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Geology and Coal Resources

of the

Carbon Creek-Mount Bickford Map-area

by

W. H. MATHEWS

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Geology and Coal Resources of the Carbon Creek-Mount Bickford Map-area.

INTRODUCTION.

The geological investigation of the Carbon Creek-Mount Bickford map-area was made with the purpose of obtaining information on the coal resources of the Carbon Creek basin and of the area between this coalfield and the Hasler Creek field. Particular attention was paid to the structure and distribution of coal-bearing rocks and to any exposures of coal of possible commercial significance. Much of the area between the Carbon Creek and Hasler Creek coalfields proved to be underlain by a succession of marine sediments, hitherto virtually unknown, and a more or less detailed study of these rocks was made during the survey.

A drilling programme in the Carbon Creek basin is being planned by the owners of coal lands there, and the result of this work is expected to provide much more information on the continuity and tonnage of the coal deposits, and may also indicate some modification to the stratigraphy and structure as interpreted by the writer from surface exposures.

One month in 1944 was spent in field-work, chiefly in the Carbon Creek basin, and two months in 1945 chiefly in the area south-east of the Carbon Creek basin and in the Pine River Valley. J. G. Fyles and W. E. Redpath assisted in the field during 1944, and W. E. Thomson and R. R. Steiner in 1945.

No adequate topographic map of the area was available at the commencement of field-work, but vertical air photographs had been taken of the Carbon Creek basin and the Pine River valley. Geological information was plotted in the field directly on these photographs, and a map subsequently prepared from them. The topography on the accompanying map is represented by the drainage pattern and by approximate contours at about 500-foot intervals, since ground control, especially in the southern part of the Carbon Creek basin, was inadequate for more detailed mapping. No photographs were available during the survey of the area south-east of the Carbon Creek basin, and a plane table-map on a scale of 1 mile to the inch was prepared as geological investigations were being carried on. Additional information on this area has been obtained from United States Army Air Force trimetrogon photographs loaned by the Department of Mines and Resources, National Air Photographic Library, Ottawa.

The writer wishes to acknowledge the assistance extended to him during the course of the work by J. Beattie, of Gold Bar, and by J. O. Howells, in charge of the work carried on by the Burns Foundation on the Carbon Creek coal lands; to W. A. Bell and F. H. McLearn, of the Geological Survey of Canada, and to P. S. Warren, of the University of Alberta, who examined the fossil collections obtained in the area.

LOCATION AND ACCESSIBILITY.

The map-area is situated in the foot-hills of the Rocky Mountains between the Peace and Pine Rivers. It is 40 miles long, in a south-easterly direction parallel to the trend of the folding, and averages 8 to 10 miles wide.

The northern part can be reached from the settlement of Gold Bar, at the end of a 99-mile road extending by way of Hudson Hope from the Alaska Highway at Fort St. John. The mouth of Carbon Creek is 10 miles by river-boat up the Peace River from Gold Bar. A pack-trail extends southward up the west side of Carbon Creek from the Peace River to the coal showings at Eleven (11 Mile) Creek, and trappers' trails continue from this point not only up Carbon Creek, but also up Eleven Creek and up another tributary of Carbon Creek to Carbon (Indian) Lake. Another pack-trail leads from the head of Peace River canyon, 20 miles below Gold Bar, by way of Gething Creek and Wright Lake to a point on Carbon Creek 15 miles from the Peace where it joins the trail mentioned above.

A pack-trail is reported to extend up the Moberly Valley into the central part of the area, but this trail was probably almost completely destroyed by the forest fires which swept through the valley during the summer of 1945.

The Pine River valley is served by a good pack-trail, and construction had been commenced in September, 1945, on the Pine Pass Highway, which is to parallel this trail. On the completion of the highway the southern end of the area will be about 100 miles by road from the end of the Northern Alberta Railway at Dawson Creek and 170 miles from Prince George.

STRATIGRAPHY.

Table of Formations.

Age.	*Group.*	*Formation and Thickness.*	*Character.*
Recent		0′–1,080′+	Alluvium
Pleistocene			Terraced drift Till
Erosion surface			
Upper Cretaceous		Dunvegan, 200′±	Sandstone, conglomerate
Lower Cretaceous	Fort St. John	Cruiser, 1,000′± Goodrich } 2,500′ Hasler Commotion, 1,300′–1,500′ Moosebar, 800′±	Chiefly shale Sandstone, conglomerate Chiefly shale Sandstone, quartzite, conglomerate, minor shale Shale, conglomerate at base
	Bullhead	Non-marine part, 4,000′–4,500′	Sandstone, shale, coal
Lower Cretaceous or Upper Jurassic	Bullhead	Marine part— Monach, 300′–400′ Beattie Peaks, 750′–1,200′ Monteith, 1,000′–1,750′	Sandstone Chiefly shale Sandstone, quartzite in upper part
Jurassic		Fernie, 500′–800′	Chiefly shale, sandy near top
Triassic		Schooler Creek, 2,500′+	Calcareous sandstone, siltstone, impure limestone
Base concealed			

General.

The rocks of the Carbon Creek-Mount Bickford map-area consist entirely of sediments ranging in age from Middle Triassic to Upper Cretaceous. The succession includes limestones, siltstones, and calcareous sandstones of Triassic age, and an alternating succession of sandstone and shale formations belonging to the Jurassic, the Lower Cretaceous, and the base of the Upper Cretaceous. The rocks formerly included within the Lower Cretaceous Dunlevy formation of the Bullhead group are here subdivided into three new formations—the Monteith, Beattie Peaks, and Monach formations—from bottom to top respectively. The twofold division of the Bullhead group adopted in the Dunlevy-Portage Mountain area (Beach and Spivak, 1944) could not be extended into the Carbon Creek-Mount Bickford map-area. With these exceptions, however, the nomenclature of the stratigraphic succession is the same as that already established in adjacent parts of the Peace River foothills.

Schooler Creek Formation.

Triassic rocks of the Schooler Creek formation outcrop in the map-area only in the vicinity of the Peace River. This formation has been intensively studied by F. H. McLearn, of the Geological Survey, in outcrops along the north side of the Peace River from the Beattie Ranch (Gold Bar), 10 miles east of the mouth of Carbon Creek, to the mouth of the Nabesche River, 13 miles west of Carbon Creek. As described by McLearn (1940), the formation "is more than 2,500 feet thick and consists mostly of calcareous, very fine sandstone, somewhat less calcareous siltstone, and less shelly, crinoidal, partly oolitic, argillaceous, and arenaceous limestone. There is thus a high percentage of detrital sediment in the formation. Some of the shelly limestones are massive; others have a fissile fracture, after weathering, because of the presence of flat shells like *Halobia* and *Monotis*. The absence of volcanic material in the formation is worth noting, for tuffs, agglomerates, and flows are quite common in the Triassic of Western British Columbia."

The Schooler Creek formation does not lend itself readily to lithological subdivision, but fossils are common, and thanks to the detailed work of McLearn, it is now possible to recognize well-defined faunal horizons throughout the succession. The oldest of the known horizons contains a *Nathorstites*-bearing ammonoid fauna. Another zone, characterized by *Lima poyana*, lies between about 1,000 and 1,600 feet above the *Nathorstites* zone. Still higher are zones characterized by various species of *Halobia*, and at the top of the formation a zone characterized by *Monotis subcircularis*. The *Nathorstites* zone is believed to be of Ladinian or late Meso-Triassic age, the *poyana* zone of Karnian or early Neo-Triassic age, the *Halobia* zone of Karnian and Norian age, and the *Monotis subcircularis* zone of Norian or late Neo-Triassic age.

No additional information on the stratigraphy of the Schooler Creek formation was obtained during geological investigations in the map-area, but fossils were collected at several localities and have been identified by McLearn. These collections include:—

(1.) From the creek 4 miles south-east of Gold Bar and at or close to the site of the Permian fossils reported by Beach and Spivak (1944).

"'*Myophoria*' n. sp.
Myophoria cf. *silentiana*.
Pleuromya sp.

Age: Early Upper Triassic—about *poyana* epoch."

(2.) South bank of Peace River, 1 mile south of Gold Bar.

"*Pecten nihannianus*.
Myalina sp.
Cœnothyris sp.
Spiriferina sp.

Age: Upper Triassic."

(3.) Several localities on a hill 3 miles west of the mouth of Carbon Creek and south of the Peace River.

" Crushed echinoderms.
Crinoid stems.
Lima sp.
Halobia pacalis.
Bones of marine reptile.

Age: Upper Triassic."

(4.) Half-mile south-east of top of this hill.

" *Monotis subcircularis.*

Age: Late Upper Triassic."

(5.) Half-mile east of top of this hill.

" *Monotis subcircularis.*

Age: Late Upper Triassic."

Fernie Formation.

A succession of several hundred feet of non-resistant shaly beds which overlies the Schooler Creek formation and underlies the arenaceous beds of the marine part of the Bullhead formation is referred to as the Fernie formation. Since it is poorly exposed within the map-area, its precise thickness has not been determined. At least 350 feet of shaly beds are present at the base of Indian Head, and about 500 feet of shaly beds is estimated to be present on the eastern slope of Carbon Peak between the Bullhead group and the Schooler Creek formation. McLearn (1940) estimates the thickness of the formation at Brown Hill, on the Peace River 4 miles west of the mouth of Carbon Creek, as 700 feet. Stelck (1941) reports the presence of 835 feet of shales, siltstones, and minor fine-grained sandstones on Le Moray Mountain, 9 miles south-west of the map-area, on the Upper Pine River.

Shales predominate in any known section of the Fernie formation, but some sandstone beds are present in the upper part, and the succession apparently grades upwards into the predominantly arenaceous Monteith formation.

Fossils are rare in the Fernie formation, but McLearn (1940) reports the existence of " some marine pelecypods and poorly preserved ammonoids " and that " the formation is, partly at least, to be compared with the Jurassic Fernie formation . . ."

Stelck (1941) reports the presence of fossils in the Fernie formation in the two localities on the Upper Pine Valley, on Gold Creek, and Le Moray Mountain, each about 9 miles south-west of the map-area. The Gold Creek fauna, from a horizon " believed to be near the bottom of the shales," contains:—

" Gastropoda.
Pleurotomaria cf. *borealis* (Warren).

Pelecypoda.
Oxytoma n. sp. cf. *O. mcconnelli* Whiteaves.
Chlamys cf. *mcconnelli* McLearn.
Gryphæa n. sp.
Pecten (sub genus) sp. undet.
Pecten (sub genus) sp. undet.

Brachiopoda.
Orbiculoidea (Discina).
Furcirhynchia n. sp. cf. *Rhynchonella furcillata* Theodori.
Furcirhynchia n. sp.
Homeorhynchia? n. sp.
Rhynchonella (sub genus) n. sp.

" The age of this fauna as determined from the genus *Furcirhynchia* is middle Lower Jurassic."

On Le Moray Mountain the following forms were collected from outcrop and talus more than 650 feet above the base of the formation. More than one horizon may be represented:—

" *Belemnites.*
Pleuromya sp.
Pleuromya sp.
Cucullæa?
Pecten (sub genus).
Aucella sp.
Aucella sp.
Gryphæa.
Lima cf. *stantoni* McLearn.

" The presence of two species of *Aucella* suggest the presence of at least two horizons and also suggest Upper Jurassic."

The presence of a fauna somewhat similar to the latter in the stratigraphically higher shales and sandstones in the marine part of the Bullhead group should be noted.

BULLHEAD GROUP.

General.

A succession of sandstones and shales, in part coal-bearing, lying between the Jurassic Fernie shales and the Lower Cretaceous Moosebar (?) shales has been named the Bullhead group. In the Dunlevy-Portage Mountain map-area (Beach and Spivak, 1944) this group has been divided, at the top of a thick and conspicuous conglomerate zone, into the overlying Gething formation and the underlying Dunlevy formation. In the Carbon Creek-Mount Bickford map-area it has not been possible to utilize this subdivision, and the coal-bearing rocks are, therefore, mapped as a single unit and referred to in the text as the " non-marine part of the Bullhead group " or simply as the " non-marine Bullhead."

Although the Bullhead group was at first thought to be entirely continental, a marine fauna, including a species of *Aucella,* had been found prior to 1940 near the base of the Bullhead at Teepee Rocks Spur, on the north side of the Peace River 5 miles west of the mouth of Carbon Creek. The great thickness of the marine succession was not, however, recognized until the work on the Carbon Creek-Mount Bickford map-area was nearly complete. From 2,000 to 3,000 feet of sandstone, quartzite, shale and minor conglomerate, partly or completely of marine origin, were discovered. The succession, moreover, could be subdivided into the three new formations—the Monteith, the Beattie Peaks, and the Monach. Although fossils have been obtained from these formations, it has not been possible to determine whether they are late Upper Jurassic or early Lower Cretaceous forms. The retention of this part of the succession in the Bullhead group has been recommended, at least until its distribution, age, and relationship to adjacent formations have been more completely determined. With this usage, therefore, the term " Bullhead group " now denotes the succession of sandy and shaly beds, both non-marine and marine, between the Jurassic Fernie shales below and the Lower Cretaceous Moosebar shales above. As mentioned above, the continental coal-bearing upper part of this group is to be referred to as the " non-marine Bullhead," and the marine lower part, comprising the Monteith, Beattie Peaks, and Monach formations, is to be referred to as the " marine Bullhead."

Revision of Lower Cretaceous Stratigraphy.

<table>
<tr><th>Group.</th><th>Dunlevy-Portage Mountain Area, 1944.</th><th colspan="2">Carbon Creek-Mount Bickford Map-area, 1946.</th><th>Age.</th></tr>
<tr><td>Fort St. John group</td><td colspan="3">Moosebar formation</td><td rowspan="2">Lower Cretaceous</td></tr>
<tr><td rowspan="2">Bullhead group</td><td>Gething formation</td><td colspan="2">Non-marine Bullhead (coal-measures)</td></tr>
<tr><td>Dunlevy formation</td><td>Marine Bullhead</td><td>Monach formation
Beattie Peaks formation
Monteith formation</td><td>(?)</td></tr>
<tr><td colspan="4">Fernie formation</td><td>Jurassic</td></tr>
</table>

The marine part of the Bullhead group possibly corresponds to the marine beds reported by Warren* from the lower part of the Nikanassin formation of western Alberta and the basal part of the Kootenay formation in south-western Alberta.

Monteith Formation.

The Monteith formation is so named after its excellent exposures on the north face of Mount Monteith, but has been studied in greatest detail on the creek draining the western slope of the Beattie Peaks. In the latter locality the formation comprises about 1,750 feet of arenaceous beds resting with no apparent unconformity on a succession of shales and sandstones, believed to be the upper part of the Fernie formation, and underlying the predominant shales of the Beattie Peaks formation. The thickness of the formation diminishes towards the northern part of the map-area, where, at Indian Head, overlooking the Peace River, it does not exceed 1,000 feet. The greater part of the Monteith formation is made up of dark-grey arkosic sandstone, massive to flaggy, and in place showing cross-bedding and ripple marks. This sandstone occurs in beds usually from 10 to 30 feet thick, each separated by a few feet of shale or shaly sandstone.

The uppermost 500 feet of the formation is made up of white quartzite, commonly stylolitic and locally vuggy. Since in a few places grey arkosic sandstone or brown-weathering ferruginous sandstone is interbedded with the quartzite, it is evident that the recrystallization of the latter has not been brought about by regional metamorphism. It is notable, however, that only purer arenaceous beds have been converted to quartzite, and that the original composition or, perhaps, texture controlled the alteration.

The presence of stylolites in the quartzite is of considerable interest, as stylolites are rare, though not unknown, in rocks other than limestones (*see* Price, 1934; Stockdale, 1936 and 1945; and Tarr, 1916). As far as is known, the stylolitic films in this area parallel the bedding. Individual stylolite columns may be as much as ½ inch long and tend to have grooved sides and pointed terminations. Some flat-topped columns have, however, been observed. Stockdale (1922) in his classic paper states that "stylolites are found along inclined bedding planes, with their direction of penetration vertical, instead of at right angles to the stratification." In the occurrence

* Warren, P. S.: Oral communication.

within the Monteith formation, however, no such relations have been observed. Instead, the stylolites are perpendicular, or nearly so, to the bedding and may be inclined at high angles to the vertical. It is possible, however, that the stylolites were vertical when developed and that they have subsequently been folded.

Because of their resistant character the rocks of the Monteith formation tend to outcrop in conspicuous strike-ridges. Most of the higher summits of the map-area are outcrops of this formation, generally of the upper quartzite member.

No identifiable fossils have been obtained in *situ* from the Monteith formation, but talus derived from either the Upper Monteith or Lower Beattie Peaks formation has yielded a marine fauna including "what appears to be a small *Aucella*, and possibly new species of *Modiola* and '*Dentalium?*'* A Jurassic age may possibly be indicated, but no reliable dating can be offered." No terrestrial fossils, plant fragments, or coaly beds have been found in the formation. The occurrence of cross-bedding and ripple marks suggests that the sediments were deposited in shallow water.

Beattie Peaks Formation.

This formation is so named from its exposures on the western slopes of the Beattie Peaks, where it consists of a succession of shaly beds underlain by the upper quartzite member of the Monteith formation and overlain by the sandy Monach formation. Its thickness at this locality is about 1,200 feet, but, like the Monteith formation, it thins northward and at Indian Head only about 750 feet of shaly beds are present. On Beaudette Creek, where the Beattie Peaks formation is exposed in the steeply dipping eastern limb of an anticline, the thickness is less than 600 feet, but on the western limb of this same fold it may exceed 700 feet.

The formation throughout the map-area is made up of shales, shaly sandstone, some sandstone beds, and, in a few localities, some quartzite. A few beds of clay ironstone, rarely more than 4 feet thick, are present.

Because of the weakly resistant character of the rocks of the Beattie Peaks formation, continuous exposures are rare, even on steep slopes and at high elevations. Since, however, the formation lies between the resistant Monteith and Monach formations, it has been protected from deep erosion and is found, for the most part, in the upland areas.

Fossils found in float derived from either the upper part of the Monteith or the lower part of the Beattie Peaks formations have already been noted. Fossils derived without question from the Beattie Peaks formation include *Aucella, Pecten, Yoldia, Oxytoma,* and '*Dentalium?*' together with numerous unidentifiable worm-trails, and rare ammonoid fragments.* It is uncertain whether the fauna represents a very late Upper Jurassic or an early Lower Cretaceous age. Plant fragments were found in the Beattie Peaks formation near the summit of Frankroy Mountain, but no other fossils of continental origin were seen. The formation is probably entirely marine.

Monach Formation.

The Monach formation is so named from its exposure on the Monach, one of the mountains west of Upper Carbon Creek, but is equally well exposed on the summit of the Beattie Peaks, where it has been studied in most detail. It consists of dominantly sandy marine beds overlying the shaly Beattie Peaks formation and underlying the coal-measures of the non-marine part of the Bullhead group. The thickness of the Monach formation is approximately 300 to 400 feet throughout the map-area.

The Monach formation consists of several thick sandstone members, each separated by a few feet of shaly beds. Much of the sandstone occurs in coarse cross-bedded layers which weather into stacks of plates, each about ½ to 1 inch in thickness and 1 foot or more across.

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* Determinations by F. H. McLearn, Geological Survey of Canada.

In resistance to erosion the sandstone members of the Monach formation are exceeded only by the quartzite of the Monteith formation. Outcrops of the Monach formation form the summits of not only the Monach and the twin Beattie Peaks, but also the western summits of Mount Frankroy and a row of subordinate peaks in the chain east of Carbon Creek. Nearly horizontal beds of the Monach formation outcrop on the highest parts of Mount Cowper and of a hill 2½ miles northwest of Mount Frankroy. Here the flat summit areas are bounded by a series of giant steps, developed on the harder sandstone members, and these in turn are bounded by almost precipitous slopes developed on the underlying less-resistant Beattie Peaks shales. Where steeply dipping, the resistant sandstone members of the Monach formation outcrop in a series of thick ledges.

Fossils found in the lower and middle part of the Monach formation included *Belemnopsis?* and *Acroteuthis?* (a belemnitid), and at least two forms of *Aucella.** Again it is uncertain whether these represent late Upper Jurassic or very early Lower Cretaceous species. No fossils have been found in the upper part of the formation.

Non-marine Part of the Bullhead Group.

The coal-measures or non-marine part of the Bullhead group include the Gething formation and the upper part of the underlying Dunlevy formation described in the Dunlevy-Portage Mountain area (Beach and Spivak, 1944). There is an abrupt change in the character of the sediments, and locally a conglomerate bed, at the contact with the underlying marine Monach formation. The apparently uniform thickness of the Monach formation, however, indicates that there is no appreciable angular unconformity between the two stratigraphic units. The upper limit of the coal-measures at the contact with the overlying Moosebar formation is also marked by an abrupt change in the character of the sediments and by a persistent conglomerate bed, but here, too, no distinct angular unconformity is indicated.

A conglomerate bed 20 feet thick is present at the base of the coal-measures on the Beattie Peaks and 2 miles west of Mount Monteith, but is elsewhere apparently absent. The lower part of the non-marine Bullhead consists of an alternation of sandstones and shales in about equal proportions. These sandy and shaly beds are usually from a few feet to about 30 feet in thickness. Symmetrical ripple marks are abundant. Carbonaceous shales and thin coal-seams are present within a few 10's of feet of the base of the succession. Massive sandstone and conglomerate 30 feet in thickness occur about 1,100 feet above the base of the coal-measures on Mount Bickford and about 1,500 feet above the base on Beaudette Creek.

A lenticular conglomerate zone, 20 to 50 feet thick, possibly 1,500 feet above the base of the coal-measures, marks a distinct erosional unconformity. The conglomerate crops out in two localities on the hill 4 miles west of Mount Monteith; at one locality it rests upon beds about 30 feet stratigraphically higher than at the second locality 100 yards away. Fossils below this unconformity, however, are similar in age to those at higher horizons in the coal-measures.

In the higher parts of the continental beds the alternation of sandstones and shales persists. Rarely more than 10 to 20 feet of shales are found without intervening sandstone beds, but thicker sandstone members are present. One such member, outcropping near the mouth of Ten (10 Mile) Creek and at least 3,500 feet above the base of the non-marine beds, is 55 feet thick and includes some conglomerate. Conglomeratic bands, one about 8 feet thick and another about 25 feet thick, outcrop on Eleven (11 Mile) Creek between 3,500 and 4,500 feet above the base of the continental beds. Such thick sandstone and conglomeratic members may serve as horizon markers in limited areas, but they are not known to have extensive distributions.

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* Determinations by F. H. McLearn, Geological Survey of Canada.

Coal-seams of possible commercial interest (*see* pages 19 to 25) occur in the continental beds as little as 300 feet above their base, and several seams are known in the lower 2,000 feet of the succession, but thick seams are most common in the upper part of the coal-measures.

The non-marine part of the Bullhead group is much less resistant to erosion than the marine part and has been deeply eroded to form the broad valleys occupied by Carbon and Fisher Creeks.

Fossils found in the coal-measures consist of plant remains* and fresh-water pelecypods and gastropods.† One collection from the shales underlying a coal-seam 1,300 feet above the base of the continental beds 1 mile east of Bickford Lake contains:—

" Bryophyta.
Marchantites blairmorensis Berry.
Ferns.
Coniopteris brevifolia (Fontaine).
Cladophlebis virginiensis Fontaine.
Incertæ sedis.
Podozamites lanceolatus (Lindley and Hutton) Fr. Braun.
Sagenopteris sp.
Cycadeoids.
Ptilophyllum arcticum (Goeppert).
Conifers.
Elatides dicksoniana (Heer) Seward.

"An Aptian age is indicated; i.e., an age contemporaneous with that of the Gething formation."

Another collection from the beds about 100 feet below the unconformity, described above, and 4 miles to the west of Mount Monteith contain:—

" Cycadeoids.
Ptilophyllum arcticum (Goeppert) Seward.
Ptilophyllum speciosum (Heer).
Pterophyllum concinnum Heer.
Conifers.
Pityophyllum nordenskioldi (Heer).
Elatides dicksoniana (Heer).
Elatides curvifolia (Dunker) Nathorst.
Incertæ sedis.
Podozamites sp.

" An Aptian age is indicated. All are members of the flora of the Gething formation of the Bullhead group."

One fossil has been found in the middle of the succession, on the north slope of the Pine Valley, about 1 mile west of Crassier Creek, and perhaps 3,000 feet above the base of the coal-measures. Bell identifies this fossil as:—

" Ginkgoales.
Ginkgoites pleuripartita (Schimper) Seward.

" The Lower Cretaceous *G. pleuripartita* is practically indistinguishable from the Jurassic *G. digitata*, but it is a common member of the Lower Cretaceous up to and including the Gething formation."

All other collections have been obtained from the upper part of the coal-measures, either in one locality on Beaudette Creek 2½ miles above its mouth, or near the junction of Carbon Creek and Eleven (11 Mile) Creek. The collections from the former locality include:—

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* Identified by W. A. Bell, Geological Survey of Canada.
† Identified by F. H. McLearn, Geological Survey of Canada.

" Ferns.
Cladophlebis virginiensis Fontaine.
Coniopteris brevifolia (Fontaine).
Coniopteris sp.
Cycadeoids.
Ptilophyllum arcticum (Goeppert) Seward.
Conifers.
Pityophyllum nordenskoldi (Heer) Seward.
Elatides dicksoniana (Heer).

" Most of these are long ranging species indicative of Lower Cretaceous age, . . . [but *Elatides dicksoniana*] is confined so far as known to the Aptian formations; e.g., the Gething formation . . . [and] the *Coniopteris* sp. is seemingly [the] same species as occurs in the Luscar formation of Aptian age."

The collections from the Carbon Creek-Eleven Creek area between 3,500 and 4,500 feet above the base of the coal-measures contain:—

" Ferns.
Cladophlebis virginiensis forma *acuta* Fontaine n. comb.
Cycadophytes.
Nilssonia cf. *densinerve* (Fontaine) Berry.
Ptilophyllum speciosum (Heer).
Ptilophyllum arcticum (Goeppert) Seward.
Pseudocycas n. sp. and early form closely allied to *P. unjiga* (Dawson) Berry.
Conifers.
Podozamites lanceolatus (Lindley and Hutton) Fr. Braun.
Elatides curvifolia (Dunker) Nathorst.
Seed organism of uncertain origin."

These fossils indicate " a Lower Cretaceous Aptian age contemporaneous with that of the Gething formation."

" Mollusca.
Fresh-water unionids and gastropods."

MOOSEBAR FORMATION.

The base of the Moosebar formation is marked by a persistent conglomerate bed 10 to 20 feet thick and by an abrupt change in the character of the sediments from a succession of coal-bearing sandstones and shales to a succession of marine, predominantly shaly strata. The formation is overlain by the sandstones, shales, and conglomerate of the Commotion formation. Exposures of the Moosebar formation are confined to the south-eastern and eastern parts of the map-area. Several hundred feet of shales with some shaly sandstones are exposed on Beaudette Creek, 1½ miles from the Pine River. Several hundred feet of shales exposed to the east of the map-area, on the south fork of Gething Creek, 3 miles north-east of Mount McAllister, are believed to represent the Moosebar formation. An exposure on Crassier (Pass) Creek, 3 miles from the Pine River, has been described by Wickenden and Shaw (1943), and previously, under the name " Pine River Formation," by Spieker (1920). No complete section of the formation is exposed in the map-area; hence its total thickness in this locality is not known. Wickenden and Shaw estimate the thickness of the Moosebar formation in the adjoining Mount Hulcross-Commotion Creek area as about 800 feet.

The rocks of the Moosebar formation, with the exception of the basal conglomerate, are not resistant to erosion and rarely outcrop, except on cut-banks. The site of the formation is marked by such valleys as those of Fisher, Crassier, and Falling Creeks.

The only fossil obtained in the Moosebar formation by the writer is from an exposure on Beaudette Creek; it has been identified by McLearn as *Pecten* sp., and is not diagnostic.

Commotion Formation.

The Commotion formation, overlying the Moosebar formation, consists of relatively resistant sediments, chiefly sandstone, but including some shale and, in the upper part, a conspicuous conglomerate bed.

The Commotion formation is exposed on the ridge east of Crassier Creek, where it has been described by Spieker (1920), who regarded it as part of the " Bullhead Mountain Formation," and mapped by Wickenden and Shaw (1943). The outcrops of the formation can be traced in aerial photographs northward, with but one short gap at the Moberly River, to a point 4 miles south-east of Mount McAllister. In this vicinity a conspicuous steeply dipping conglomerate zone is exposed, but the less resistant beds are chiefly concealed. An exposure of the lower part of the Commotion formation has been found on the south fork of Gething Creek, 3 miles north-east of Mount McAllister, outside the map-area, where it overlies the Moosebar formation. Here the formation possesses a gradational contact with the underlying shales and consists chiefly of sandstones, in part ripple-marked, and at least one thin conglomerate bed. A conspicuous quartzite bed is exposed on the middle fork of Gething Creek on the northward extension of these beds, and sandstone beds, also referred to this formation, outcrop near the north end of Carbon (Indian) Lake.

The thickness of the formation has been estimated by Wickenden and Shaw (1943) in the Mount Hulcross-Commotion Creek area as at least 1,300 to 1,500 feet. No additional information on the total thickness of the formation has been obtained within the map-area.

No fossils have been found in any exposures of the Commotion formation within the map-area.

Hasler Formation.

The shaly beds overlying the Commotion formation have been defined by Wickenden and Shaw (1943) as the Hasler formation. These shales are known to outcrop within the map-area at only one locality, 5 miles south-east of Mount McAllister. An excellent exposure of about 350 feet of these beds, dipping about 45 degrees northeastward, is exposed in a cut-bank about 1,500 feet east of the outcrop of the Commotion conglomerate. In this exposure shales predominate, but several sandstone-beds 4 to 15 feet thick are present in the middle and upper part and conglomerate-beds several inches thick are common in the lower part. Fragments of a dicotyledonous leaf have been obtained from the sandstone-beds, but are too incomplete for identification and indicate only an age later than the Gething formation.*

Goodrich Formation.

The name " Goodrich formation " has been suggested by Wickenden and Shaw for the beds overlying the Hasler shales and underlying the Cruiser shales. Within the map-area the only exposures of beds which can be referred to this formation occur on the slopes of the north-eastern spur of Mount McAllister, 1 mile east of Wright Lake. These beds consist chiefly of sandstone and minor conglomerate. The underlying beds are concealed. The stratigraphic interval between the top of this formation and the top of the Moosebar formation exposed on the South Fork of Gething Creek is estimated to exceed 4,000 feet, considerably more than in the Mount Hulcross-Commotion Creek map-area (Wickenden and Shaw, 1943), where it is estimated to be between 2,950 and 3,300 feet.

Cruiser Formation.

About 1,000 feet of shales overlying those sandstones on the north-eastern spur of Mount McAllister which have been referred to the Goodrich formation may, in turn,

* Determination by W. A. Bell, Geological Survey of Canada.

be correlated with the Cruiser formation of the Mount Hulcross-Commotion Creek area (Wickenden and Shaw, 1943).

DUNVEGAN FORMATION.

About 200 feet of sandstones and conglomerates overlying the above-mentioned shales may be referred to the lower part of the Upper Cretaceous Dunvegan formation. These beds outcrop on the summit of the spur 2 miles north-east of Mount McAllister and form the top of the Mesozoic succession as exposed in the map-area.

STRUCTURE.

The map-area lies within the foot-hill belt of the Rocky Mountains and, as in other parts of the foot-hills, has been subjected to more or less intense folding and some faulting.

Both folds and faults, like the foot-hill belt itself, trend north-westerly. A distinct change in trend from about north 45 degrees west on the Pine River to about north 20 degrees west on the Peace River is evident.

Individual folds show marked variations both along the strike and down the dip of their axial planes. Folding, as a rule, tends to be concentric rather than similar. Changes in the character of a fold along strike can generally be related to the convergence or divergence of adjacent folds, but in some cases an anticline or syncline may pass along strike into a monocline and terrace before dying out on the limb of a larger fold. Many of the anticlines are distinctly flat-topped, resembling a drop-leaf table. At depth these flat-topped anticlines may pass into more regularly curved folds, then into sharp-crested anticlines (*see also* Fitch, 1942) in which the dip of the strata tends to increase as the axial plane is approached, and at still greater depths into complex faulted and folded anticlinal structures. Along the Peace River, within and to the east of the map-area, the anticlinal belts are much narrower and more closely folded than the adjoining synclinal belts, but this rule does not apply in the southern part of the map-area. Folding tends to be closer in the structures of the western side of the map-area than in those farther east.

Major faults, as a rule, follow anticlinal axes, but a few are found on the limbs of folds, and one east of Beattie Peaks follow a synclinal axis. Most, if not all, faults are of the reverse type, and with the exception of the fault mentioned above, east of the Beattie Peaks, the block to the west of a fault has been raised with respect to that on the east. The dips of the faults, wherever determined, are moderate to steep to the west. In some localities a system of uniformly spaced westerly dipping minor reverse faults cuts individual gently dipping sandstone-beds and dies out in the adjoining shales. This system of faults has effected a shortening of the strata in an east-west direction and a general thickening of the succession.

The map-area embraces two major anticlinal belts and an intervening synclinal belt. Each anticlinal belt is composed of two or more smaller anticlines with intervening synclines. The smaller folds commonly have an *en echelon* arrangement.

The eastern anticlinal belt, representing the north-westerly continuation of the "Pine River anticline," is relatively simple (*see* structure sections on map in pocket), but is intersected in the northern part of the map-area by a major fault which follows the fold axis for 15 miles from Mount McAllister to the Peace River. This fault, well exposed south-east of Wright Lake, dips westward at about 60 degrees and has a displacement of about 10,000 feet, bringing the Upper Monteith formation west of the fault into contact with the base of the Dunvegan formation east of the fault. At the Peace River the fault has a displacement of about 3,000 feet. South-east of Mount McAllister the fault lies in the eastern limb of the Pine River anticline. It has not been recognized at the Pine River and probably dies out some miles to the north.

The central synclinal belt includes the Carbon Creek basin and the Fisher Creek syncline, both of which contain infolded coal-measures. The northern part of the

Carbon Creek basin is a simple fold, but south of Eleven Creek the structure is complicated by several minor folds, and with a gradual south-easterly rise in the synclinal axes and a convergence of the adjoining anticlinal belts, the basin loses its identity near the head of McAllister Creek. The Fisher Creek syncline is modified near its axis by three parallel minor folds and, south of the Pine River, by faulting in its western limb.

The western anticlinal belt consists, on the Pine River, of a single overturned and closely folded anticline, locally modified by faulting along the fold axis. Between Mount Bickford and the Monach several *en echelon* folds can be recognized in this anticlinal belt, but only a single major fold exists between Mount Wrigley and Mount Barr.

A distinct south-easterly plunge of the fold axes is evident in both anticlinal belts and the Carbon Creek basin along the Peace River, but south of Eleven Creek and Carbon Lake this direction of pitch is reversed and a structurally high area exists between Mount Monteith and Mount Frankroy. Fold axes in all three belts have again a marked south-easterly plunge south-east of the Moberly River.

QUATERNARY GEOLOGY.

Erratics and striæ, left by the Pleistocene ice-sheet, are found up to an elevation of 6,000 feet, and it is possible that the ice-sheet covered the highest peaks of the area. The erratics include boulders of grey shell-bearing limestone, evidently derived from the Palæozoic or Triassic strata, and of sericite schists from the Precambrian rocks exposed in the central and western belts of the Rockies. These together with the striæ indicate a general easterly movement of the ice. No evidence of more than one period of glaciation has been recognized within the map-area.

Erosional features attributable to ice-action are rarely in evidence. A few cirques present on the higher peaks have been produced by local glaciers, and a few shallow rock-rimmed basins on the higher ridges may have been formed by the more extensive ice-sheet. The Moberly Valley in the central part of the map-area possesses a V-shaped cross-section modified by aggradation on the valley-floor and is by no means a glaciated trench. The valleys of the Peace and Pine are partly filled with unconsolidated sediments which effectively conceal the cross-profile of the lower part of the bed-rock surface. A few outcrops of bed-rock rising above the drift in the central part of the Peace River valley, one 3 miles west of the mouth of Carbon Creek and two others south of Gold Bar, suggest that a typical U-shaped trench of glacial origin is not present. Some tributary valleys, such as the one 6 miles south-west of Gold Bar, are hanging, but it is probable that rock structure rather than glacial erosion is chiefly responsible for this relationship. Some streams pass with high gradients through rocky canyons in their lower courses, having cut through a deep drift-cover and into bed-rock spurs.

Erosional features produced by running water temporarily diverted by ice have been observed at several localities in the area and include:—

Two short abandoned stream-channels at an elevation of about 3,000 feet on the west side of the Carbon Creek valley near Nine Creek.

Three steep-walled easterly draining channels between the elevations of 2,800 and 3,500 feet on the south wall of the Peace River valley north of Carbon Peak.

A stream-channel, now dry, in the pass 3 miles south of Mount McAllister.

In the latter locality a stream flowing eastward across a rocky spur on the south side of the valley deposited a pitted outwash plain at the site of the present divide between the Carbon and Moberly watersheds.

Glacial drift is common throughout the area but is scanty at higher elevations and, as a rule, is deep only near the valley-bottoms, where till is closely associated with terraced deposits of fluvioglacial origin. Deep deposits of drift, with or without a terraced surface, have diverted several of the tributaries of Carbon Creek across rock spurs, giving rise to canyons and exposing the coal-measures. Difficulties may be anticipated in the vicinity of the deeply buried former channels of these streams, not only in exploration for coal, but also in any mining operations. For example, the buried channel near the mouth of Eleven Creek, approximately a half-mile south of the present canyon, is filled in places with at least 300 feet of drift occupying the former site of many thousands of tons of coal.

Terraced drift is common in the valley of the Peace River and its tributaries up to an elevation of about 2,400 feet, not only within the map-area, but also westward for at least 10 miles to the Ne-parle-pas Rapids, and eastward at intervals, through the Peace River Canyon and past Hudson Hope to an extensive plain, composed of lacustrine sediments, which has a similar elevation (Beach and Spivak, 1943). A continuous pitted terrace, locally more than a third of a mile wide, extends westward from the mouth of Carbon Creek valley along the south wall of the Peace River valley for 4 miles. Relics of the same terrace can be found for at least 12 miles up Carbon Creek valley. Insufficient evidence is available to prove a northward slope to the terrace in this part, and any gradient, if present, is less than 10 feet to the mile. A cut-bank in the terraced deposit on Carbon Creek, 8 miles from its mouth, exposes a faintly stratified till in the lower part and poorly sorted gravel and sand in the upper part. Both the texture of the deposit and the presence of kettles clearly indicate that the deposit was laid down in close association with glacial ice. The well-defined, extensive, and nearly horizontal upper limit of the deposit probably marks the former level of an ice-dammed lake which extended up the Peace River valley. The terraced deposits of Carbon Creek and other tributaries to the Peace River may include some sub-aerial outwash built above the lake-level.

A second pitted terrace, at an elevation of about 2,050 feet, covers an area 1 by 3 miles on the south side of the Peace River west of Carbon Creek, and a relic of the same terrace exists to the east of Carbon Creek. The inner edge of this terrace is not marked by meander scarps such as would be formed by river erosion of the higher terraced deposit, and it has evidently been formed, like the higher terrace, by deposition. This terrace may, therefore, mark a second and lower lake-level.

The terraced drift has been modified in many places by late-glacial and post-glacial stream erosion. Unpaired terraces and slip-off slopes veneered with stream-laid silt sand, and gravel, as well as gulleys, cut-banks, and meander scars, are common both along the Peace River above Carbon Creek and on Carbon Creek itself. As a result of this erosion, terraced surfaces of destructive origin may be present at any elevation between the upper limit of terraced drift and the level of the present streams.

The scarcity of terraced drift along the Peace River below Carbon Creek provides a marked contrast with the area up-stream. For 6 miles below Carbon Creek, on the south wall of the valley, the higher terrace is present at the 2,400-foot level, but is narrow and fragmentary, while the lower terrace, at the 2,050-foot level, is little wider or more continuous. Terrace fragments are also present on the north wall of the valley. The general absence of cut-banks and meander scars wherever the terraces are missing indicates that late-glacial and post-glacial river erosion cannot be responsible for their complete removal. A mantle of unmodified till on much of the lower slopes of the valley wall indicates, moreover, that these areas have not been affected by stream-action since the disappearance of Pleistocene ice. It would appear, therefore, that much of the valley below the mouth of Carbon Creek has never been occupied by terraced drift and that its deposition may have been prevented by the presence of relic masses of glacial ice.

Post-glacial alluvium has filled this part of the valley-bottom for a width of 1½ to 2 miles to a height of a few 10's of feet above the present level of the Peace River. A part of this fill, at Branham Flats, 4 miles south-west of Gold Bar, has been worked for its gold content by a dragline operation, apparently without success.

Terraced drift is absent within the map-area on both the Moberly and Pine River valleys. Post-glacial alluvium has, however, filled the steep-walled Moberly Valley for an average width of almost half a mile, and the Pine River valley for a width of from ½ to almost 2 miles. The depth of unconsolidated fill in the Pine River valley, indicated by drilling at the Commotion Creek well, 13 miles east of the map-area, is 1,080 feet.

Alluvial fans have been built at the mouths of some of the streams, creating local dams. Carbon Creek has been partly blocked by such a fan at the mouth of McAllister Creek and, above this obstacle, meanders with a low gradient across silt-covered flats. Wright Lake apparently once drained westward to Carbon Creek, but has been dammed to such a height by an alluvial fan built at its south-western end by a stream from the south that it now drains north-eastward across the former divide into the head of Gething Creek. Carbon (Indian) Lake may have a similar origin, although the nature of the dam at its north-eastern end is not obvious.

COAL DEPOSITS.

GENERAL.

Distribution.

The known coal deposits of the map-area are confined to the continental beds of the Bullhead group, which outcrop for the most part in two main areas, the Carbon Creek basin and the Fisher Creek syncline, both lying within the central synclinal belt. The coal-bearing beds of the Bullhead group also outcrop in several areas west of the western anticlinal belt, both within and beyond the limits of the map-area. Although none of these areas are known to contain thick coal-seams, and some are of very limited extent, they nevertheless warrant further investigation. Coal-seams of mineable thickness presumably occur in the eastern limb of the Pine River anticline near Crassier Creek, but bed-rock is almost entirely drift-covered and so far no mineable seams have been discovered.

Coal has been reported to occur in both the Dunvegan formation (Williams, 1934) and the upper part of the Commotion formation in adjacent areas (Wickenden and Shaw, 1943), but to date no coal has been found in either formation within the map-area. The exposures of the Hasler formation, 5 miles south-east of Mount McAllister, contain fossils of continental origin, but here, too, no coal has been discovered. The other formations of the map-area are chiefly, if not entirely, of marine origin and are hence not coal-bearing.

The coal-seams are not uniformly distributed through the continental beds of the Bullhead group, but most of the thicker seams occur in the uppermost 1,000 feet. These uppermost beds have been spared from erosion only in the central parts of the Carbon Creek basin and of the Fisher Creek syncline, as well as on the eastern limb of the Pine River anticline near Crassier Creek, and hence many of the more valuable coal-seams underlie a much smaller area than do the coal-measures as a whole. The coal-rich upper beds of the Carbon Creek basin, for example, are estimated to underlie an area of about 5 square miles, whereas the total area in the basin underlain by the continental beds of the Bullhead group is about 120 square miles. About 10 to 12 square miles of these uppermost beds are present in the area mapped in the Fisher Creek syncline, but about half of this area is overlain by the Moosebar formation and is, therefore, buried to a depth which may reach 1,000 feet.

Number and Thickness of Seams.

The number of coal-seams of mineable thickness in the Carbon Creek basin and Fisher Creek syncline remains uncertain. Large parts of the coal-measures are concealed, and the possibility of repetition or omission of beds by folding and faulting, as well as the difficulty of correlating seams over long distances, adds to the difficulty of estimating their numbers. In the Carbon Creek basin, at least ten seams locally exceeding 4 feet in thickness and at least five other seams between 3 and 4 feet in thickness are known. In the Fisher Creek syncline, at least three seams exceeding 4 feet in thickness and two seams between 2 feet 11 inches and 4 feet in thickness are known. When the structure is more clearly understood and the concealed parts of the coal-measures have been explored by drilling, more seams of commercial width may be disclosed, especially in the heavily drift-covered areas of the Fisher Creek syncline and the eastern limb of the Pine River anticline.

Little is known of the variability in thickness of individual coal-seams, since many are known at one locality only or cannot be correlated with other exposures near-by. However, some information is available on the range in thickness of some of the seams of the Eleven Creek area in the central part of the Carbon Creek basin (*see* Table 2, page 25). Here one seam exposed at three points along a line a third of a mile long ranges from 4 feet to 4 feet 4 inches or possibly 5 feet in thickness. Another seam varies between 5 feet 7 inches and 6 feet 3 inches in thickness over a distance of three-quarters of a mile. However, in this same distance an adjacent seam, including shale partings, ranges from 10 feet 4 inches to 17 feet, but a part of this variation may be attributed to thickening of the seam at the crest of a fold. Two other seams, each slightly more than 4 feet thick, apparently correspond to two seams, each 1 foot in thickness, only 1,000 feet away; but the possibility of faulting in this locality renders the correlations uncertain. Other tentative correlations of seams and their variations in thickness are given later in the text and in Tables 1 and 2. In view of the possibility of marked variations in thickness of individual seams, and incomplete knowledge of their continuity, however, it is impossible to offer, on the basis of existing information, an estimate of the total available tonnage of coal in either the Carbon Creek or Fisher Creek areas.

Grade.

Interest in the coal deposits of the Peace River District has been attracted by the exceptionally low ash content and high calorific value of many of the seams. Several of the seams in the Carbon Creek-Mount Bickford map-area possess this high quality, although, as in coalfields elsewhere, other seams may have a high ash content and correspondingly low calorific value.

Most of the coal samples from the map-area were obtained from surface exposures in creek-canyons, and a few from open-cuts or from short adits not more than 20 feet below the surface. All the samples may, therefore, have been more or less influenced by weathering. Weathered coal tends to have a higher moisture content and a lower calorific value than fresh coal from the same seam. In a few cases, moreover, both as a result of weathering and of infiltration of soil into the surface coal, the ash content of the samples may be appreciably higher than in fresh coal from the same seam. In sampling, loose coal was removed from the face and shale partings rejected, as noted in the tables of analyses. Coal from the channels was not packed in air-tight containers.

Analyses of coal samples from the map-area indicate that several of the seams contain less than 5 per cent. ash and, in this respect, compare very favourably with coals from other North American fields. The calorific value is high, being more than 13,000 B.T.U.'s per pound for many seams, even in surface samples, and the calorific value of nearly all coal samples computed on an ash-free moisture-free basis exceeds 14,000 B.T.U.'s per pound. The carbon ratio, that is the ratio of the content of fixed carbon to volatile combustible matter, ranges from 1.7 to 4.7 and averages about 2.5. Most of the coal can be considered as medium-volatile bituminous according to the classification by rank as proposed by a committee of the American Society of Testing Materials (*see* Stansfield, 1937, p. 6). The marked variations in the carbon ratio may be attributed in part to weathering of coal samples, although there is a tendency to higher carbon ratios in the lower seams and in the more closely folded areas. With one exception, all samples were found to be of non-coking coal. Some of the seams have been crushed and would produce only friable coal or slack, but many of the seams are of relatively strong coal which would withstand a considerable amount of handling.

Experience of householders in the Peace River District indicates that the similar coals from the Hasler Creek and Hudson Hope areas produce an extremely hot fire in ordinary stoves and heaters. If Peace River coals were to be marketed on the Pacific Coast for domestic use, provision should be made for special adjustments and fire-brick walls for stoves and furnaces, or for blending the Peace River coal with some other coal having a higher content of volatile combustible matter. As steam-coal for use in larger installations, the cleaner Peace River coals are probably unexcelled.

Structure.

Both the coalfields of the map-area lie in synclines, and most of the coal-seams within these fields lie in the upper parts of the coal-measures near the axes of the synclines. Most of the seams are shallow, probably not exceeding a depth of 1,000 feet, except in the southern part of the Fisher Creek syncline, where the coal-measures are concealed beneath the Moosebar shales. This relatively shallow depth would favour exploration and development of the coal deposits. Most of the coal, however, lies below the level of the main streams and would have to be worked from shafts. The structure in the northern part of the Carbon Creek field is simple and the seams dip gently. Elsewhere, however, the moderate to steep dips of the strata and the presence of minor folds and faults would undoubtedly lead to difficulties in development and extraction of the coal, but the problems are apparently not markedly greater than those encountered and overcome in coal-mining elsewhere in the foothills of the Rockies.

Coal-seams of the Carbon Creek Basin.

The coal in the Carbon Creek field was first discovered in 1911, when Messrs. Cowper Rochfort and David Barr, with George McAllister, recognized the presence of coal float on the shores of the Peace River at the mouth of Carbon Creek and traced it to its source. Ten square miles of the coal-lands were subsequently acquired by Rochfort, Barr, and associates. The support of the late Senator Burns, of Calgary, was obtained for the development of the coal deposits, and the controlling interest in the coal-lands of the Carbon Creek basin is now held by the Burns Foundation. The Carbon Creek coal-occurrences were examined in 1923 by J. D. Galloway (1923) and reported upon for the British Columbia Department of Mines. In 1928 E. Beltz made a detailed examination of the exposures in the creek-canyons near the centre of the Carbon Creek basin for private interests. In 1943 a less detailed examination of the coal deposits was made by N. C. Stines (1943). Development-work, including trail-construction, stripping, and sampling, was carried on in 1944 and 1945 under the supervision of J. O. Howells.

The lowest of the thicker coal-seams known to occur in the northern part of the Carbon Creek basin is exposed on a small creek which enters Carbon Creek from the west, 5 miles above the Peace River. This seam lies about a quarter of a mile west of Carbon Creek and is about 1,000 feet above the base of the coal-measures. Its thickness is 2 feet 11 inches. An analysis (No. 1) of a sample from this exposure is given in Table 1.

Four seams are believed to be present near the junction of Carbon Creek and Seven Creek. The lowest of these seams, about 5 feet in thickness, is exposed on Seven Creek 2.2 miles from its mouth, and apparently also on a creek joining Carbon Creek from the east a few hundred yards above Seven Creek. This seam may also correspond to the one described by Galloway as occurring on Carbon Creek itself about half a mile below Seven Creek, but which could not be found by the writer. Analyses (Nos. 2, 3, and 4 respectively) of samples from these exposures are given in Table 1. This seam lies about 2,000 feet above the base of the coal-measures. The second seam, some 3 feet in thickness, lying approximately 250 feet above the first, is exposed on Seven Creek about 1.5 miles above its mouth, and apparently also on Carbon Creek opposite the mouth of Seven Creek (Analyses 5 and 6, Table 1). The third seam, 2 feet 4 inches thick, about 150 feet above the second, and a fourth seam, 2 feet 2 inches thick, 20 feet above the third, are exposed on Seven Creek 1.5 miles from its mouth (Analyses 7 and 8, Table 1).

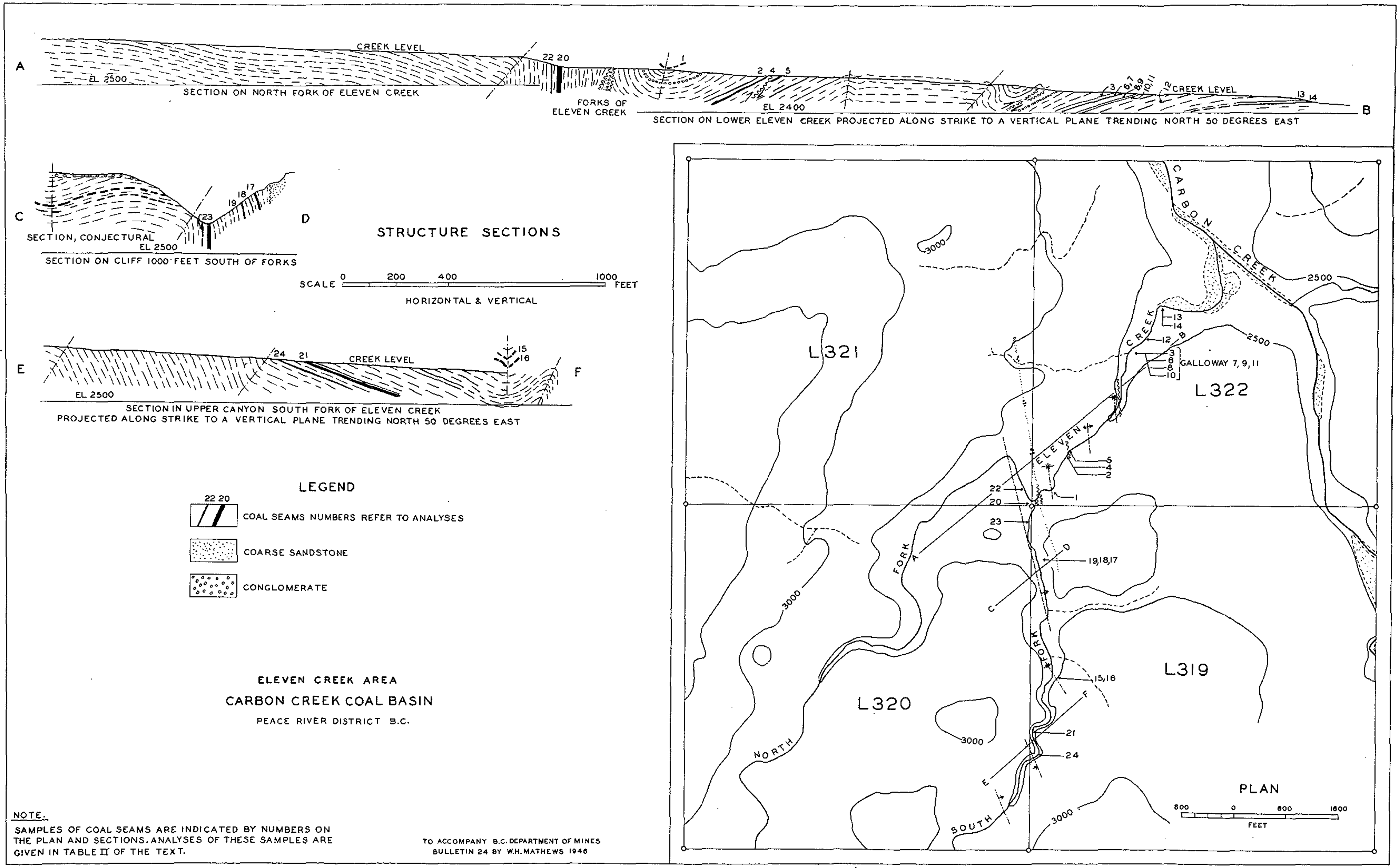
No other seams are known to occur in the northern part of the basin between these four seams and the seam, 3,000 to 4,000 feet above the base of the coal-measures, exposed on Nine Creek 1.2 miles from its mouth. The latter seam is described by J. D. Galloway as being 5 feet 4 inches thick, exclusive of a 2-inch shale parting 10 inches from the base of the seam (Analysis 9, Table 1). In 1944 and 1945 the lower part of this seam was inaccessible, and only the upper 4 feet 2 inches could be sampled (Analysis 10, Table 1). This seam may correspond to the lowest seam, about 6 feet thick, exposed in the canyons of Eleven Creek.

A seam 2 feet 7 inches thick, probably less than 1,000 feet above the base of the coal-measures, exposed in the western part of the basin on Eleven Creek 5 miles from its mouth (Analysis 11, Table 1) cannot be correlated certainly with any of those described above.

Several seams in the lower part of the coal-measures in the southern part of the basin outcrop on McAllister Creek and on a tributary entering it 2.8 miles above its junction with Carbon Creek. An exposure of one seam on the latter tributary 1 mile above McAllister Creek, possibly 1,000 feet above the base of the coal-measures, is 8 feet 9 inches thick, but has probably here been markedly thickened at the crest of a fold (Analysis 12, Table 1). A second seam 2 feet 6 inches thick exposed on McAllister Creek 2.2 miles above its junction with Carbon Creek lies perhaps 2,500 feet above the base of the coal-measures (Analysis 13, Table 1). A third seam, 2 feet 9 inches to 3 feet thick, exposed on McAllister Creek 1 mile above its junction with Carbon Creek, is perhaps 3,000 feet above the base of the coal-measures (Analysis 14, Table 1). The stratigraphic position of these three seams is difficult to determine because of the complexity of folding in this part of the basin.

The majority of the seams in the Carbon Creek field are exposed in the central part of the basin between the mouths of Ten Creek and McAllister Creek, at horizons probably at least 3,500 feet and possibly 4,500 feet above the base of the coal-measures. Nine seams locally exceeding 4 feet in thickness are present in about 650 feet of strata within this area. Most of the seams are exposed in the canyons of lower Eleven Creek and its southern fork, but in spite of the almost continuous exposures of the coal-measures found along these creeks, the existence of several faults renders the correlation of several seams and the determination of the intervals between them impossible on existing evidence. The succession of these seams, spacing where known, thicknesses, and analyses are given in Table 2. The positions where the samples, listed in Table 2, were taken are indicated in the plan and structure sections, Eleven Creek Area, Carbon Creek *Coal-basin* [redacted]. **Facing page 22**

One seam 34 inches thick, and apparently corresponding with one of the lower seams on the Eleven Creek section, is exposed on Ten Creek about 0.5 mile from its mouth (Analysis 15, Table 1). A pair of seams, the lower 5 feet 7 inches thick (Analysis 16, Table 1) and the second about 16 feet higher in the succession, 2 feet 6 inches to 6 feet thick (the latter figure reported by Stines) (no sample), outcrop on Carbon Creek 0.7 mile above the mouth of Eleven Creek. Their relationship to the seams on Eleven Creek is concealed by drift. They may correspond to the two lowest seams on Eleven Creek, since the lower seams in each case are of comparable thickness and the spacing between the seams is similar. The upper seam on Carbon Creek is, however, much thinner than the upper of the two seams on Eleven Creek. Two other


A
CREEK LEVEL
22 20
EL 2500
SECTION ON NORTH FORK OF ELEVEN CREEK
FORKS OF ELEVEN CREEK
2 4 5
EL 2400
CREEK LEVEL
13 14
B
SECTION ON LOWER ELEVEN CREEK PROJECTED ALONG STRIKE TO A VERTICAL PLANE TRENDING NORTH 50 DEGREES EAST
C
D
23
19
18
17
SECTION, CONJECTURAL
EL 2500
SECTION ON CLIFF 1000 FEET SOUTH OF FORKS
STRUCTURE SECTIONS
SCALE 0 200 400 1000 FEET
HORIZONTAL & VERTICAL
E
F
24
21
CREEK LEVEL
15
16
EL 2500
SECTION IN UPPER CANYON SOUTH FORK OF ELEVEN CREEK
PROJECTED ALONG STRIKE TO A VERTICAL PLANE TRENDING NORTH 50 DEGREES EAST
LEGEND
22 20
COAL SEAMS NUMBERS REFER TO ANALYSES
COARSE SANDSTONE
CONGLOMERATE
ELEVEN CREEK AREA
CARBON CREEK COAL BASIN
PEACE RIVER DISTRICT B.C.
NOTE.
SAMPLES OF COAL SEAMS ARE INDICATED BY NUMBERS ON THE PLAN AND SECTIONS. ANALYSES OF THESE SAMPLES ARE GIVEN IN TABLE II OF THE TEXT.
TO ACCOMPANY B.C. DEPARTMENT OF MINES
BULLETIN 24 BY W.H. MATHEWS 1946
CARBON CREEK
2500
3000
L321
L322
L320
L319
CREEK
13
14
12
3
6
8
10
GALLOWAY 7, 9, 11
ELEVEN
5
4
2
1
22
20
23
19,18,17
15,16
21
24
NORTH
FORK
SOUTH
PLAN
800 0 800 1600
FEET

seams, the lower 5 to 6 feet thick, the upper 3 feet 5 inches thick, separated by 18 feet of shale and sandstone, are exposed on Carbon Creek 3 miles above Eleven Creek. The lower seam outcrops in the creek, and only the uppermost 2 feet 6 inches could be sampled (Analysis 17, Table 1). The upper seam is exposed on the banks of the creek, and the full width could be sampled (Analysis 18, Table 1).

Other seams less than 3 feet thick are known, but have not been sampled. A seam (No. 13, Table 2) 4 feet 9 inches thick, including a 1-inch and a 2-inch shale parting, first disclosed by stripping on lower Eleven Creek in 1945, has not been sampled by the writer.

At several localities in the Carbon Creek basin, coal-seams have been partly burned. The shales and sandstones in their vicinity have commonly been baked to a brick-red colour, and in one place, on the south fork of Eleven Creek 0.2 mile from its junction with the main stream, the shales overlying one burned seam have been fused into a scoriaceous clinker, mottled in shades of red, yellow, brown, and green. In this locality contact of burned and unburned areas is exposed on the post-glacial canyon walls and nearly parallels the present surface. The burning has, therefore, taken place in post-glacial times, but in no place within the basin are the fires known to be still smouldering. The overlying beds have slumped down to occupy the position formerly occupied by the burned coal, and except on very continuous exposures the position of a burned coal-seam may not be detected. Comparison of an analysis of a sample taken only 1 foot from a burned area with the analysis of a sample from the same seam much farther from the burned area indicates that the coal close to the old fire was not materially affected by the heat.

Coal-seams of the Fisher Creek Syncline.

Little prospecting for coal has been carried on in the southern part of the map-area, partly because of the scarcity of continuous exposures, partly because of the remoteness of this area from easy transportation, and partly because of the reserve on staking of coal-lands which has been in effect since 1907. The presence of coal on Mount Bickford was reported by Williams (1934), and the occurrence of coal on Beaudette Creek is known to the residents of the Pine River valley to the east.

Only seven occurrences of coal in seams greater than 3 feet thick were found in this area by the writer.

One seam 3 feet 2 inches thick occurs 0.5 mile north-east of Bickford Lake, only about 300 feet from the base of the coal-measures (Analysis 1, Table 3). A second seam 4 feet thick is exposed 0.3 mile farther east and about 1,000 feet higher in the succession (Analysis 2, Table 3).

Five exposures of coal were found on Beaudette Creek, but may represent only three seams. Two of the seams are exposed on the eastern limb, and three on the western limb of a closely folded minor anticline in the uppermost part of the coal-measures. Although no faulting is apparent, the successions on opposite limbs of this fold do not correspond closely and the correlation of seams remains uncertain. The coal in all but one of the exposures is badly crushed and the seams lenticular. The first seam encountered on ascending Beaudette Creek, 2 miles from its mouth and a few hundred feet south-west of the fault separating the Moosebar formation from the coal-measures, varies from 5 to 15 feet thick and is 8 feet 5 inches thick where sampled (Analysis 3, Table 3). The second seam, 4 feet 4 inches thick and not badly crushed, lies about 150 feet stratigraphically lower in the succession than the first and about 200 feet up-stream from it (Analysis 4, Table 3.) The third seam, exposed on the western limb of the anticline a few hundred feet up-stream from the second, is 2 feet 11 inches thick (Analysis 5, Table 3). The fourth exposure, a seam which may correspond to the second, is 4 feet 2 inches thick and about 50 feet stratigraphically above the third. The fifth and last exposure, a seam which may correspond to the first encountered, is crushed and lenticular, varies up to 10 feet thick and is 9 feet where sampled (Analysis 7, Table 3).

TABLE 1.—ANALYSES OF COALS.

Northern Part of Carbon Creek Basin.

Analysis No.*	Distance above Base of Coal-measures.	Thickness sampled.	H_2O.	Vol. Comb.	Fixed Carbon.	Ash.	Sulphur.	B.T.U.'s.
1	1,000′	2′ 11″	3.3	21.6	70.1	5.0	0.49	13,590
2	2,000′	5′ 0″	5.8	24.3	64.7	5.2	0.52	12,800
3	2,000′	5′ 4″	5.2	20.4	59.2	15.2	0.47	11,410
4	2,000′	4′ 6″†	2.1	22.0	69.4	6.5	......	....
5	2,250′	3′ 0″	2.6	17.9	49.8	29.7	0.54	9,580
6	2,250′	3′ 5″	2.7	18.3	57.6	21.4	0.71	11,410
7	2,400′	2′ 4″	2.8	24.2	64.0	9.0	0.65	13,320
8	2,420′	2′ 2″	4.2	21.4	61.0	13.4	0.58	12,040
9	3,500′	5′ 4″‡	5.5	24.8	61.5	8.2	......	....
10	3,500′	4′ 10″§	2.8	25.8	63.9	7.5	0.67	12,930
Western Part of Carbon Creek Basin.								
11	1,000′	2′ 7″	5.0	19.5	72.1	3.4	0.46	13,320
Southern Part of Carbon Creek Basin.								
12	1,000′	8′ 9″‖	4.5	15.6	66.9	13.0	0.36	12,090
13	2,500′	2′ 6″	2.5	16.4	77.5	3.6	0.50	14,180
14	3,000′	2′ 10″	2.0	20.0	69.7	8.3	0.76	13,470
Central Part of Carbon Creek Basin. (Except Eleven Creek, *see* Table 2.)								
15	3,500′–4,000′	2′ 10″	4.4	25.6	65.4	4.6	0.57	12,850
16	3,500′–4,000′	5′ 7″	7.3	22.7	55.4	14.6	0.48	10,620
17	3,500′–4,000′	2′ 6″¶	1.8	21.5	75.6	1.1	0.52	14,620
18	3,500′–4,000′	3′ 5″	1.5	30.2	64.3	4.0	0.78	13,980

* For locality *see* text, pages 21 to 23.
† Taken by J. D. Galloway—full width of seam, but excluding 5 inches of bone.
‡ Taken by J. D. Galloway—full width of seam, excluding 2 inches of shale parting.
§ Base of seam not accessible.
‖ Probably thickened locally at crest of a fold.
¶ Five- to six-foot seam, base not accessible.

TABLE 2.—ANALYSES OF COALS—ELEVEN CREEK, CARBON CREEK BASIN.

Interval between Seams.	No.	Thickness sampled.	H_2O.	Vol. Comb.	Fixed Carbon.	Ash.	Sulphur.	B.T.U.'s.
	*1	3′ 6″	3.4	30.4	52.7	13.5	0.56	11,830
120 feet								
	2	1′ 9″	3.4	29.2	61.0	6.4	0.85	12,670
	3	1′ 8″	4.5	29.8	60.3	5.4	0.73	12,730
10 feet								
	4	4′ 1″	3.3	27.0	66.3	3.4	0.57	13,150
	5	4′ 3″	1.9	27.2	68.6	2.3	0.77	13,980
	6	4′ 4″	3.5	26.1	67.3	3.1	0.49	13,620
	7	5′ 0″‡	4.6	25.2	66.6	3.6	......	....
15 feet								
	8	1′ 4″	2.7	24.9	56.8	15.6	0.70	12,000
	9	1′ 4″‡	2.9	23.7	56.2	17.2	......	....
3 feet 6 inches								
	10	2′ 2″	2.7	27.7	66.9	2.7	0.67	13,650
	11	2′ 1″‡	3.4	26.2	67.7	2.7	......	....
45 feet (±)								
	12	4′ 9″	.....	......	......	......	......	....
80 feet (±)								
	13	1′ 1″	2.2	29.4	65.9	2.5	0.79	13,750
4 feet 9 inches								
	14	2′ 10″	3.4	24.5	68.4	3.7	0.70	13,150
(?)								
	15	4′ 0″§	3.0	19.5	46.1	31.4	0.44	9,140
25 feet								
	16	6′ 0″	3.3	23.3	70.7	2.7	0.59	13,650
100 feet (?)								
	17	4′ 4″‖	7.2	25.3	57.2	10.3	0.59	10,950
18 feet								
	18	4′ 5″‖	9.6	20.5	54.9	15.0	0.47	10,360
25 feet								
	19	4′ 3″‖	5.5	25.1	67.7	1.7	0.53	12,700
125 feet								
	20	17′ 0″‖	2.2	25.1	58.1	14.6	0.62	11,840
	21	9′ 2″¶	2.9	23.6	57.9	15.6	0.50	11,740
15–20 feet								
	† 22	6′ 0″	2.6	25.5	69.2	2.7	0.61	13,970
	† 23	6′ 3″	7.2	25.6	64.0	3.2	0.48	12,230
	† 24	5′ 7″	3.6	23.9	70.1	2.4	0.61	13,580

* Highest known seam.
† Lowest known mineable seam in Eleven Creek area.
‡ Sampled by J. D. Galloway.
§ Only upper 3 feet 4 inches sampled.
‖ Thickness may be abnormally great.
¶ Excluding 14-inch shale parting.

TABLE 3.—ANALYSES OF COALS—FISHER CREEK SYNCLINE.

No. and Locality.*	Thickness sampled.	H_2O.	Vol. Comb.	Fixed Carbon.	Ash.	Sulphur.	B.T.U.'s.
1. North-east of Bickford Lake	3′ 2″	2.6	16.2	77.2	4.0	......	14,240
2. North-east of Bickford Lake	4′ 0″	1.7	17.5	63.2	17.6	......	12,140
3. Beaudette Creek	8′ 5″	1.7	18.1	36.3	43.9	......	8,100
4. Beaudette Creek	4′ 4″	1.5	25.4	58.7	14.4	......	12,890
5. Beaudette Creek	2′ 9″	1.6	22.9	59.6	15.9	......	12,630
6. Beaudette Creek	4′ 2″	2.2	21.5	65.1	11.2	......	12,850
7. Beaudette Creek	9′ 0″	2.2	18.8	46.1	32.9	......	9,630

* For more precise locality and stratigraphic position *see* text, pages 23 and 24.

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