GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 76-8

THE GEOLOGY OF THE BONNET PLUME BASIN, YUKON TERRITORY

D.K. NORRIS
W.S. HOPKINS JR.

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

1977

GEOLOGICAL SURVEY
PAPER 76-8

THE GEOLOGY OF THE BONNET PLUME BASIN, YUKON TERRITORY

D.K. NORRIS
W.S. HOPKINS JR.

1977

Printing and Publishing
Supply and Services Canada,
Ottawa, Canada K1A 0S9,

from the Geological Survey of Canada
601 Booth St., Ottawa, K1A 0E8

or through your bookseller.

Catalogue No. M44-76-8
ISBN - 0-660-00800-9

Price: Canada: $3.00
Other Countries: $3.60

Price subject to change without notice

CONTENTS

Illustrations

THE GEOLOGY OF THE BONNET PLUME BASIN, YUKON TERRITORY

Abstract

The Bonnet Plume Basin is a composite physiographic and structural depression of restricted areal extent within the Columbian Orogen of the Cordilleran Orogenic System of northern Yukon Territory. It rests asymmetrically on the western flank of the Richardson Anticlinorium. The nonmarine Cretaceous and Tertiary deposits of the basin, as a whole, were defined initially as the Bonnet Plume Formation. Additional data on the physical stratigraphy and biostratigraphy of these deposits, however, indicate that the formation can be divided into two mappable units, an upper sandstone, shale and lignite succession of Maastrichtian and Paleocene ages, and a lower conglomerate and sandstone succession of Middle or Late Albian age.

The Bonnet Plume Basin formed in response to kinematic activity on the assemblage of nearly vertical, north-trending, right-lateral, strike-slip faults extending from the Arctic Archipelago through the basin to the Mackenzie and Selwyn Fold Belts. Differential uplift of fault blocks in the core of the assemblage, in pre-Albian time, resulted in local stripping of the miogeoclinal-platform succession down to the oldest Precambrian rocks known in the region. A major reversal in this sense of motion, from the Albian through the mid-Tertiary, caused this structurally depressed core of the fault array to trap a thick sequence of successor deposits, initially at least as widespread as the width of the array but, ultimately, in the mid-Tertiary confined largely between two major strands of the fault system. There may be more than one billion tons of lignite in seams, having a thickness greater than 1.5 m, preserved at the northern extremity of the basin.

Résumé

Le bassin de Bonnet Plume est une dépression physiographique et structurale composite, d'une étendue régionale limitée, datant de l'orogenèse du Columbien et appartenant au système orogénique de la Cordillère, dans le nord du Yukon. Ce bassin repose assimétriquement sur le flanc ouest de l'anticlinorium Richardson. Les dépôts non marins du Crétacé et du Tertiaire de ce bassin ont d'abord été définis, dans leur ensemble, comme étant la formation de Bonnet Plume. Des données supplémentaires, relatives à la stratigraphie et à la biostratigraphie physiques des dépôts, indiquent toutefois que cette formation peut se diviser en deux unités distinctes du point de vue cartographique, à savoir une succession supérieure de grès, de schistes argileux et de lignite appartenant au Maastrichtien et au Paléocène et une succession de conglomérats et de grès de l'Albien moyen et supérieur.

Le bassin de Bonnet Plume résulte des mouvements qui ont affecté l'ensemble des failles fortement inclinées, orientées vers le nord, à décrochement dextre et de glissement directionnel; ces failles commencent à l'archipel Arctique, traversent le bassin et se rendent jusqu'aux zones plissées de Mackenzie et de Selwyn. Le soulèvement différentiel de blocs faillés, qui s'est produit avant l'Albien au coeur de l'ensemble, a provoqué l'affleurement local de la succession en plate-forme miogéosynclinale, jusqu'aux plus vieilles roches précambriennes connues dans cette région. Par ailleurs, la grande inversion du sens de ce mouvement, qui s'est produite de l'Albien jusqu'au milieu du Tertiaire, a fait que le noyau à structure abaissée du réseau de failles a emprisonné une épaisse succession de dépôts ultérieurs qui, à l'origine, égalait la largeur du réseau mais, qui, finalement, s'est réduite au milieu du Tertiaire à l'espace situé en grande partie entre deux ensembles principaux du système de failles. Il peut y avoir plus d'un milliard de tonnes de lignite dans les veines, dont l'épaisseur dépasse 1.5 m et qui sont conservées à l'extrémité nord du bassin.

THE GEOLOGY OF THE BONNET PLUME BASIN, YUKON TERRITORY

INTRODUCTION

The Bonnet Plume Basin is a structural depression of restricted areal extent within the Columbian Orogen of the Cordilleran Orogenic System of northern Yukon Territory. It rests asymmetrically on the western flank of Richardson Anticlinorium. The basin was formed in response to differential vertical displacements on a group of generally north-trending, nearly vertical faults in post-Paleocene time.

The two principal rivers traversing the structure are the north-flowing Wind and the Bonnet Plume. Both join the Peel River at the north boundary of the basin. Chappie and Margaret Lakes are located strategically for geological or other scientific base camps, the former lying between the Wind and the Bonnet Plume Rivers toward the north end of the basin, and the latter immediately east of Bonnet Plume River in the southeast corner of the basin. Chappie Lake is rather shallow and hence less suitable for float-equipped aircraft.

The basin is contained entirely within the Wind River map-area (106E) (Norris, 1975). Physiographically, it is bounded on the north by Peel River, on the east by the fault line scarp of Knorr Range, on the west by Wind River (approximately), and on the south by the Wernecke Mountains. It has an areal extent of 1800 km^2 (700 sq miles). Its surface is relatively featureless, ranging in elevation between 300 and 500 m (1000-1600 ft) above sea level, and it contains thick glacial drift deposits on lower Wind and Bonnet Plume Rivers and along the Peel between their mouths (Hughes, 1972, p. 3). At its maximum, the Laurentide ice sheet covered Bonnet Plume Basin in pre-Wisconsin or early Wisconsin time and, in the late Wisconsin, a glacial lake was impounded there because the Peel drainage course was blocked by the ice sheet (Hughes, *op. cit.*, p. 2, 3).

The stratigraphy of the relatively young deposits in the structure was studied by E.W. Mountjoy (1967) who first used the term Bonnet Plume Formation and provided documentation of the age of part of the succession. The basin region was visited by D. K. Norris in 1962 during the initial field phase of Operation Porcupine and the general form of its structure was indicated on the preliminary, regional compilation of the project area (Norris *et al.*, 1963). Norris, in succeeding years, augmented both the structural and stratigraphic control on the basin in the preparation of final maps on a scale of 1:250 000 for the whole of the project area. Some of these are now on open file (*see* Norris, 1975).

The purpose of this paper is to present these additional structural and stratigraphic data for the Bonnet Plume Basin. The paper is a progress report. It relies on the accompanying geological map and structure section and is necessarily subject to refinement in the light of new data.

Manuscript received: December 19, 1975
Authors' address: Institute of Sedimentary and Petroleum Geology
3303 - 33rd Street N.W.
Calgary, Alberta T2L 2A7

ACKNOWLEDGMENTS

The writers are indebted to A. W. Norris, R. A. Price and G. C. Taylor for the use of unpublished field data acquired by them during the initial phase of the Operation Porcupine project. L. D. Dyke provided basic stratigraphic control for the Precambrian rocks of the region. H. R. Balkwill and G.H. Eisbacher kindly read the manuscript and offered valuable comments.

HISTORY OF EARLY EXPLORATION

As far as the writers are aware, the first published report of a survey of the Bonnet Plume Basin was that of Edouard de Sainville who, in the account of his travels to the mouth of the Mackenzie River (de Sainville, 1898), briefly outlined his trip up the Peel River. He stated that he ascended the river to Latitude 65°33'N, but the longitude given (133°57'W) falls between the Snake and the Bonnet Plume Rivers. The fact that he observed in several places a bed of lignite 2 to 5 m (6.5-16.4 ft) thick and that his trip was "un des voyages les plus perilleux que j'aie jamais entrepris" (de Sainville, *op. cit.*, p. 302) would suggest that he encountered the turbulent waters of the lower canyon of the Peel and that he ascended the Bonnet Plume (rather than the Snake) to a point about opposite the north flank of Knorr Range. Indeed, the native population, long before his visit, were in the habit of leaving their canoes at the mouth of Trail River and walking across country to intersect the Peel at Mountain Creek in order to avoid the whirlpools of the lower canyon (Camsell, 1906, p. 30cc).

According to Camsell (*op. cit.*, p. 10cc), de Sainville made an earlier trip up the Peel in the summer of 1893. On that occasion he left his canoe at the mouth of the Bonnet Plume, walked about 40 km (25 miles) up this river, crossed the basin to the Wind River which he descended to its junction with the Peel, and returned to his canoe. He reported the occurrence of hot springs at the mouth of Bonnet Plume River and the existence of burning lignite beds along the Peel between the Wind and the Bonnet Plume Rivers.

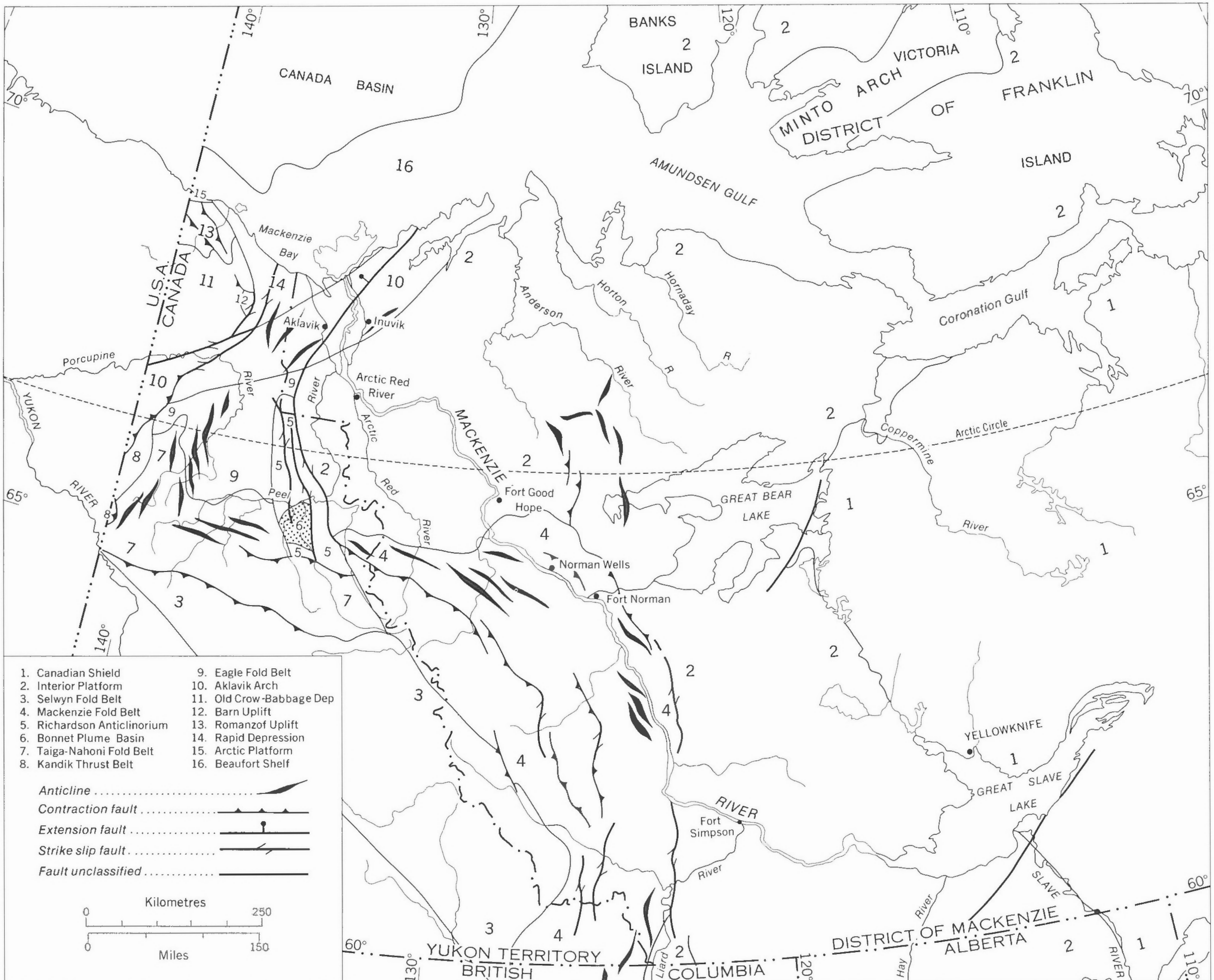

FIGURE 1. Index map of the northern Cordillera and Interior Platform of Canada, showing the Bonnet Plume Basin in relation to the other tectonic elements

Five years later, in 1898, about ninety persons on their way to the goldfields of the Klondike wintered on the Wind River a few miles upstream from its mouth. Their cluster of cabins, which they named "Wind City", was reported by Camsell (idem) still to be standing in 1905, although Stelck (1944) noted that they had totally disappeared by 1943. Some of these prospectors are said (Camsell, *op. cit.*, p. 20cc) to have explored Hungry Creek, a major tributary of the Wind River from the west, during the autumn and winter of 1898.

Camsell crossed the Wernecke Mountains to Peel River via Braine Pass and Wind River in 1905 and has given a detailed account of his explorations (Camsell, 1906). To the writers' knowledge, he was the first to make specific reference to the Bonnet Plume Basin as a "basin" (Camsell, *op. cit.*, p. 24cc) and to refer the clastic rocks overlying the Paleozoic limestone of Illtyd Range to the Cretaceous System "From their lithological resemblance to Cretaceous rocks in other parts of the North-west" (Camsell, *op. cit.*, p. 26cc).

The first meaningful geological maps and a structure section of part of the Bonnet Plume Basin were made by C. R. Stelck when he was under assignment to the Canol Project (Stelck, 1944). In poor weather and under extremely hazardous river conditions, he traversed from Hungry Lake to the mouth of Trail River via Hungry Creek and the Wind and Peel Rivers; it is a monument to his pioneering and scientific expertise that he and his two assistants survived. In spite of the conditions, he produced a geological interpretation of the region that is the basis of all further studies, and it was Stelck (*op. cit.*, p. 7) who gave the name Bonnet Plume Basin to the structural depression between the Peel and Bonnet Plume Rivers.

REGIONAL GEOLOGICAL SETTING

INTRODUCTION

The modern Bonnet Plume Basin is a composite physiographic and structural depression in the Cordilleran Orogenic System of northern Canada. It lies near the eastern margin of the Foreland Thrust and Fold Belt of the Columbian Orogen and occupies a structural depression near the southern limit of Richardson Anticlinorium (Fig. 1). To the west and south lies the Taiga-Nahoni Fold Belt and, to the north and east, the Richardson Anticlinorium. By the writers' definition, it is bounded by Knorr Fault on the east, by Lower Cretaceous (Albian) clastic strata on the south and southwest, by Deslauriers Fault on the west, and by lower Paleozoic clastic rocks in the core of Richardson Anticlinorium on the north (*see* Fig. 2).

The Cretaceous and Tertiary successor deposits of the basin overlie deformed Proterozoic to Permian strata of the eastward-tapering, miogeoclinal-platform infrawedge. A few basic sills and dikes intrude the latter in Mackenzie and Wernecke Mountains.

The Proterozoic section in the environs of the Bonnet Plume Basin can be divided into two discrete lithostratigraphic assemblages, the one containing Helikian and possibly Aphebian rocks, and the other Hadrynian. The assemblages are separated and bounded above by regional unconformities (*see* Fig. 2, Legend). The lower contact of the Helikian and older succession, on the other hand, is not exposed.

The phyllitic argillites and quartzites (Ho) at the base of the stratigraphic succession are exposed extensively beyond the southern extremity of the Bonnet Plume Basin on both sides of the Bonnet Plume River. Commonly, they are intensely cleaved and, at least locally, are of lower greenschist facies. Quartz-chloritoid-mica-schist comprises the bulk of the pyramidal-shaped mountain immediately east of Quartet Lakes (*see* Norris, 1975). The schist is overlain, with spectacular unconformity, by Lower, Middle and Upper Cambrian clastic and carbonate rocks in Wernecke Mountains 10 to 20 km (6-12 miles) south of the basin. Across Knorr Fault these clastic and carbonate rocks are in contact with Helikian carbonate and clastic strata which are, in turn, overlain by presumed distal equivalents of part of the Hadrynian Rapitan Formation (Fig. 2).

Immediately west of the Bonnet Plume River near Margaret Lake, a pebble, cobble and boulder diamictite (Hrl), composed of quartzite and chert, and estimated to be 3500 m (11 000 ft) thick, intervenes between the phyllite and the Lower Cambrian carbonate and clastic strata (Ꞓl). It is assigned to the Rapitan Formation (Ziegler, 1969, p. 83) and, as far as is known, represents the northwesternmost occurrence of the lower part of the formation in the Columbian Orogen.

On the east flank of Knorr Range as well as on the north flank of the Bonnet Plume Basin, rocks younger than Early Cambrian are dominated by clastics which contrast markedly with the thick, coeval carbonate banks (ꞒDb) of the Wind River-Royal Creek area. Clearly the Bonnet Plume Basin and the Knorr Range lie in the southward extension of the Road River Trough (Lenz, 1972, p. 329, 330).

Between Knorr Range and Peel River, the lower and middle Paleozoic succession is overlain by Upper Devonian and Mississippian clastic strata. Opposite these, on the west flank of the basin, clastic and carbonate rocks as young as Middle Permian occur in the vicinity of lower Hungry Creek. Near Lake Deception, these younger strata are in fault contact with Upper Devonian and older Paleozoic clastic strata which form the upper canyon of the Peel River and flank the Bonnet Plume Basin on the north.

The Paleozoic and older rocks are blanketed widely by chert and quartzite pebble-conglomerate and sandstone (lKbp) of late Early Cretaceous (Albian) age on the south and west sides of the basin. Northwest-trending, nearly vertical faults extend downward through the coarse Albian clastic rocks into the underlying succession and divide the region into a number of discrete, elongate blocks. Thus, down-dropped segments of the Albian clastic blanket occur between and on both sides of the horsts comprising the lower Paleozoic rocks of Illtyd Range, as well as in the structurally depressed, eastern flank of the Knorr Range fault block. These clastic strata, along with the overlying sandstone, shale and lignite beds, comprise the Bonnet Plume Formation. Apart from the Quaternary sediments, they are the youngest deposits in the basin.

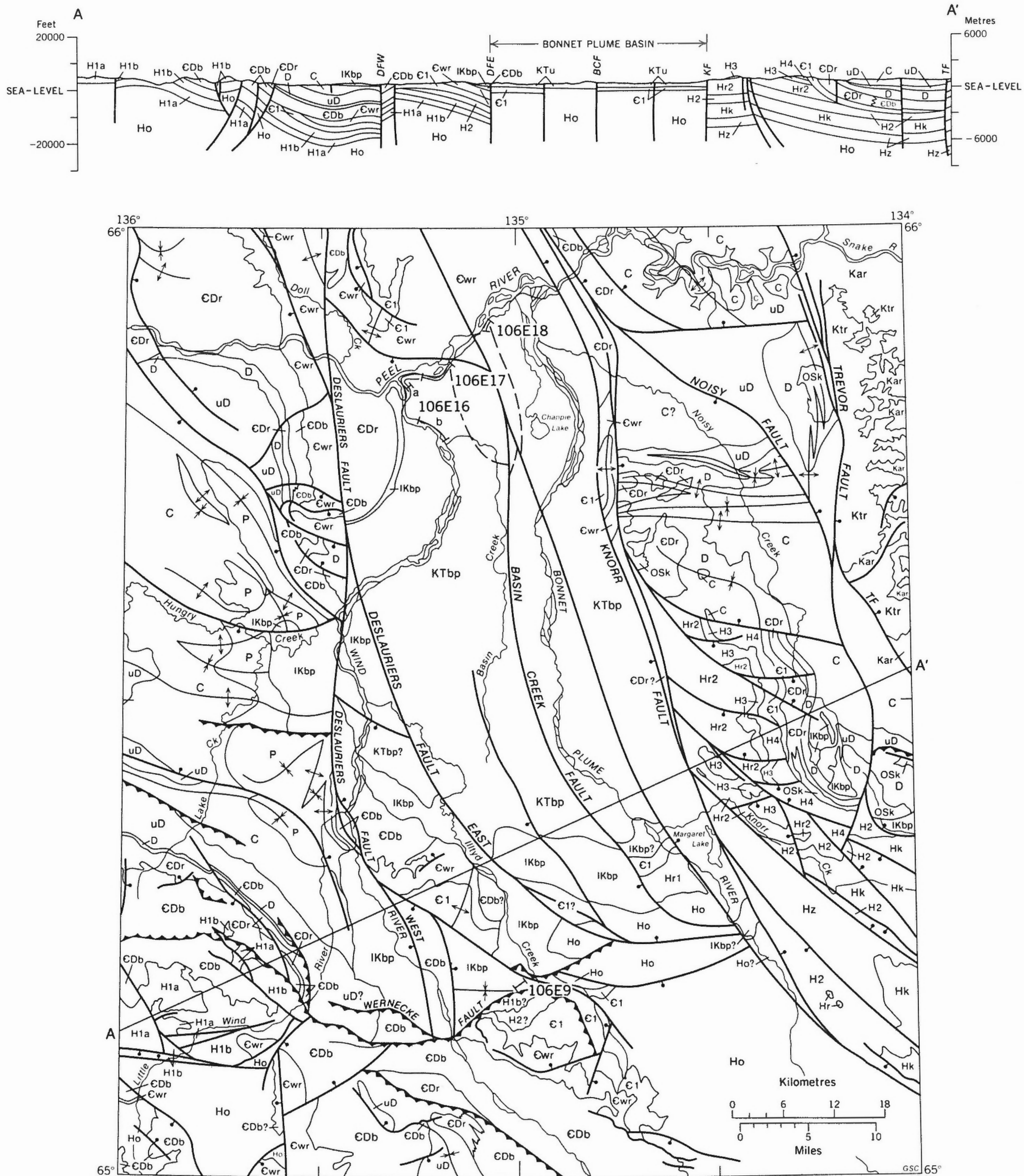

FIGURE 2. Geological map and structure section of the Wind River map-area (106E), Yukon Territory. Dashed line outlines area presumed to be underlain by commercially important lignite seams south of Peel River. Geology after Norris (1975)

LEGEND

MESOZOIC

CRETACEOUS AND TERTIARY

UPPER CRETACEOUS AND LOWER TERTIARY

- **KTbp** — *BONNET PLUME FORMATION (Upper part)* sandstone, shale, conglomerate, lignite

LOWER CRETACEOUS TO LOWER TERTIARY

- **KTu** — *BONNET PLUME FORMATION (undivided)* (Structure Section only)

CRETACEOUS

LOWER CRETACEOUS

- **lKbp** — *BONNET PLUME FORMATION (Lower part):* sandstone, conglomerate, shale

CRETACEOUS

LOWER AND UPPER(?) CRETACEOUS

- **Ktr / Kar** — *TREVOR FORMATION:* sandstone; *ARCTIC RED FORMATION:* shale, siltstone

PALEOZOIC

PERMIAN

LOWER AND MIDDLE PERMIAN

- **P** — Unnamed sandstone, siltstone

UNCONFORMITY

CARBONIFEROUS

LOWER AND UPPER CARBONIFEROUS

- **C** — *HART RIVER AND ETTRAIN FORMATIONS:* shale, limestone

DEVONIAN

UPPER DEVONIAN

- **uD** — *CANOL AND IMPERIAL FORMATIONS* and unnamed shale, sandstone

DISCONFORMITY

SILURIAN AND DEVONIAN

UPPER SILURIAN, LOWER AND MIDDLE DEVONIAN

- **SDu** — *DELORME, ARNICA, CRANSWICK and HUME FORMATIONS* and unnamed shale

DISCONFORMITY

ORDOVICIAN AND SILURIAN

UPPER ORDOVICIAN AND LOWER SILURIAN

- **OSk** — *MOUNT KINDLE FORMATION:* dolomite, chert

CAMBRIAN TO DEVONIAN

UPPER CAMBRIAN TO LOWER DEVONIAN

- **ЄDb** — Unnamed dolomite, limestone
- **ЄDr** — *ROAD RIVER FORMATION:* shale, chert, limestone

DISCONFORMITY

CAMBRIAN

MIDDLE CAMBRIAN

- **Єwr** — Unnamed dolomite, sandstone conglomerate

LOWER CAMBRIAN

- **Є1** — Unnamed dolomite, sandstone, bioherms

ANGULAR UNCONFORMITY

PROTEROZOIC

HADRYNIAN

- **H4** — Unnamed dolomite, limestone, shale
- **H3** — Unnamed dolomite, shale
- **Hr** — *RAPITAN FORMATION:* Hr1, diamictite; Hr2, mudstone, dolomite

HELIKIAN

- **H2** — Unnamed dolomite, shale, gypsum
- **Hk** — *KATHERINE FORMATION:* quartzite, shale
- **Hz** — *TSEZOTENE FORMATION:* quartzite, shale, basic sills

HELIKIAN

- **H1b** — Unnamed orange dolomite, shale
- **H1a** — Unnamed grey and orange dolomite

UNCONFORMITY ?

HELIKIAN AND APHEBIAN?

- **Ho** — Unnamed argillite, quartzite (base not seen)

Geological contact (approximate)

Fault (solid circle indicates downthrow side)

Fault (undifferentiated)

Thrust fault

Anticline

Syncline

Line of section A A'

Stratigraphic section 106E17

Presumed outer limit of coal seams

GSC

FIGURE 2. Continued

BONNET PLUME FORMATION

The name Bonnet Plume Formation was proposed "for the thick succession of poorly consolidated sediments which unconformably overlie Permian and older rocks of the southern Richardson Mountains" (Mountjoy, 1967, p. 11). According to Mountjoy (*op. cit.*, p. 12), these sediments are exposed best along the east side of the Wind River between its mouth and Basin Creek and along the south side of Peel River between the mouth of Wind River and Mountain Creek. His partial sections are located on Figure 2 and identified as 106E16a and b, 106E17 and 106E18 in this paper. The first two correspond to Mountjoy's Section 5 (type section; *see* Fig. 3), the second to his Section 6, and the third to his Section 7.

According to Mountjoy (*op. cit.*, p. 12), the Bonnet Plume Formation consists predominantly of sandstone which is medium to coarse grained, cross-bedded, with thin lenses and layers of fine pebble-conglomerate. Lignite beds are much more abundant in the upper part of the formation. Quartz and chert pebble-conglomerate, more than 180 m (600 ft) thick, occur at the base of Section 106E16a, 1.5 km (1 mile) above the mouth of Wind River on the right bank. There, the conglomerate rests with a local relief of 15 m (50 ft) on upturned shale of the early and middle Paleozoic Road River Formation. The angular unconformity separating the Bonnet Plume and Road River Formations, first reported by Camsell (1906, p. 28cc), is equally well exposed on the left bank (Fig. 4).

Mountjoy (*op. cit.*, p. 11) stated that the type Bonnet Plume Formation is more than 1500 m (5000 ft) thick, allowing for uncertainties in thickness beneath covered intervals along lower Wind River. In a second section (106E17), he measured more than 1200 m (4000 ft) of Bonnet Plume Formation and, although he did not attempt to correlate beds between the two sections, it is presumed that they represent equivalent stratigraphic intervals because they both begin at the unconformity with underlying Paleozoic rocks.

A true thickness of 1200 m (4000 ft) of Bonnet Plume Formation on the south bank of the Peel in Section 106E17 requires that the unconformity with the underlying Road River Formation be present at a

FIGURE 3. Upper Bonnet Plume Formation (KTbp) on the right bank of lower Wind River (Sec. 106E16b) overlain with angular unconformity by glaciofluvial and glaciolacustrine deposits (Qgf). View is to the northeast. GSC 199156

vertical depth of about 1190 m (3900 ft), for an average dip of 15 degrees for the section. Because the Road River Formation is exposed extensively opposite the section on the north side of the river at approximately the same topographic level, a major east-trending fault, downthrown to the south, is required beneath the river bed in order to juxtapose the two sections. The structural geometry of the bedrock surrounding the northern end of the Bonnet Plume Basin, however, militates against this, and the authors question the validity of these published thicknesses of the Bonnet Plume Formation. If the 15-degree inclination of the strata in the Bonnet Plume Formation was the initial dip of foreset beds, Mountjoy's measurements would appear to represent an apparent thickness in the direction perpendicular to these foresets. The true thickness of the Bonnet Plume Formation, therefore, would be considerably less, perhaps of the order of only a few hundred metres.

Mountjoy (*op. cit.*, p. 59) suggested, moreover, that the lignite seams at the top of Section 106E18 opposite the mouth of Mountain Creek (in the vicinity of the burning lignite locality reported by de Sainville) probably correspond to those in the upper part of Section 106E17; hence the youngest beds of the Bonnet Plume Formation occur in both sections along the Peel. Samples of spores and pollen collected by Mountjoy 500 m (1600 ft) below the top of the type section, as well as those from the topmost bed of Section 106E17, are late Late Cretaceous (Campanian-Danian) or Paleocene in age according to G. E. Rouse (*in* Mountjoy, *op. cit.*, p. 47, 51).

Rouse later resampled Mountjoy's sections for palynological purposes. With Srivastava (Rouse and Srivastava, 1972), he presented an interpretive reconstruction of the Bonnet Plume Formation in the northern part of the basin and provided improved data on the ages of the succession. They confirmed Mountjoy's suggestion of the equivalence of the upper parts of Sections 106E17 and 106E18 and identified three well-defined palynomorph assemblages in the Bonnet Plume Formation. The lowest assemblage was considered to be mid-Late Albian and the middle to be Maastrichtian in age; the uppermost they interpreted as Paleocene. Therefore, a hiatus of approximately 35 m.y., or about one-half the length of the Tertiary Period, and unknown to Mountjoy at the time of his investigations, appears to be present within the Bonnet Plume Formation.

SUBDIVISIONS OF THE BONNET PLUME FORMATION

The Bonnet Plume Formation can be divided into two mappable units, termed informally, the lower and upper Bonnet Plume Formation. The lower unit comprises relatively resistant, conglomeratic beds (lKbp) and embodies Units 1 to 6 in Mountjoy's type section (106E16) on Wind River (Mountjoy, 1967, p. 49-50). It rests with angular unconformity on several Paleozoic formations (*see* Fig. 2) and corresponds to Rouse and Srivastava's Zone 1. It is Middle to Late Albian in age. The upper Bonnet Plume Formation is a succession of sandstone, shale and lignite (KTbp) embracing Units 7 to 58 of Mountjoy (*op. cit.*, p. 43-49) and Zones 2 and 3 of Rouse and Srivastava (1972). It is considered to be Maastrichtian to Paleocene in age (Rouse and Srivastava, *op cit.*, p. 1165-1169) and is, therefore, distinctly younger than the lower part.

Both the lower and upper Bonnet Plume Formation commonly strike northward parallel to the long dimension of the Bonnet Plume Basin and, along Peel River, dip inward to a maximum of 15 degrees. Rarely, as on Wind River immediately west of the Illtyd Range, the formation strikes almost due east and dips more than 45 degrees. No exposure of an unconformity between the two units is known, but the contact is presumed to be disconformable. Where the two occur together in normal stratigraphic succession they appear to have approximately the same attitude.

In the course of structural and stratigraphic studies in the Wind River map-area, Norris (1975), with the assistance of A. Hedinger and A. Johnson, examined the lower Bonnet Plume Formation (Appendix 1) on the north flank of Wernecke Mountains between Illtyd Creek and Wind River (Sec. 106E9; *see* Fig. 2). The conglomerate, shale and sandstone sequence there is equivalent to the lower part of the type section of the Bonnet Plume Formation (Sec. 106E16a). Because it is overridden from the south by Proterozoic and Cambrian rocks along the east-trending Wernecke Fault (WF) and is depressed to the north against Lower Cambrian carbonate and clastic strata along a major southeast-trending splay of Deslauriers Fault, its measured thickness of 677 m (2200 ft) is a minimum. The thickness is, however, more than three times that observed by Mountjoy in Section 106E16a in the northwest corner of the basin.

The phenoclasts in Section 106E9 are, in decreasing order of abundance, black chert, white and light grey quartzite, and grey and green chert. They range up to 20 cm in maximum observed dimension, are commonly subangular to subrounded, poorly sorted and poorly cemented to the matrix. The apparent absence of limestone, dolomite, iron-formation and igneous pebbles, and the dominance of resistant lithologies suggest that the bulk of the clasts may have been derived from older conglomerates such as those of the Middle Cambrian (*see* Fig. 2, Legend). More significantly, it seems unlikely that the iron-bearing Rapitan Formation, as well as still older Precambrian units which served as hosts to basic igneous intrusions, were exposed extensively to erosion in the surrounding uplands in the late Early Cretaceous.

The sandstone units in Section 106E9 are composed, characteristically, of chert, quartz and quartzite fragments, are variably conglomeratic, and contain sequences which become finer upward. Although covered on the higher ground between Illtyd Creek and Wind River, mudstone and carbonaceous shale interbeds, up to 10 m (30 ft) thick are exposed in the lower part of the section along Illtyd Creek.

Three precisely located samples from Units 9, 13 and 14 of the described section were collected between 275 and 325 m (900 and 1060 ft) above the base; these included both carbonaceous shale and mudstone. The samples were macerated and examined by Hopkins, who found that the microflora was comparatively small, both in number of species and

FIGURE 4. Angular unconformity between the lower Bonnet Plume Formation (lKbp) and the Road River Formation (ЄDr) on the left bank of lower Wind River. View is to the northwest. GSC 199157

individuals, and that preservation was rather indifferent. Recovered pollen and spores were essentially the same for all three samples. No phytoplankton were found.

Generally, the microflora is dominated by two species of the aquatic moss family Sphagnaceae. One species of Lycopodiaceae is present, but in very small numbers. Ferns (Pterophyta) are well represented by eleven species. Seed ferns (Caytonaceae) are present as indicated by the spore form-genus *Vitreisporites*. The Taxodiaceae are common, but the Pinaceae, as represented by the bisaccate conifer pollen, are not especially abundant. *Classopollis* pollen is present, but rare. The angiosperms are represented by at least two species but, although present in all samples, are not common. The identified microflora is included in Table 1 and listed according to presumed botanical affinity in Appendix 2.

On the basis of overlapping ranges of certain pollen forms, as well as on the total appearance of the microflora, it is concluded that the beds sampled are of Middle or Late Albian age, probably the latter. Undoubted *Glyptostrobus*, either as megafossils or pollen, has not been found in pre-Albian rocks. *Perinopollenites* sp., a probable representative of the Taxodiaceae, has not been reported in rocks younger than Cenomanian. Furthermore, the presence of two tricolpate pollen species indicates an age of Middle Albian or younger. However, tricolporate or triporate angiosperm pollen grains characteristic of the Cenomanian or younger are absent.

A fourth sample, collected from a coaly stringer in an unmeasured, steeply dipping sandstone, carbonaceous shale and conglomerate section 16 km (10 miles) north-northwest of Section 106E9 along the east bank of Wind River (GSC loc. C-9890), contained the most diverse microflora (*see* Table 1) and supported the conclusion that these sections are Middle or Late Albian in age.

The results of these recent palynological studies, therefore, confirm the conclusion of Rouse and Srivastava (1972) that the lower part of the Bonnet Plume Formation is Albian in age. Moreover, a major hiatus appears to separate the lower, conglomeratic unit from the higher sandstone, shale and lignite succession.

The initial areal extent of the lower Bonnet Plume Formation probably was much greater than that of the restricted Bonnet Plume Formation. In addition to the occurrences on lower Wind River, there are tectonically isolated segments of the unit on the north flank of Wernecke Mountains, on the east flank of Knorr Range at the headwaters of Noisy Creek, and in the lower Hungry Creek area adjacent to Deslauriers Fault (*see* Fig. 2, geological map).

Sequences within the unit which, upward become progressively finer grained, include stringers of coal and beds of shale, containing spores of the aquatic moss family Sphagnaceae, pollen of the family Taxodiaceae, and spores of moisture-loving ferns; this suggests a piedmont, fluviatile environment of deposition, with bogs or swamps in the low-lying areas. The general appearance of the microflora indicates, moreover, a humid, warm-temperate to subtropical climate in which the temperature rarely, if ever, fell to the freezing point. This is consistent fully with the mid-Cretaceous climatic interpretations from other nearby areas.

The paleoecological interpretation by Rouse and Srivastava (*op. cit.*, p. 1173) of rocks included in the upper Bonnet Plume Formation, moreover, indicates cooler and possibly wetter conditions developing at the close of the Maastrichtian and the beginning of the Paleocene. They based their conclusions on the marked increase in the pollen of coniferous trees which, together with those of certain angiosperms and the disappearance of pollen genera, are believed to indicate conditions close to subtropical.

The varied assemblages of clastic rocks ranging from boulder conglomerates to shales and mudstones, suggest localized, rapid piedmont deposition from high-gradient, alluvial systems for the Bonnet Plume Formation. They are successor deposits consisting of fine to coarse debris derived from uplifted, older, deformed rocks and laid down, in some places with spectacular unconformity, in restricted, structurally depressed areas.

STRUCTURAL GEOMETRY AND TECTONIC EVOLUTION

The Bonnet Plume Basin lies toward the southern extremity of the Richardson Anticlinorium. It is a structural and physiographic depression because of repeated movements on various components of the array of faults which extend the length of the anticlinorium (*see* Fig. 5). The greater areal extent of the lower part of the Bonnet Plume Formation, compared with that of the upper part (Fig. 6), indicates, in addition, that the Bonnet Plume Basin originated in two main stages. Because the initial (Albian) downwarp was considerably broader than the later (Maastrichtian and Paleocene) basin, it will be referred to as the Ancestral Bonnet Plume Basin.

The outline of the Ancestral Bonnet Plume Basin shown in Figure 6 is based on the assumption that its eastern flank may have been controlled, at least partly, by faulting and that the periphery on the other flanks was at least that of the present, mappable limits of the lower Bonnet Plume Formation. Moreover, the presence of erosional remnants of this unit east of Knorr Range suggests that the larger Ancestral Bonnet Plume Basin may have been situated more or less symmetrically with respect to the long axis of the Richardson Anticlinorium. The estimated outline of the basin indicated in Figure 6 delimits an area of approximately 4000 km^2 (1600 sq miles).

Within the limits of the Ancestral Bonnet Plume Basin, an elongate, structurally positive feature "more or less coincident with the present Knorr Range and its southern extension into the Wernecke Mountains...was emergent from at least Early Ordovician to early Siegenian...and again from the Late Emsian to Givetian" (Lenz, 1972, p. 328). The feature was named the Bonnet Plume High by Lenz (*idem*). More recent field work, however, resulted in the discovery by W. H. Fritz (pers. com., 1973) of graptolites in shale and chert on the east flank of Knorr Range of Middle Ordovician to Early Silurian

TABLE 1

Palynomorph distribution in discussed samples

X = palynomorph present in sample

Age: Albian Prep. Number: 950-1 GSC Loc.: C-9890 Sample Location: 65°15.5'N, 135°18'W	Age: Albian Prep. Number: 928-16 GSC Loc.: C-27178 Sample Location: 65°12.3'N, 134°58'W	Age: Albian Prep. Number: 928-15 GSC Loc.: C-27177 Sample Location: 65°12.3'N, 134°58'W	Age: Albian Prep. Number: 928-14 GSC Loc.: C-27176 Sample Location: 65°12.3'N, 134°58'W	TAXON
X	X		X	*Pleuricellaesporites psilatus*
X	X	X	X	*Sphagnum antiquasporites*
X	X	X	X	*Cingutriletes* cf. *C. clavus*
X				*Aequitriradites spinulosus*
X			X	*Sestrosporites pseudoalveolatus*
X				*Lycopodiacidites caperatus*
X				*Lycopodium* sp.
X	X			*Osmundacidites wellmanii*
	X			*Todisporites* cf. *T. minor*
X	X			*Baculatisporites comaumensis*
			X	*Appendicisporites* sp.
X	X		X	*Cicatricosisporites* spp.
X	X		X	*Gleicheniidites senonicus*
X	X	X	X	*Laevigatosporites* sp.
			X	warty monolete spore
			X	reticulate monolete spore
X			X	*Cyathidites australis*
	X			*Dictyophyllidites* sp.
X	X			*Deltoidospora* sp.
X				*Leptolepidites* sp.
X	X		X	*Vitreisporites pallidus*
		X		*Monosulcites* sp.
	X			*Cycadopites* sp.
	X		X	*Phyllocladidites* sp.
			X	*Tsugaepollenites* sp.
X	X	X	X	bisaccate conifer pollen
X	X		X	*Glyptostrobus* sp.
X	X		X	*Sequoiapollenites* sp.
X	X			*Perinopollenites elatoides*
X	X	X	X	*Inaperturopollenites* sp.
X	X			*Classopollis torosus*
X		X		*Retitricolpites* cf. *R. virgeus*
X	X	X		*Cupuliferoidaepollenites minutus*

age (B. S. Norford, pers. com., 1973). Thus, the feature was inundated for a longer part of the early Paleozoic than was originally surmised, and it is suggested that the Bonnet Plume High was just one of several intermittently positive, fault-bounded masses within southern Richardson Anticlinorium. The mosaic of both the intertonguing and laterally contiguous Road River Formation and unnamed carbonate banks suggests that a structurally controlled, variably shallow and deep seaway persisted intermittently in the position of the Bonnet Plume Basin during the early Paleozoic. This seaway connected the Richardson Trough with the Selwyn Basin.

The second phase Bonnet Plume Basin, defined by the areal extend of the Maastrichtian and Paleocene part of the Bonnet Plume Formation, is limited on the east by Knorr Fault (Figs. 5, 7), on the south and west by the contact with the lower Bonnet Plume Formation and the eastern strand of the Deslauriers Fault, and on the north by outcrops of the Road River Formation and the Peel River. Its present area, also a minimum estimate, is approximately 1800 km^2 (700 sq miles) or about one-half of that of the ancestral basin.

Ho - Helikian and Aphebian? argillites and quartzites

H - undifferentiated Hadrynian strata

Hrl - Rapitan diamictites

€Dr? - questionable Road River Formation

KTbp - Bonnet Plume Formation

BCF - Basin Creek Fault

KF - Knorr Fault

BPR - Bonnet Plume River

Figure 5. The structural style of Knorr Range and southeastern Bonnet Plume Basin. View is to the south. N.A.P.L. oblique photo T4-96R.

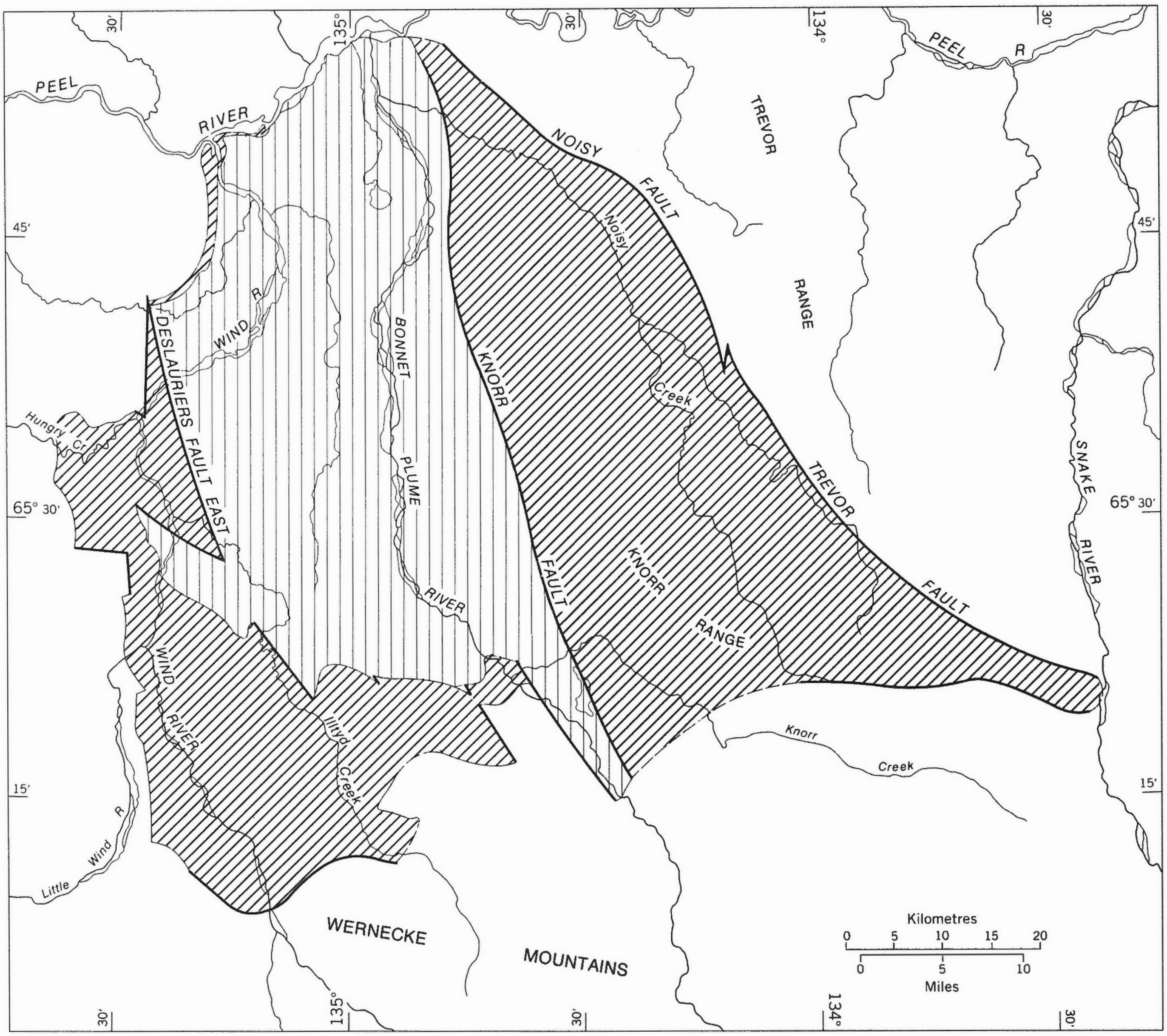

FIGURE 6. Outline map of Ancestral Bonnet Plume Basin (diagonal pattern) and of the modern basin (vertical pattern).

The group of north-trending, curvilinear, nearly vertical faults, which locally controlled the genesis and shape of the Bonnet Plume Basin, is herein named the Richardson Fault Array. It is a regional system of faults which is confined laterally to the Richardson Anticlinorium, and which crosses the Aklavik Arch to become the Eskimo Lakes Fault Zone (Coté *et al.*, 1974) in the region of the Tuktoyaktuk Peninsula (Fig. 1) and, in turn, the Cape Kellet Fault Zone (Lerand, 1973, p. 325) on the continental shelf southwest of Banks Island. Southward, the array swings in arcuate fashion into the Mackenzie Fold Belt and the Selwyn Basin where individual strands change into major, high-angle, reverse faults. Some strands of the array extend into the Bonnet Plume Basin from the north and the south but, because of poor exposure, it is uncertain if or how they cross the basin to link with faults at the opposite extremities.

Although the surface traces of the more clearly defined strands of the Richardson Fault Array are subparallel, those of interconnecting faults display an anastomosing or braided pattern in the manner of some of the great strike-slip faults of the world. In the Wellington Peninsula of North Island, New Zealand, for example, the Alpine Fault Zone comprises four major, active strike-slip faults threading their way through an array of interconnected, curvilinear, subsidiary breaks, some of which are now inactive, but which cut the terrain into a myriad of large and small, diamond- and sigmoidal-shaped blocks (*see* Stevens, 1974, p. 61).

Rouse and Srivastava (1972, Fig. 2) presented a diagrammatic block reconstruction to illustrate the stratigraphy and structure of the northern part of the Bonnet Plume Basin and to demonstrate two inward-facing panels of Maastrichtian and Paleocene beds. The synclinal axis shown by them corresponds to that mapped by Stelck (1944, Sheet No. 3) on Peel River, approximately 2 km (1.2 miles) above the mouth of Mountain Creek. The results of regional studies by the writers confirm the suggestion by Rouse and Srivastava that a fault passes through the covered interval between the two panels. Hence, the structure appears to consist of two blocks of coeval rocks facing one another across the Basin Creek Fault (Fig. 2). Section 8 of Rouse and Srivastava (*op cit.*) corresponds exactly with Mountjoy's Section 7 (106E18) (1967, p. 49-62) as plotted by him on vertical air photographs and transferred by the writers to Figure 2. It is, moreover, the location of the burning lignite seams indicated by Stelck (*idem*) opposite the mouth of Mountain Creek.

The angular unconformity beneath the Bonnet Plume Formation near the mouth of Wind River (Fig. 4) indicates that the lower and middle Paleozoic Road River succession was deformed and bevelled differentially prior to the development of the Ancestral Bonnet Plume Basin. Deformation and uplift was greatest in the south. On the north flank of the Wernecke Mountains (Fig. 2), it resulted in the total stripping of the Road River Formation and the underlying, unnamed Middle Cambrian clastic unit (Ꞓwr) so that the Albian conglomerates (lKbp) rest on the Lower Cambrian and, in some fault blocks, on the Helikian phyllites and quartzites.

In the Interior Platform and Eagle Fold Belt (Fig. 1), on the other hand, Albian strata are part of a widespread, transgressive sequence generally resting paraconformably on older rocks. It is concluded, therefore, that the pre-Albian deformation, so evident beneath the ancestral basin, was dictated by and essentially confined to displacements within the Richardson Fault Array. Moreover, the structural conformity of the lower and upper units of the Bonnet Plume Formation would indicate that further depression of the ancestral basin in the Late Cretaceous apparently was accomplished with minimum external rotation of individual fault blocks prior to the deposition of the Maastrichtian and Paleocene beds.

One of the most striking features of the Bonnet Plume Basin is its interruption of southeast- and east-trending structures on both flanks. In Taiga Ranges, for example, east-trending, commonly symmetrical, cylindrical folds, cut by both north- and south-dipping reverse faults, turn southeastward into Wernecke Mountains (*see* Norris, 1975, Hart River map-area). The more northerly of these folds and faults are truncated abruptly by Deslauriers Fault (Fig. 2) and its splay which trends south along Wind River. Clearly they pre-date at least some of the later activity on the Deslauriers Fault system. It is not known whether similarly trending structures continue eastward beneath the Bonnet Plume Basin, although northeast-trending beds with a 65 degree dip occur in the lower Bonnet Plume Formation a few kilometres west of Margaret Lake.

North of Knorr Range, a bundle of east-trending folds in Middle Devonian and younger Paleozoic strata is confined between Noisy Fault and a splay of Knorr Fault. Their axial surfaces are perpendicular to that of folded Cambrian beds lying between splays of Knorr Fault. Since they involve Mississippian rocks, the folds are late Paleozoic or younger.

Within the Knorr Range, there is a family of southeast- and east-trending splays of the Knorr Fault. Some of the splays terminate eastward against the unconformity at the base of the Cambrian rocks, and others persist upward into the lower and middle Paleozoic strata with marked decrease in stratigraphic separation. Principally, they are Precambrian structures. Still other splays in the vicinity of Rapitan Creek cut the Proterozoic succession into discrete, northwest-trending blocks; some of their activity probably persisted into the Tertiary, contributing to uplift of the Knorr Range and to formation of the modern Bonnet Plume Basin.

The two structures contributing most significantly to the development of the Bonnet Plume Basin, however, were the Knorr and the Deslauriers Faults. Displacements on them in post-Paleocene time resulted in the relative uplift of the outer blocks within the Richardson Fault Array and the relative depression of the inner ones to preserve the Bonnet Plume Formation in the core of the array.

Stratigraphic offsets and omissions across these and other faults of the array indicate differential uplift and probably right-hand, strike-slip offsets dating back to the Precambrian. The most dramatic evidence of these motions may be seen across the Knorr Fault in the vicinity of Margaret Lake in the southeast corner of the Bonnet Plume Basin. West of the fault, the Precambrian section is very much abbreviated compared with that east of it. Beneath unnamed Lower Cambrian strata (Ꞓl) are diamictites of the Hadrynian Rapitan Formation (Hrl) resting on phyllitic argillites and quartzites (Ho), the oldest rocks known in the Precambrian succession (*see* Fig. 2). Large parts of both the Helikian and Hadrynian sections are absent at the unconformities marking the upper and lower boundaries of these diamictites.

In the Knorr Range (Fig. 7) east of the Knorr Fault, on the other hand, intervals containing mudstone correlated with some part of the Rapitan Formation (Hr2) are overlain by 2000 m (6500 ft) of Hadrynian rocks, and are underlain by more than 5000 m (16 000 ft) of Helikian strata younger than the phyllitic argillites and quartzites (Ho).

The region just west of the Knorr Fault must have been relatively uplifted in the late Helikian and again in the late Hadrynian to account for these stratigraphic omissions. Furthermore, from lithofacies considerations, an argument can be made for major, right-lateral, strike-slip displacement on the Knorr Fault, probably in conjunction with this differential vertical motion.

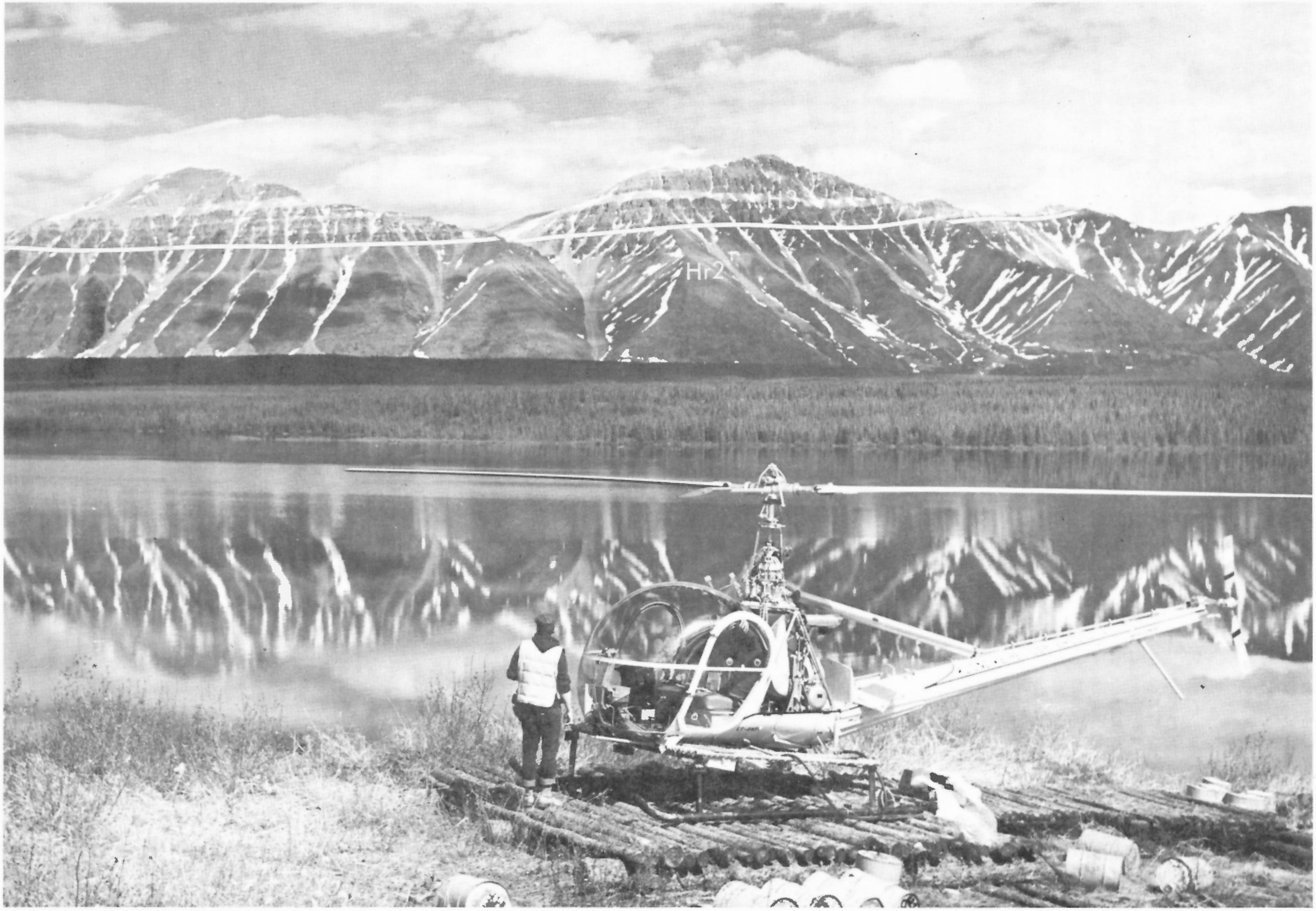

FIGURE 7. Rapitan Formation (Hr2) overlain by unnamed Hydrynian beds (H3) in Knorr Range as seen from Margaret Lake, Yukon Territory. View is to the northeast. GSC 117362

In the type area on Snake River, 50 km (30 miles) east of the Knorr Range, the Rapitan Formation is divisible into two units, a lower one composed of diamictites with iron formation, and an upper one comprising mudstone with dolomite interbeds. They are widespread at the headwaters of Snake River. In the Knorr Range, however, only a mudstone is recognized. It is either a facies equivalent of the diamictites or it is correlative with the upper unit of the type area and the diamictites either have been removed or were not deposited at an unconformity separating the two units.

The presence of diamictites west of Margaret Lake, between the Basin Creek and Knorr Faults, and nearly opposite Rapitan mudstone units in Knorr Range, can be explained by strike-slip faulting (Fig. 2). It is postulated that they were initially part of the main body of diamictites at the headwaters of Snake River, and that their present location is due to right-lateral offset of about 40 km (25 miles) on the Knorr Fault, mostly before the Early Cretaceous. The right-lateral separation of 12 km (8 miles) implied for the lower Bonnet Plume Formation on the splay between the Knorr and Basin Creek Faults suggests, moreover, additional post-Albian displacement.

The nature of this faulting is revealed further by the variation in vertical separation along and across the strike of some components of the Richardson Fault Array. For example, the lower Bonnet Plume Formation rests on Proterozoic phyllites and quartzites at the southern end of the Bonnet Plume Basin and on lower Paleozoic clastic strata at the northern end. This attests to differential uplift and bevelling along the strike of some of the faults before Albian time. Moreover, the absence of Rapitan diamictites immediately west of the Basin Creek Fault indicates pre-Albian, differential uplift and bevelling across the strike of some components of the Richardson Fault Array.

Deslauriers Fault, at the western limit of the array, may have had large-scale, strike-slip movement in addition to vertical motion. Right-lateral strike-slip is suggested by the fault-bounded, northeast-dipping panel of middle and lower Paleozoic rocks comprising Mount Deception. These strata appear to be the counterpart of the carbonate succession in northern Illtyd Range, offset approximately 20 km (12 miles) northward. Pre-Albian vertical motion is suggested by the stratigraphic position of the Albian beds in the Bonnet Plume Formation on the middle and lower Paleozoic rocks between the principal splays of the Deslauriers Fault, and on the upper Paleozoic strata west of the splays. Post-Albian vertical motion, moreover, is revealed by the presence of the lower Bonnet Plume Formation in the downthrown block adjacent to the Deslauriers Fault West. Truncation of this block at the Wernecke reverse fault documents additional depression of the basin and uplift of the Wernecke Mountains in still later Late Cretaceous or possibly Tertiary time.

In spite of the complex kinematic history of the several blocks contained within the Richardson Fault Array which led ultimately to the development of the Bonnet Plume Basin, two important generalizations can be made: one is that there was large-scale differential uplift of the core of the anticlinorium to expose the oldest Precambrian rocks (Ho) in pre-Albian times; the other is that there was a major reversal in this sense of motion from the Albian onward to form the basin.

ECONOMIC POTENTIAL

The economic potential of the Bonnet Plume Basin and of its immediately surrounding area results principally from lignite deposits, which may ultimately be of considerable value as a source of thermoelectric power in the beneficiation of the Snake River iron ore. Gold, hot springs and natural hydrocarbons appear to be of minor, if not insignificant, importance.

Mountjoy (1967) reported three lignite seams more than 1.5 m (5 ft) thick in Section 106E18 on the easterly of the two inclined panels, and two seams in Section 106E17 on the westerly panel. A conservative estimate is an aggregate thickness of lignite of 12 m (40 ft) in seams greater than 1.5 m for both panels to a stratigraphic depth of 120 m (400 ft), over a half-canoe shaped area of 90 km^2 (35 sq miles) extending south from Peel River (*see* Fig. 2).

The lignite potential of the Bonnet Plume Basin is estimated to be 1.5 x 10^9 short tons. This is based on the following assumptions: (a) there are 1.1 million short tons per square mile foot (Mackay, 1947, p. 14); (b) the two seam-intervals in the two panels are equivalent; (c) the seams are continuous and maintain their aggregate thickness over the area indicated in Figure 2; and (d) the dip of the seams can be ignored (leading to more conservative figures on tonnage because their areas projected into the horizontal plane is smaller). The estimate differs by about 25 per cent from the 1.9 x 10^9 tons of "mineable" lignite reported by MacKay (*op. cit.*, p. 108), using quite different basic data. In any event it appears that the lignite resources of the area are quite large.

No outcrops of lignite in the Bonnet Plume Formation are known to the writers other than those reported in northern Bonnet Plume Basin and there are no published data to support their presence elsewhere. Indeed, it is entirely possible that the Bonnet Plume Formation is much more restricted than indicated on Figure 2 because its actual extent is masked by glaciofluvial and glaciolacustrine deposits.

Colours of gold are reported from a bar on the Peel River above the mouth of the Wind River (Camsell, 1906, p. 46cc), from the gravels of Hungry Creek (Camsell, *op. cit.*, p. 29cc), and from the mouth of Little Wind River (Camsell, *op. cit.*, p. 28cc). None of these reports was verified by the writers but, from the regional geology, it appears unlikely that they could be of commercial value.

According to Camsell (*op. cit.*, p. 20cc), hot springs are said to occur on one of the small tributaries which joins Hungry Creek from the south and on Bonnet Plume River at the upstream side of its junction with the Peel (Camsell, *op. cit.*, p. 31cc).

The Toltec Peel River YT N-77 well, spudded in Upper Devonian strata (Norris, 1975, Wind River map-area), was abandoned because of mechanical failure at a depth of 1123 m (3683 ft). It was located on the crest of an anticline discovered by Stelck (1944, Pl. V) in the lower canyon of the Peel River, a few kilometres northeast of the Bonnet Plume Basin. Two albertite dykes exposed along the Peel River were shown by Stelck (*idem*) in association with the fold and suggest structural control of seepage of hydrocarbons from middle and lower Paleozoic rocks on the east flank of the Richardson Anticlinorium.

REFERENCES

Camsell, C.
1906: Report on the Peel River and tributaries; Geol. Surv. Can., Ann. Rept., New Series, v. 16, pt. CC, 1904, p. 1-49.

Coté, R. P., Rector, R. J. and Lerand, M. M.
1974: Gulf describes geology of Parsons Lake gas find; Can. Petrol., Apr. 1974, p. 72-78.

de Sainville E.
1898: Voyage a l'embouchure de la Rivière Mackenzie; Bull. Soc. de Géographie, septième série, tome dix-neuvième p. 291-307, 389.

Hughes, O. L.
1972: Surficial geology of northern Yukon Territory and northwestern District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 69-36, Map 1319A.

Lenz, A. C.
1972: Ordovician to Devonian history of northern Yukon and adjacent District of Mackenzie; Can. J. Earth Sci., v. 20, p. 321-361.

Lerand, M.
1973: Beaufort Sea *in* The future petroleum provinces of Canada, R. G. McCrossan, ed.; Can. Soc. Petrol. Geol., Mem. 1, p. 315-386.

MacKay, B. R.
1947: Coal reserves of Canada; reprint of Chapter 1 and Appendix A of Report of the Royal Commission on Coal, 1946.

Mountjoy, E. W.
1967: Upper Cretaceous and Tertiary stratigraphy, northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Paper 66-16.

Norris, D. K.
1975: Geological maps of parts of Yukon and Northwest Territories; Geol. Surv. Can., O.F. 279.

Norris, D. K., Price, R. A. and Mountjoy, E. W.
1963: Geology northern Yukon Territory and northwestern District of Mackenzie; Geol. Surv. Can., Map 10-1963.

Rouse, G. E. and Srivastava, S. K.
1972: Palynological zonation of Cretaceous and Early Tertiary rocks of the Bonnet Plume Formation, northeastern Yukon, Canada; Can. J. Earth Sci., v. 9, p. 1163-1179.

Stelck, C. R.
1944: Final geological report on "The Upper Peel River Area" Yukon Territory (Canada); Imperial Oil Ltd., Canol Project Assignment No. 23.

Stevens, G. R.
1974: Rugged Landscape, the geology of central New Zealand, including Wellington, Wairarapa, Manawatu and the Marlborough Sounds; A. H. and A. W. Reed, Wellington, Sydney, London.

Ziegler, P. A.
1959: Frühpaläozoische Tillite im östlichen Yukon-Territorium (Kanada); Ecologae Geologicae Helvetiae, v. 52, p. 735-741.

APPENDIX 1

Section 106E9, lower Bonnet Plume Formation, Illtyd Creek. The following partial section of the lower Bonnet Plume Formation was measured by A. Hedinger, A. Johnson and D. K. Norris on the north flank of the Wernecke Mountains immediately west of Illtyd Creek (*see* Fig. 2, geological map). It is faulted against Lower Cambrian rocks at its base and against the Precambrian at its top. The section is located at Longitude 134°58'W and Latitude 65°12'N. It may be identified on NAPL vertical aerial photograph A20624-88 by means of the following Cartesian co-ordinates measured with respect to the centre of the picture, where the north direction coincides with the positive Y-axis. Base of section: X = +2.48 cm, Y = +4.80 cm; top of section: X = -0.02 cm, Y = +2.28 cm. All measurements are in metres (feet).

Unit	Lithology	Thickness	Height Above Base
	BONNET PLUME LOWER PART FORMATION		
22	Alternating conglomerate and coarse-grained sandstone, light brown, weathering medium to dark brown; thick bedded where exposed; phenoclasts subangular to well rounded, up to 2 cm maximum observed dimension; lithologically very similar to that of lower units; matrix of coarse sandstone, subangular grains up to 2mm; poorly cemented and rather porous. Unit is composed of two thick ribs and is the topmost unit of the measured section. It is fault-bounded at the top and appears to be a repeat of Unit 20	---	---
21	Covered interval with sparse outcrops of coarse-grained sandstone. Synclinal axis or reverse fault	---	---
20	Sandstone, conglomeratic at base, medium orange-brown, weathering brownish grey. Composed of medium- to coarse-grained, subangular to subrounded chert and quartzite clasts, fairly well packed but poorly sorted; phenoclasts range from 2 to 10 mm; lithology similar to that of lower units. Several fining-upward sequences in this unit.	144.8 (475)	677.0 (2221)
19	Covered interval with rare outcrops of grey-weathering, fine-grained sandstone	21.3 (70)	532.2 (1746)
18	Sandstone, conglomeratic in basal ten feet, grading to medium- to coarse-grained sandstone; lenses of conglomerate common; orange, weathering orange-brown to grey; sandstone contains up to 10 per cent phenoclasts, mostly chert and quartzite, in a matrix of subangular to subrounded sand; fair porosity; mostly covered	27.4 (90)	510.9 (1676)
17	Sandstone with conglomeratic lenses, medium grey, weathering grey and buff; coarse-grained, angular to subrounded; poorly packed, fair porosity; phenoclasts from 3 to 50 mm, varicolored cherts, vein quartz and purple quartzite. Unit becomes finer upward to a fine-grained, grey-weathering sandstone. Contact with Unit 18 covered	22.9 (75)	483.5 (1586)
16	Covered interval	13.7 (45)	460.6 (1511)
15	Conglomerate, light orange-brown, weathering greyish-brown; matrix about 20 per cent of rock, mostly coarse-grained, subangular sand; phenoclasts range from 2 to 100 mm, subrounded to well-rounded, mostly varicolored chert, purple quartzite and grey quartzite; poorly cemented and rather porous; massive; ridge former. Rare lenses of reddish, medium- to coarse-grained sandstone with current laminations. Attitude 115°, 25°SW	123.4 (405)	446.9 (1466)
14	Mudstone, black, massive, chunky-weathering, mostly covered (GSC loc. C-27127)	4.6 (15)	323.5 (1061)
13	Shale, carbonaceous, black, deeply weathered, partly covered (GSC loc. C-27126)	9.1 (30)	318.9 (1046)

Unit	Lithology	Thickness		Height Above Base	
12	Conglomerate of quartz and chert, light grey, porous, massive, weathering into angular chunks and blocks up to 0.5 m on a side; partly soft and disaggregated. Phenoclasts comprise black chert, white quartzite, and green chert in decreasing order of abundance. Uppermost 0.5 m is porous-weathering, light grey, quartz, chert sandstone. Base not exposed. Attitude 275°, 30°SW	9.8	(32)	309.8	(1016)
11	Mostly covered, with sparse showings of conglomerate, as in Unit 15	18.3	(60)	300.0	(984)
10	Conglomerate, as in Unit 15	0.9	(3)	281.7	(924)
9	Shale, carbonaceous, black, massive; base covered (GSC loc. C-27128)	6.1	(20)	280.8	(921)
8	Conglomerate, light grey, weathering light to medium grey; sandy lenses; matrix of medium- to coarse-grained, angular sand; phenoclasts range from 5 to 50 mm maximum observed diameter, consisting mainly of varicolored cherts and quartzites, less commonly of other sedimentary rock fragments. As a whole the rock is resistant although poorly cemented. Sandstone lenses are fine to medium grained, grey weathering and occur mostly in upper part of unit	38.1	(125)	274.7	(901)
7	Pebble conglomerate, light grey, weathering slightly darker grey; medium- to thick-bedded; matrix of medium- to coarse-grained sand; phenoclasts of pebble size, angular to subrounded, consisting mostly of purple quartzite, grey and green chert, and rarely shale; poorly sorted. Unit grades into a fine- to medium-grained, grey-weathering sandstone. In places there are lenses of fine-grained, maroon-weathering sandstone. Ridge former. Attitude 115°, 30°SW	51.8	(170)	236.6	(776)
6	Sandstone of quartz and chert, light greyish-brown, weathering to the same color; fine-grained, laminated; slightly resistant and mostly covered; about 30 m (100 ft) above base, unit becomes coarser and clasts more angular. Contact with Unit 7 gradational	42.8	(140)	184.8	(606)
5	Covered interval	25.0	(82)	142.0	(466)
4	Pebble to cobble conglomerate, grey and brown, weathering light to medium grey; matrix 40 per cent of rock and consisting of medium to coarse sand; phenoclasts from 5 mm to 20 cm, mostly of sedimentary origin, subangular to subrounded; poorly sorted and cemented, thick-bedded where exposed, though exposure is generally poor. Unit is a ridge former. Contact with Unit 3 gradational over 3 to 5 m	19.8	(65)	117.0	(384)
3	Sandstone of chert, quartz and quartzite, light grey to brown, weathering light grey; fine-grained but contains nests of coarse sand and small pebbles; mostly subangular grains; poorly cemented; medium-bedded; poorly exposed. About 15 m above base are conglomeratic lenses containing pebbles up to 3 cm of chert and quartzite. Contact with Unit 2 gradational	45.1	(148)	97.2	(319)
2	Mostly covered with some poor outcrops of medium- to coarse-grained sandstone similar to Unit 1	24.7	(81)	52.1	(171)
1	Sandstone of chert, quartz, and quartzite, medium grey, weathering light grey and brown, coarse- to very coarse grained; some beds with grains to 5 mm, angular to subangular, well-packed but poorly cemented; poorly sorted nests of pebbles up to 1 cm occur near the base of unit; thick-bedded where exposed. Attitude 110°, 25°SW. Base covered	27.4	(90)	27.4	(90)

APPENDIX 2

IDENTIFIED MICROFLORA IN THE LOWER BONNET PLUME FORMATION

Division EUMYCOTA

Class BASIDIOMYCETES
Pleuricellaesporites psilatus Clarke

Division BRYOPHYTA

Family SPHAGNACEAE
Sphagnum antiquasporites Wilson and Webster
Cingutriletes cf. *C. clavus* (Balme) Dettmann

Class HEPATICAE
Aequitriradites spinulosus (Cookson and Dettmann) Cookson and Dettmann

Division LYCOPODOPHYTA

Family LYCOPODIACEAE
Sestrosporites pseudoalveolatus (Couper) Dettmann
Lycopodiacidites caperatus Singh
Lycopodium sp.

Division PTEROPHYTA

Family OSMUNDACEAE
Osmundacidites wellmanii Couper
Baculatisporites comaumensis (Cookson) Potonié
Todisporites cf. *T. minor* Couper

Family SCHIZAEACEAE
Appendicisporites sp.
Cicatricosisporites spp.

Family GLEICHENIACEAE
Gleicheniidites senonicus Ross

Family POLYPODIACEAE and/or DENNSTAEDTIACEAE
Laevigatosporites sp.
warty monolete spores
reticulate monolete spores

Family CYATHEACEAE or DICKSONIACEAE
Cyathidites australis Couper

Family CHEIROPLEURIACEAE
Dictyophyllidites sp.

PTEROPHYTA - *Incertae sedis*
Deltoidospora sp.
Leptolepidites sp.

Division PTERIDOSPERMOPHYTA

Family CAYTONIACEAE
Vitreisporites pallidus (Reissinger) Nilsson

Division CYCADOPHYTA and/or GINKGOPHYTA

Order BENNETTITALES, CYCADALES and/or GINKGOALES
Monosulcites sp.
Cycadopites sp.

Division CONIFEROPHYTA

Family PODOCARPACEAE
Phyllocladidites sp.

Family PINACEAE

Tsugaepollenites sp.

Miscellaneous bisaccate conifer pollen

Family TAXODIACEAE

Glyptostrobus sp.

Sequoiapollenites sp.

Perinopollenites elatoides Couper

Family CUPRESSACEAE and/or TAXACEAE

Inaperturopollenites sp.

Family CHEIROLEPIDACEAE

Classopollis torosus (Reissinger) Couper

Division ANTHOPHYTA

Class DICOTYLEDONAE

Retitricolpites cf. *R. virgeus* (Groot, Penny, Groot) Brenner

Cupuliferoidaepollenites minutus (Brenner) Singh