locality, proceed south from Blackfalds, turning east on the road to Joffre and then south on the Burbank turnoff. A small, unmarked gravel road leads to a park/picnic area which allows easy access to the banks of the river.

Blindman (LSD 15-13-39-27W4, Map Sheet 83 A/5, Elevation 2750 ft) (Plate 12)

This fossil locality is approximately 1.0 km upstream from the Burbank site on the Blindman River, and may be accessed by the same route mentioned previously. The exposure is on the east bank of the Blindman River, on a meander loop near the mouth of the river. The train trestle is visible just upstream of this site.

Crestomere (LSD 16-26-42-28W4, Map Sheet 83A/2, Elevation 2952 ft) (Plate 10)

This site is approximately 1.0 km south of the "metropolis" of Crestomere, on secondary highway 792. Crestomere itself is located on Highway 53, 17 km west of Ponoka. This exposure is vegetated, however suitable strata are available for palynology. Due to the vegetation, this locality may be easily overlooked.

OBED-MARSH (Figures 16 and 26)

Access Corridor Exposures (Figure 26, Plate 14)

OM-0.6	LSD 5-24-53-24W5	Elevation 4330 ft
OM-1.6	LSD 14-13-53-24W5	Elevation 4350 ft
OM-1.7	LSD 10-13-53-24W5	Elevation 4350 ft
OM-2.5	LSD 2-13-53-24W5	Elevation 4100 ft

All exposures at Obed-Marsh are on property of the Obed Mountain Coal Company, a subsidiary of Unocal Limited. Permission must be obtained before investigating these sites.

The access corridor to the mine begins at Highway 16 (Yellowhead Highway), approximately 19 kilometers east of Hinton, at the Dalehurst campsite. The entrance to the mine is clearly marked at the highway. The corridor exposures are designated by their distance away from the mine offices (ie. OM-1.7, is approximately 1.7 kilometers down the access corridor from the mine offices). All four of these cuts expose strata on both sides of the access corridor, and three of the four descriptions are from exposures on the east side of the corridor (except OM-2.5). From the mine office, the access corridor goes down into the Athabasca River valley, and therefore strata exposed at OM-2.5 are likely to be older than those exposed at OM-0.6. However, the palynology does not illustrate this clearly.

Obed Mine Exposures (Figure 16, Plate 13)

ON-1	LSD 5-27-53-24W5	Elevation 4560 ft
ON-2	LSD 10-27-53-24W5	Elevation 4610 ft

These two exposures are from the highwall at the active minesite. The designation ON-1 refers to the Obed North Block, Obed No. 1 Seam, while ON-2 refers to Obed No. 2 Seam.

Obed Coreholes (Figure 16)

Obed 76-54 LSD 7-8-53-24W5

Obed 76-21 LSD 12-15-53-24W5

Both coreholes are from the original exploratory drilling program carried out by Unocal (then Union Oil Company of Canada) in 1976. These cores are housed at the Energy Resources Conservation Board, Core Research Facility in Calgary. Unfortunately, the coal seams were removed by Unocal in their preliminary coal characterization studies. However abundant carbonaceous strata above and below the coal seams were available for palynological sampling.

Plate 7. Hand Hills outcrop locality. Arrow pointing to Jacob's staff (1.5 m). View is to the northwest.

Plate 8. Delburne outcrop locality. Arrow pointing to Jacob's staff (1.5 m) (upper left-hand corner). View is to the north.

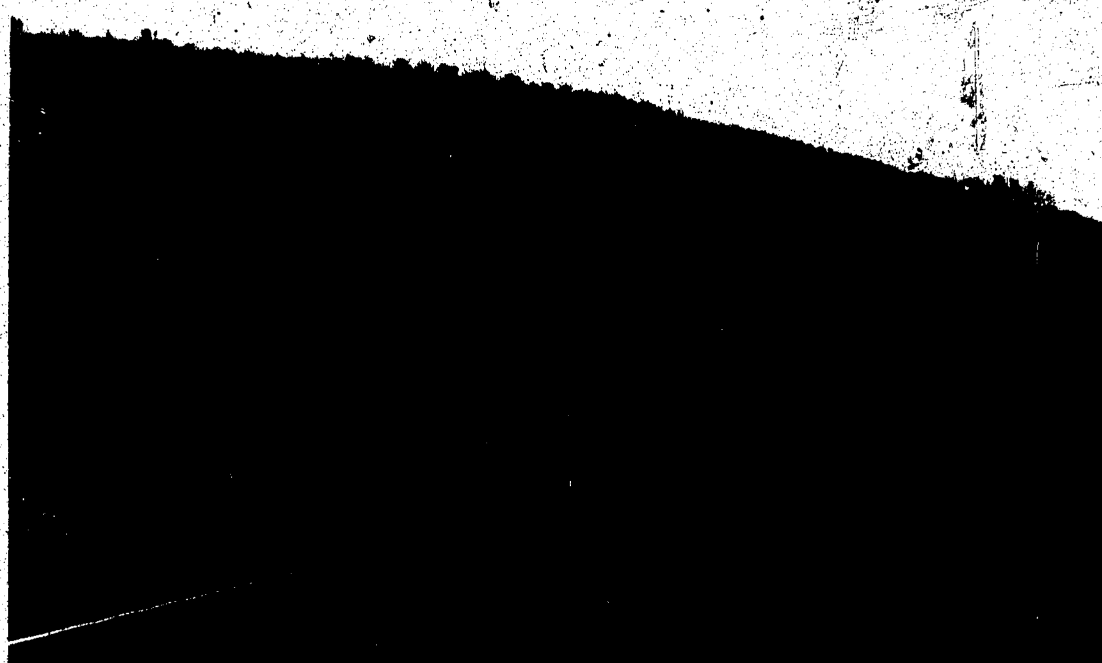


Plate 9. Joffre Bridge locality. Lower arrow points to approximate level of mammal fossils (equivalent to Erickson's Landing); upper arrow illustrates the level of the prolific fossil leaf-layer (Crane and Stockey, 1984) (looking west on Highway 11, immediately west of Joffre Bridge).

Plate 10. Crestomere outcrop locality. Arrow points to Jacob's staff (1.5 m) (upper left-hand corner). View is to the west.

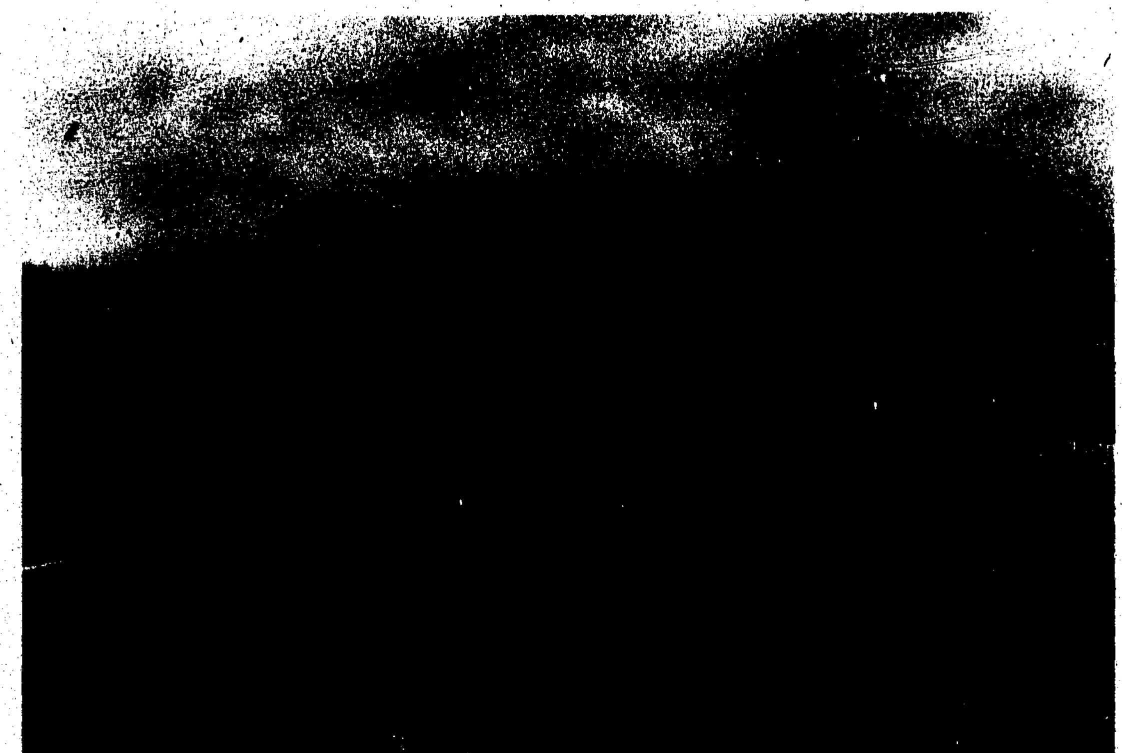


Plate 11. Burbank outcrop locality, on the Red Deer River. View is to the east, immediately downstream from the confluence with the Blindman River (no scale).

Plate 12. Blindman River outcrop locality. View is of the east bank of the Blindman River, immediately upstream from the confluence with the Red Deer River (no scale).

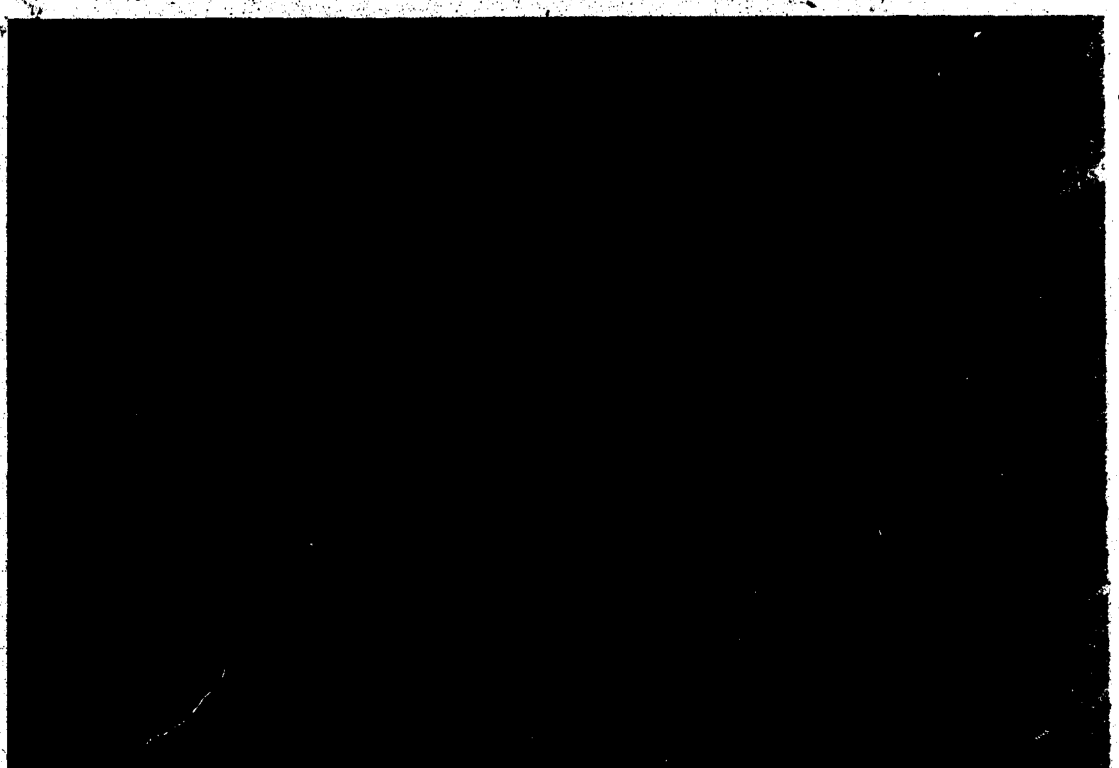
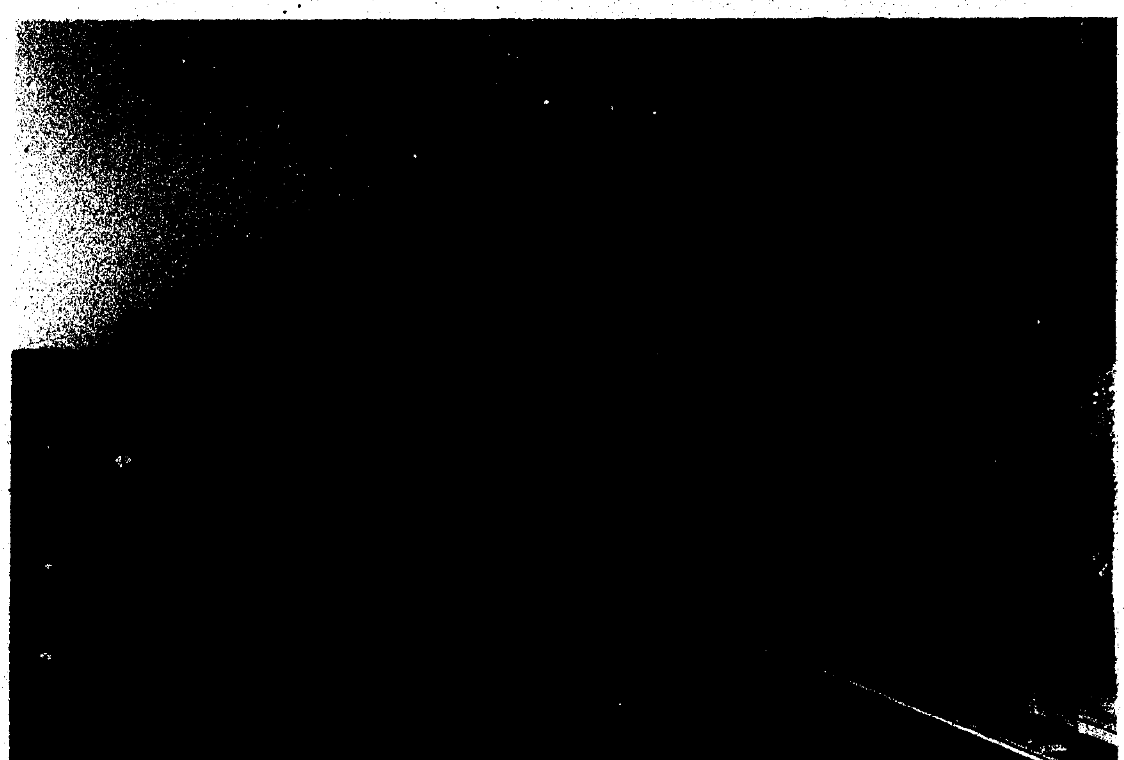


Plate 13. View of the open pit at the Obed-Marsh mine. Lowermost coal seam is the Obed No. 1 seam, with the Obed No. 2 seam evident at the top right of the photo. Interburden between the two seams is approximately 17 m (photo of mineface from Obed North pit).

Plate 14. Photo illustrating road cuts along the access corridor to the Obed-Marsh minesite. Exposure in the middle of the photo is section OM-1.7, with OM-1.6 evident further up the road (view is northwest, looking towards the minesite).



APPENDIX C

LABORATORY PROCEDURES, SLIDE EXAMINATION AND REPOSITORY

SAMPLE PREPARATION

The technique used in macerating the samples follows closely that used by Singh (1964). This procedure has been in use at the Palynology Laboratory of the Alberta Research Council since that time with minor, helpful modifications employed to enhance palynomorph recovery. A complete outline of the present procedure is given.

PREPARATION OF SHALE SAMPLES

Sample Lay-out: Crush 20 grams of sample. This allows a larger surface area for the hydrochloric acid to react upon. Place the sample in a labelled nalgene container.

Hydrochloric acid treatment of calcareous samples: This is to dissolve the carbonates in a calcareous sample. Dampen the sample with water. To dissolve the carbonates, slowly add concentrated hydrochloric acid to the sample. If the sample starts to overflow the container due to the reaction, add a few drops of alcohol to break the foam. Dilute sample with water if the reaction is too violent. The reaction is complete when the addition of more acid causes no effervescence.

Neutralize the sample. Wash with distilled water and centrifuge at 1500 rpm for 3 minutes to concentrate. Decant the water and repeat the procedure twice more.

Hydrofluoric acid treatment: This is to dissove the silicate bonds and release the organic matter. The sample is treated with concentrated hydrofluoric acid (49%) for a 24 hour period. Neutralize.

Hydrochloric acid treatment: This treatment is to dissolve the fluoride precipitates. Concentrated hydrochloric acid (38%) is added to the sample for 5 minutes. Neutralize.

Oxidation: This is to oxidize or transform the partially decomposed organic debris into alkali-soluble humic acids, thereby deleting unwanted organic matter and producing ultimately a palynomorph-rich residue. Schulze solution, a dilute mixture of nitric acid and potassium chlorate is used to oxidize the sample. Stir occasionally and check the sample for a color change (approximately 5 minutes). Neutralize.

Alkali treatment: To remove the unwanted organic matter (humic compounds), potassium carbonate (K2CO3-5%) is added to the sample for approximately 3 minutes. Sieve the sample with a 100 mesh sieve (149 micron) and pan. The sample remaining on the sieve is checked for megaspores, and the material passing through is collected and centrifuged.

Heavy liquid separation: A solution of zinc bromide with a specific gravity of 2.0 is used to separate the organic and mineral fractions of the sample. Pour one test tube of zinc bromide into the sample and bring the sediments into suspension. Divide the suspended residue into two test tubes and fill with zinc bromide. Centrifuge for at least 10 minutes. Allow test tubes to sit until a true separation is distinct between the float (organic) and mineral fraction. The middle of the test tube should be clear without any suspended material.

Scoop up the organic float fraction and wash with 10% hydrochloric acid. This is to prevent precipitates from forming in a reaction between the zinc bromide and distilled water. Neutralize.

Darvan #4: Darvan #4 is a low-sudsing soap that helps to disperse the fine particles in the sample. Short centrifuging keeps the fine debris in suspension and allows decanting of unwanted particles. Fill each test tube halfway with Darvan and fill the rest with water. Centrifuge for one minute at 1800 rpm. Decant the water and repeat the procedure until the supernatant liquid is clear. (This step is optional).

Staining: The spores and pollen are stained with Safranin-O for 10 minutes. Approximately 6 drops of stain are added to the residue. Neutralize.

Mounting: The sample is sieved with a micro-mesh sieve (10 microns) to obtain a final mount of selective particle size. Three drops of Elvanol are placed on a cover slip. The residue is gently mixed with the Elvanol and spread to the outer edges of the cover slip. The coverslip is dryed on a hot plate, inverted and placed on a clean labelled slide with Canada Balsam. The slide is dryed for approximately seven days in an oven (temperature at 65 degrees Celsius). A glycerine-phenol mixture is added to the residue vials for storage.

PREPARATION OF COAL SAMPLES

Sample lay-out: Crush 15 grams of sample into small pieces (1 mm in size). Place the sample into a labelled 600 milliliter beaker. Dampen with water.

Hydrofluoric acid treatment: If the sample contains a large amount of clastic material, the sample should be treated with hydrofluoric acid prior to oxidation. Hydrofluoric acid treatment should be carried out after the alkali treatment if the sample is a low ash coal. Neutralize.

Dry Schulze (oxidation): Add 15 grams of potassium chlorate and 150 milliliters of nitric acid to the sample. Test the sample for extent of oxidation by adding a few drops of 5% potassium carbonate to a few drops of sample. The sample will turn a dark color if it is completely oxidized (approximately 20 minutes). If oxidation is incomplete, no color change will be visible and the sample should remain in Schulze solution for a longer time.

After the sample has been oxidized, wash it through a 200 mesh (75 micron) phosphor-bronze sieve with water. It is difficult to wash by centrifuge in the presence of Schulze solution as internal reactions going on within the larger coal fragments cause the particles to float and make it difficult to decant the supernatant liquid. Discard the -75 micron fraction as most of the spores are not released from the larger coal fragments until treated with base. Wash the sample into a nalgene container with base (5% potassium carbonate). This is done as a standard procedure only if the sample has not been treated with hydrofluoric acid. If the sample has already been treated with hydrofluoric acid, sieving would differentially remove those spores released from the clastic fractions. In this case, centrifuge and save the float fraction.

Alkali treatment: Add 150 milliliters of 5% potassium carbonate to the sample. If the reaction is slow, heat the sample on a hot plate for 30 minutes. As a check for completion of reaction, wash the sample through a 100 mesh sieve (149 microns). Retain the minus fraction. If there is a large proprtion of sample remaining on the sieve that will not break down with further base treatment, heat the sample in a water bath with Schulze solution. Combine the plus and minus fractions, centrifuge the diluted sample and wash with water until the supernatant is clear. Treat the sample with hydrofluoric acid. Neutralize.

Sieving: Sieve the sample with a 100 mesh (149 micron) and pan. The sample remaining on the sieve is checked for megaspores and the material passing through is collected and centrifuged.

Staining: The residue is stained with Safranin-O and the slides are prepared.

PREPARATION OF CHEMICALS

Darvan #4: (a mono-calcium salt of polymerized alkyl-aryl sulfonic acid) Dissolve 12 grams of Darvan in 100 milliliters of distilled water.

Elvanol: (polyvinol alcohol) Dissolve the elvanol powder in distilled water. Boil until the liquid is clear (viscosity of the liquid will be thinner than glycerine). Filter with No. 1 Whatman filter paper.

Hydrochloric acid: (HCl 10%) Combine 10 milliliters of concentrated hydrochloric acid (38%) and 90 milliliters of distilled water to produce 100 milliliters of 10% hydrochloric acid.

Potassium Carbonate: (K2CO3 5%) Combine 200 grams of anhydrous potassium carbonate and 3800 milliliters of distilled water. Filter with No. 1 Whatman filter paper.

***Safranin-O*:** Combine 2.25 grams of Safranin-O powder, 225 milliliters of ethyl alcohol (95%) and 225 milliliters of distilled water. Filter with No 1 Whatman filter paper.

***Schulze solution*:** Combine 600 milliliters of concentrated nitric acid (70%), 300 milliliters of distilled water and 30 grams of potassium chlorate ($KClO_3$).

***Zinc Bromide*:** Combine 300 milliliters of distilled water and 566 milliliters of concentrated zinc bromide ($ZnBr_2$). The specific gravity should equal 2.0 (hydrometer reading). Filter (vacuum filter method) with No. 50 Whatman filter paper to remove the impurities and precipitates.

SLIDE EXAMINATION AND PHOTOGRAPHY

All slides were scanned using an Ernst Leitz Wetzlar microscope. Slides were examined at 40X power, and coordinates of identifed specimens given as horizontal/vertical (eg. 3.0 X 103.0) in order to be able to locate the specimens at a later date. In the scanning procedure, a complete horizontal scan of the slide was made, the slide moved vertically one complete field of view, and the horizontal scan repeated. Due to the abundant number of slides utilized for this study, only those species which were deemed stratigraphically important were identified and their coordinates recorded.

A specimen in excellent preservational mode was marked with a red felt tip marker immediately on the slide. That specimen was then photographed using a Carl Zeiss photomicroscope, under oil immersion with interference (phase) contrast. Said microscope is property of the Palynology Group, Alberta Research Council.

SLIDE LABELLING AND REPOSITORY

All slides used in this study are labelled with the author's name. In the case of the coreholes, following the author's name is the corehole designation (ie. CH-2-82) followed by the sample depth (eg. Demchuk, CH-2-82, 100.0 m). In the case of outcrop localities, the abbreviated name of the outcrop is given with the sample number (eg. Demchuk, BM-1-1). The exceptions are the samples from the Wizard Lake core, which bear the original designation given by Snead (1969) (eg. WL-31). In some cases, a sample has been micro-sieved. If this is so, the sieve fraction has been noted on the label of that slide (eg. Demchuk, CH-2-82, 100.0 m, 10-30 micron fraction).

All slides from this study are property of the Alberta Geological Survey, Alberta Research Council in Edmonton, Alberta. Under normal circumstances, the slides would be housed in the palynology slide repository of the Alberta Research Council, under the supervision of Dr. Chaitanya Singh. However, due to the recent retirement of Dr. Singh, and the premature break-up of the Palynology Group of the Alberta Research Council, the slides will remain in the possession of the author for future scientific reference.