STRATIGRAPHY AND STRUCTURE

of the

FOOTHILLS BELT, WESTERN ALBERTA,

between

HIGHWOOD AND BERLAND RIVERS.

by

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Being a thesis submitted to the University of Manitoba in partial fulfillment of the requirements for the Master of Science degree, April, 1930.

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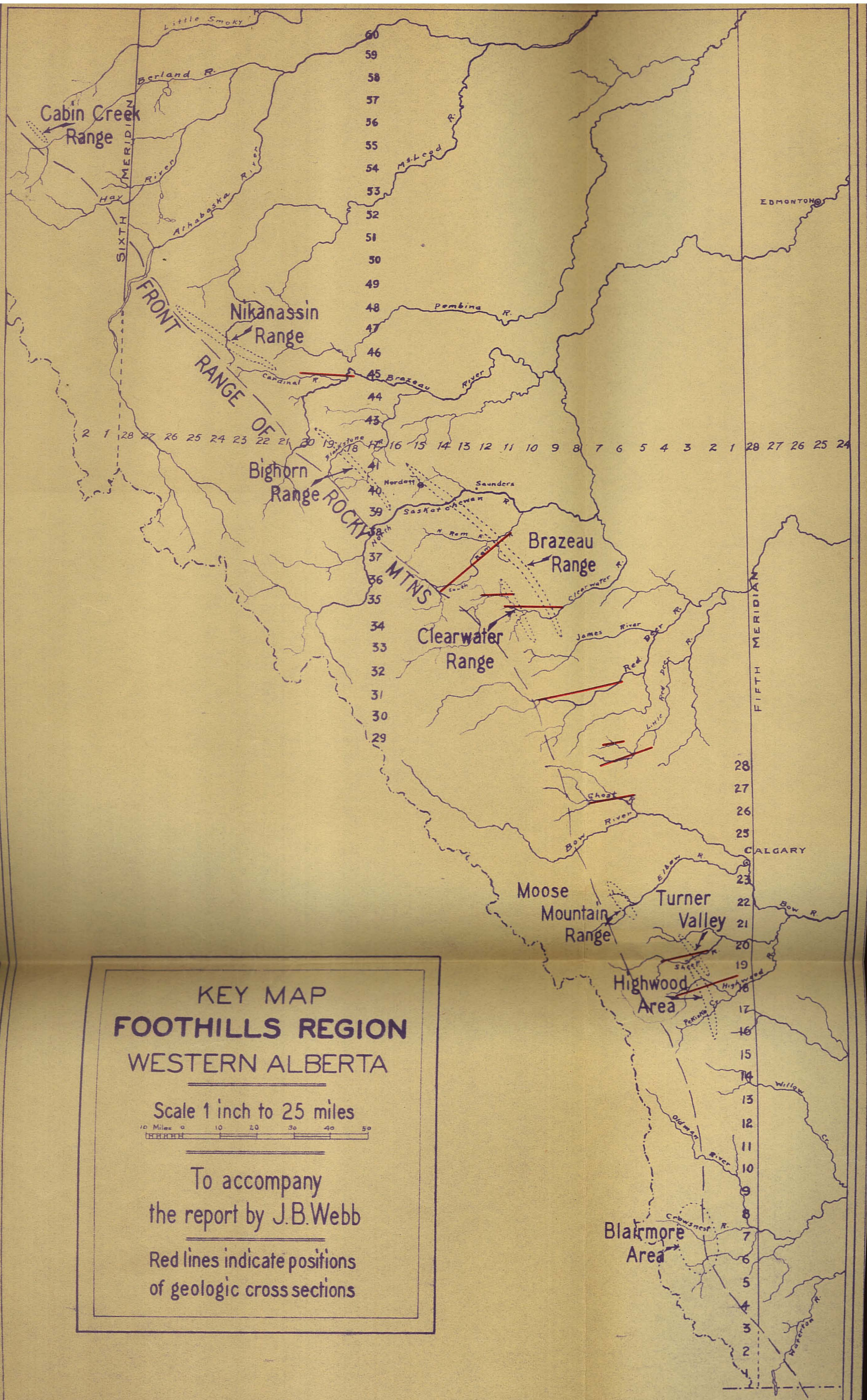
KEY MAP
FOOTHILLS REGION
WESTERN ALBERTA

Scale 1 inch to 25 miles

10 Miles 0 10 20 30 40 50

To accompany
the report by J.B.Webb

Red lines indicate positions
of geologic cross sections



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INTRODUCTION

GENERAL SUMMARY

The data and conclusions embodied in the following geological description of a portion of the foothills of Alberta are the results of three field seasons (1927 - 29) spent by the writer in this region, while in the employ of the Hudson's Bay Oil and Gas Company. Particular attention was given to the stratigraphy, and the gap which had previously existed in our knowledge of the formations and structure between Bow and North Saskatchewan rivers was satisfactorily filled. Fairly good fossil collections were obtained and determined by recognized authorities; more definite information was gained as to the range of certain genera and species, and the age of the formations in which they occur. Particular mention may be made of the northward extension of the Blairmore formation, and its correlation with those formations, previously named and described by other workers, north of the North Saskatchewan river. A correlation diagram is included herein.

The discussion of the structural features of the region is necessarily condensed; a number of structural cross-

sections are included, which have been constructed from traverses along the principal streams where outcrops are fairly abundant.

A key map shows the location of the more important topographic and structural features, and also the positions of the cross-sections.

PREVIOUS WORK

In the territory from Highwood river to Bow river, the published reports by Stewart[48], Dowling[9], Slipper[47], Cairnes[6], Hume[10-13] and Rutherford[42] have contributed much to our knowledge of this part of the foothills belt.

For the area between Bow river and North Saskatchewan river practically nothing is available in the way of published geological data. Rose[34] made a rapid reconnaissance along the principal streams many years ago.

North of the North Saskatchewan considerable work has been done by Allan[1,2], Rutherford[38-44], MacKay[17], Warren[52] and MacVicar[19-21], most of the results of which have been published.

A bibliography of foothills geology is included with this report, the numbers cited with the names of the above-mentioned authors having reference to this list.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge with thanks the determinations of various fossil collections by F. H. McLearn, of the Geological Survey of Canada; P. S. Warren of the University of Alberta, L. G. Hertlein of the California Academy of Sciences, and W. S. Dyer of the Ontario Department of Mines. Thanks are also due to E. W. Berry of Johns Hopkins

University for his work on the plant collections of 1927, and to C. Sternberg of the Geological Survey of Canada, for the identification of the few dinosaur remains that were found.

GEOLOGY

GENERAL STATEMENT

The region lying between Highwood and Berland rivers in the foothills belt is underlain by strata ranging in age from Middle Devonian to late Cretaceous or probably early Tertiary. Those outlying mountain ranges which represent the major uplifts and expose the Paleozoic and older Mesozoic formations are, from south to north, Moose Mountain range, Brazeau range, Clearwater range, Bighorn range, Nikanassin range and Cabin Creek range. The younger Cretaceous formations appear in the deep synclines and fault blocks within the foothills.

Although the entire sequence of formations appears to be conformable, one upon another, it is known that at least two breaks occurred in the sedimentary record. The most important of these was the hiatus between Mississippian and Fernie times. A lesser interval of evident uplift and erosion is indicated by the relations between the Kootenay and the overlying Blairmore formation.

STRATIGRAPHY

The following stratigraphic table summarizes the lithologic character and faunal content of the various formations. It should be noted that the Whitehorse (Triassic) formation and the Nikanassin (Kootenay) formation are absent

in the eastern part of the foothills belt. Certain of the formations thicken rapidly from east to west across the foothills.

Stratigraphic Table

Age		Formation	Lithology	Thickness
Cretac.-Tertiary	Montana & Later	Belly River and younger	Fresh-water ss. and sh. gray and green-gray beds up to 60' thick. Coal occurs at several horizons. A few gastropods and Unios, rare dinosaur bone fragments.	7000' +
Upper Cretaceous	Upper Colorado Early Montana	Upper Benton	Marine dk. gray sdy. shales. Upper 500' very sdy. Many brown ironstone conctns. Baculites ovatus common. Middle 450' finely bedded, hard calc. layers occur. Ostrea cf. congesta, Anomia sp. common. Lower 400' sdy. sh. small conctns. of brown ironstone, fine hd. ss. ribbons. Scaphites ventricosus	1350'
	Upper Colorado	Cardium Ss.	Marine ss. and sh. Upper ss. approx. 75' thick sometimes with cgte. Middle sh. sdy. with conctns. approx. 150'. Lower ss. 75' Cardium paupereulum	300' +
	Lower Colorado	Lower Benton	Marine sh. Upper part has small conctns. Middle part fine, fissile black clay sh. with ss. ribbons. Inoceramus labiatus, Prionotropis sp. in hard bands in this sh. Lower part sdy. rusty sh.	900'
Upper & Lower Cretaceous		Blairmore	Upper part gray and greenish cgtic. ss. and sdy. shales with red bands ("Dakota"). Middle contains coal seams in north. Brackish to fresh-water dark shales and ss. in lower part, containing fossils Corbula & Pachymelania. Basal conglomerate.	1100' to 1800'

Stratigraphic Table
Cont'd.

Age	Formation	Lithology	Thickness
Lower Cretaceous	Nikanassin (Kootenay)	Interbedded brownish to gray ss. and dark shales, carbonaceous toward top.	1200'
Jurassic	Fernie	Black, marine sh. with brown to light gray ss. bands. Few thin hard black limestone bands in the shale. Belemnites.	350' to 1200'
Triassic	Whitehorse	Upper part lt. grey to creamy white hard and porous ls. Lower part interbedded dk. gray to brown ss. and black shales. Ammonites occur.	600' to 900'
Mississippian	Mississippian	Uppermost 200' very porous dk. gray to compact lt. gray dolomite. Below this coarse to fine cryst. gray ls. Basal part thinly bedded, shaly ls. and sh. with thin black chert stringers. Fossils abundant.	1150'
Devonian	Devonian	Fine-gr. hd. dk. gray ls. at top, massive bed 150' in thickness. Below this inter-bedded soft shaly ls. and sh. with hd. ledges of ls. or dolomite.	1000' +

Devonian

Rocks of Devenian age are exposed in the Clearwater, Brazeau, Bighorn and Nikanassin mountain ranges. The most complete and best exposed section was found in Saskatchewan Gap, where the North Saskatchewan river has cut deeply into the Paleozoic formations which form Brazeau range.

The following section was measured:-

Overlying beds, soft shales and shaly limestones of Mississippian formation.

150' limestone, dark gray, very hard, dense to finely crystalline, makes prominent ledge. Fossils plentiful at top, Spirifer whitneyi, Athyris angelica, etc. - An Upper Devonian fauna.

400' interbedded limestone and dolomitic limestones, gray and dark gray, with few thin banded ss. beds, brownish-gray. In general softer than the top member, though few hard limestones ledges up to 30' thick are seen. Orthoceras sp. and cf. Favosites limitaris Rom.?

12' Shale, soft, sandy, bright green.

200' Limestone and sandy limestone as previously.

150' Limestone, hard, dark-gray, with softer shaly beds included. Fossils in top, Leiorhynchus parviplicatum Kelly, Atrypa reticularis (Linn.)

100' Shale, calcareous, fairly soft, light green-gray on outcrop, platy to fissile. Few fossils in top. Rizoceras? Peterioceras?

20' + Limestone, black, thinly bedded on top becoming more massive going down in section. Fossils rare. Manticoceras sp.

The lowest bed of the above section is dated as "probably Devonian" on the basis of the Manticoceras sp. Therefore the Devonian measures at least 1000 feet in thickness, and is not totally exposed.

Devonian has been used as a formation name in the field, no attempt having been made to sub-divide this series of rocks. It seems likely that the uppermost massive limestone member, which contains the Spirifer whitneyi fauna, is equivalent to the Minnewanka limestone of Banff area.(45)(53)

Mississippian

The Mississippian formation conformably overlies the Devonian, where it is exposed in the outlying mountain ranges. A good section of the lower and middle part of this series of beds is exposed in Saskatchewan Gap; the uppermost part is seen to best advantage on the railroad cuts east of Nordegg.

A composite section of the formation follows:-

Overlying beds:- Black, hard, limestones and shales of basal Fernie (Jurassic)

100' Fine grained gray to light gray dolomites interbedded with similar but porous dolomites. Black bitumen (?) residue in pores.

90' Very porous dolomite, gray to dark gray, - some thin non-porous bands, very fine-grained non-crystalline, white weathering. Pores contain much black material, with secondary calcite also. Few poorly preserved gastropods and Syringopora?

95' Chiefly massive finely crystalline gray to light gray limestone. Rare pores with black residue therein. In base coarsely crystalline ls. dark gray. Syringopora surcularia occurs here.

325' Massive to platy limestones, coarsely and finely crystalline, gray to dark gray or buff in certain beds. Chert occurs in nodules and strigers, lt. gray to black in color. Cup corals and Chonetes sp. found in middle.

3' Limestone, gray, full of Spirifer cf. striatiformis and Cliothyridina sp.

50' thinly bedded gray, sandy limestone and black chert.

125' Limestone in hard, crystalline bands up to 3' thick, separated by intervals of 20' of platy limestone and shale. Fossils plentiful, such as Spirifer striatiformis, Camarotoechia metallica, Productella pyxidata, Composita humilis, etc. - a Kinderhook fauna.

100' Limestone, creamy-gray, shaly, breaking down into small pieces.

250' Limestone, thinly bedded to shaly, basal 100' contains much black or dark gray chert in thin stringers along bedding planes. From the top of this member were collected, Spirifer striatiformis, Fenestella cf.rudis Brachythyris chouteauensis, Schizophoria chouteauensis, etc. A Kinderhook fauna of lowest Mississippian.

The thickness of this series of beds is approximately 1150 feet, and apparently does not vary a great deal in the outer mountain ranges.

The age of the formation extends from lowest Mississippian to possibly Pennsylvanian, though, for the present, the whole series is regarded and classed as Mississippian. The typical Madison coral, Syringopora surcularia, occurs some 300 feet from the top. The upper two thirds of the formation is about equivalent to the Rundle limestone, and the lower one third to the Banff shale, of the Banff area.(45)(53)

Whitehorse Formation (Triassic)

The Whitehorse formation consists of a series of marine or brackish water sediments, the upper half consisting chiefly of limestones and the lower half of fine sandstones and shales. It has been named for Whitehorse creek, a tributary of McLeod river, which enters the latter stream on the west side of the Nikanassin range at the south-west end of Cadomin Gap. The Whitehorse formation has been mapped as Triassic by B. R. MacKay* in this area, and is at least in part the equivalent of the Upper Banff Shale as mapped by Malloch(54) along the Bighorn range to the south. In the Brazeau range country to the south-east, this formation

* Personal communication.

is entirely missing; this is also the case in the far south in Moose Mountain area. It can be traced north-westward from the type locality, however, and has been recognized north of Berland river in Cabin Creek range.

A generalised section is given below:-

Overlying bed:- Soft black shale of Fernie formation.

150' Hard lt.gray to creamy white limestone, weathering slight rusty tint in places. Chiefly massive beds with thinly bedded intercalations. Pseudo-brecciated bands in lower part, also some undeterminable pelecypods.

60' Soft, gray, shaly limestone, weathering buff or light yellow. Highly porous or brecciated appearance for most part, but contains hard compact bands.

20' Hard, reddish-weathering sandstone, shaly limestone and compact shale.

45' Interbedded soft and hard, porous and compact, buff limestone, shaly limestone and calcareous shale.

375' thinly bedded, brown to dark gray, fine calc. sandstone and dark gray to black fine shales. Ss. beds up to 4' thick. Shales very fine and fissile in places. Thin bands of fossiliferous, porous, buff limestone 75' above base. Ammonites occur in these beds.

Underlying beds - Mississippian limestones.

In the Nikanassin range territory, the Whitehorse formation is from 600 feet to 750 feet in thickness; farther north, along Cabin Creek range, it would appear to be closer to 900 feet thick.

It is possible that the Triassic sea, in which these sediments were deposited, extended much farther east and south and included the Brazeau range area. The pre-Fernie period of uplift and erosion, however, was of sufficient duration and intensity to remove all evidence of Triassic sedimentation from Brazeau range.

On the other hand, the Whitehorse formation may represent the deposition along the eastern fringe of the Triassic Cordilleran trough. In this case, the formation would undoubtedly thin rapidly eastward, and the Brazeau range country was probably an area of non-deposition, as indicated by the Mississippian - Fernie hiatus.

In the Cabin Creek area, north of Berland river, a small collection of ammonites was obtained from the basal part of the Whitehorse formation. They have been tentatively identified by Warren as:-

(1) Probably Tenaspis marcovi. Hyatt and Smith.
or Ophiceras dieneri

(2) Probably Meekoceras gracilitatis. White.

(3) Resembles Ceratites blakei. Gabb
or Meekoceras n. sp.

There seems little doubt that these beds are of the lower part of the Lower Triassic. The age of the upper part of the formation is still in doubt, but stratigraphic evidence would indicate that deposition was continuous from basal into upper Whitehorse time, hence the entire formation is probably of Triassic age.

Fernie Formation (Jurassic)

The name Fernie formation was originally applied by Leach[15] to the marine Jurassic beds in the Blairmore area, near Fernie, B. C. These sediments are chiefly dark shales with sandstone and limestone bands, containing several faunas, among which Belemnites sp. is common. At the type locality the Fernie formation is about 1000 feet thick. It rests disconformably upon the underlying Paleozoic limestones and

grades upward into the terrestrial deposits of the Kootenay; the latter formation contains coal measures in the upper part.

In the Moose Mountain area, Cairnes[6] found about 250 feet of dark marine shales holding Belemnites sp. lying disconformably on the Paleozoic limestone and grading upward into a sandstone and shale series containing coal seams. Since the correlation with the Blairmore area appeared obvious, he named the marine shales the Fernie formation and the coal-bearing beds the Kootenay formation.

On Wilson creek, a tributary of James river, which drains the area immediately south and west of Brazeau range, the Fernie is readily recognized. Here it consists of some 300 feet of beds, chiefly dark marine shales with brown-weathering sandstone in the base, lying with apparent conformity upon the Paleozoic limestone. In the lower part of the dark shales, thin, hard, black limestone bands are present, and layers up to 6 inches thick composed of Belemnites guards occur. The Fernie is overlaid by the basal conglomerate of the Blairmore formation. The Kootenay of the south is entirely missing in the Brazeau range country. Sandstone beds within the Fernie become of more importance farther north, replacing in part, the fine black shales. A section of the formation measured in Dutch creek, a tributary of the North Saskatchewan, comprises the following beds:-

Overlying bed:- Basal conglomerate of Blairmore formation.

5' Sandy, poorly bedded, greenish shale.

50' Interbedded sandstone and shale, the latter increasing in importance toward the base.

100'	Sandstone, platy to massive, fine grained, hard, light grey on fresh surface, light brown on outcrop.
50'	Shale, fine, black, fissile, but with sandstone ribbons in upper 25', which increase in number and thickness toward the top.
12'	Sandstone, fine grained, hard, light grey on fresh surface, weathers rusty brown.
12'	Shale, with small sandstone bands.
3'	Sandstone as before. Contains numerous casts, consisting of black chert, of Trigonia sp., Artica sp. and Belemnites sp.
10'	Obscured shale.
3'	Sandstone as above, with similar fossil contents.
20'	Obscured shale.
50'	Black, dense cherty limestone and slabby, black, sandy shales. Rare Pecten sp. and Pseudomonotis sp.

Underlying bed - Light gray limestone (Paleozoic - Mississippian)

The Fernie formation is from 300 feet to 350 feet in thickness wherever observed along Brazeau range.

The contact between the Fernie and Mississippian limestone or dolomite appears to be uniformly conformable, but it is known that an hiatus of considerable magnitude is represented, since the Pennsylvanian, Permian, Triassic and Lower Jurassic are entirely missing.

The basal Blairmore conglomerate, which limits the Fernie formation at the top, is a widespread horizon marker, and, though generally appearing to be conformable with the underlying beds, gives evidence of a disconformable relationship at a few localities. This conglomerate is known

to rest upon successively higher beds as it is traced westward.

In the Bighorn and Nikanassin ranges to the west and north-west of Brazeau range, a much greater thickness of beds is referred to the Fernie. This series, which is roughly 1200 feet thick, rests conformably upon the white limestones of the upper Whitehorse formation, and grades upward into the interbedded sandstones and shales of the Nikanassin formation.

The stratigraphic relations between the Fernie and Nikanassin formations would appear to be comparable to those existing between the Fernie and Kootenay of the south, the two formations in each case representing a series of deposits which is entirely gradational in character from marine to brackish or fresh water sediments. Such being the case, the upper limit of the Fernie in the Nikanassin range country is purely an arbitrary line, drawn at that point in the section where the typical Fernie shales become of minor importance, giving place to what is predominantly a sandstone series with interbedded shales.

An approximate section of the Fernie of this area comprises the following beds:-

Overlying bed, thick ss. at base of Nikanassin formation.

800' Chiefly dark gray sandy shales with thin bands of brownish-weathering ss., and few thick lenses of similar ss. Thinner bedded toward base, less ss.

17' Dark gray sandstone.

50' Fine, dark gray shale.

5' Calc. ss. or sandy limestone, dark gray. Weathers brown on top, concretionary in character, with many fossils.
Belemnites sp. Gryphea sp.
Ammonites sp. Pelecypods (new)

45' Soft black shale.

12' White quartzitic ss., hard, massive bed.

195' Soft black shale, thin brown ss. ribbons, toward top.

60' Hard black cherty ls. and sdy. ls. and shale.

5' Soft black shale.

Underlying bed, white ls. at top of Whitehorse formation

North of Berland river, in the Cabin Creek area, about 300 feet of fine black shale containing Belemnites sp. overlies the Whitehorse formation, and grades upward into intercalated sandstones and shales. Just how much of this sandy series should be included in the Fernie formation is problematical.

The great thickening of the Jurassic westward from Brazeau to Nikanassin and Bighorn ranges is interesting indeed. It may indicate that the Fernie sea continued to exist much later in the western areas than it did farther east, or possibly this thick section once extended far to the east but was largely removed during the pre-Blairmore period of uplift and erosion.

Nikanassin Formation (Kootenay)

Some reference has already been made to the Nikanassin and Kootenay formations, and their probable equivalence has been indicated.

The Nikanassin formation was named by B. R. MacKay[17] for Nikanassin range, and consists of a series of brackish to fresh-water sandstones and shales which is gradational into the underlying Fernie formation, and is limited at the top by the Cadomin (basal Blairmore) conglomerate. The thickness is approximately 1200 feet. In lithological character, the Nikanassin formation presents a monotonous succession of massive to platy sandstones, chiefly rather fine-grained, with interbedded fine-grained or sandy black to dark gray shales. A change is noticeable in the character of the sandstones from the basal part upward in the section, since the lower sandstones are light gray and quartzitic on a fresh surface, whereas they become rather carbonaceous and brown to dark gray in color toward the top of the formation. The interbedded shales also contain carbonaceous material; coal seams, however, have not been found in the Nikanassin formation.

This series of beds is continuous in a northwesterly direction to beyond Berland river, having been recognized along Cabin Creek range. As previously indicated, the Nikanassin formation is not present in the Brazeau range territory to the south-east, but is well developed along Bighorn range.

Fossils are rare in these beds; merely a few poorly preserved pelecypods were found, which have been classed "new species". No determinable plant remains were obtained.

In the Moose Mountain country, south of Bow river, Cairnes[6] placed some 350 feet of sandstones and shales,

with coal seams in the upper part, in the Kootenay formation. This series grades into the marine Fernie below, and is overlaid by the basal Blairmore conglomerate at the top. (Basal Dakota of Cairnes.) The evidence of plant remains, presence of coal seams, and general stratigraphic relations lend support to the correlation of this formation with the Kootenay of Blairmore area.

On the basis of its relation to the Fernie shale, the Nikanassin formation would appear to be at least in part equivalent to the Kootenay formation. It is evident, however, that the Kootenay coal seams do not extend into the northern part of the region under discussion. It will be shown in the description of the Blairmore formation, that the commercial coal series of the northern coal areas are not of Kootenay age, - as Allan and Rutherford[38, 39, 40] have reported, - but are much younger.

The recent work of Hume on the Canyon creek section, Moose Mountain area, brings forward some evidence of a discordance at the contact between the Kootenay and Fernie formations. Cairnes[6], however, regarded the contact as quite conformable and concluded that the change from Fernie to Kootenay deposition was transitional. The present writer agrees with Cairnes that no disconformity between the Fernie and Kootenay formations is represented in this area.

It is of interest to note here an evident misuse of terms in the formational nomenclature of Turner Valley oil field[10], where some 550 feet of beds is referred to the Kootenay formation. The top of this series is marked by a poor coal seam, of rather erratic development, under-

laid by dark greenish and gray sandstones and sandy shales, with black shales becoming more prominent as the section is descended. The white or light gray, fine, quartz, "Home" sandstone lies in the middle of the formation; the shales below this bed are mostly black and fine-grained, with brownish, hard limestone bands and fine gray calcareous sandstone layers. Pelecypods and gastropods are abundant in thin zones. The base of the Kootenay is marked by the "Dalhousie" sandstone, which is generally coarse-grained and often conglomeratic.

Immediately underlying the "Dalhousie" sandstone, a coal seam occurs, and this bed is underlaid by the "Brown sandstones" which are evidently gradational downward into the marine Fernie shale.

It is the writer's conclusion, after considerable study of the Kootenay and Blairmore formations in the foothills to the west and north of Turner Valley area, that the Kootenay formation, if present at all in this field, is represented by the "Brown sandstones" and the overlying coal bed. The "Dalhousie" sandstone will then correlate with the basal Blairmore conglomerate; the lithology and faunal content of the strata between the "Dalhousie" sand and the "Kootenay coal" of Turner Valley correspond closely with the lower Blairmore beds as they are known to the west and north. The Blairmore formation as known from surface studies would thus appear to be equivalent to the Blairmore (Dakota) and Kootenay combined of Turner Valley area, where these formations are known from sub-surface study only.

The upper part of the Kootenay formation in

the Moose Mountain area has yielded plant remains which indicate the Lower Cretaceous age of these beds. It is possible that the lower part of this series of beds, which is everywhere gradational into the underlying Fernie shale, may be of Jurassic age.

Blairmore Formation

The Blairmore formation was originally defined by W. W. Leach[15,16] for the Blairmore map area, as a series of sandstones and shales underlaid by the coal-bearing measures of the Kootenay formation and limited at the top by the overlying Crowsnest Volcanics. F. H. McLearn[23,24] later obtained some fossil collections in that area and published merely an outline of his results, but just recently a full description of those collections and the stratigraphy has been published by McLearn[33], in collaboration with S. S. Buckman and E. W. Berry.

A persistent thick conglomerate marks the base of the Blairmore, its relation to the underlying Kootenay seeming to be slightly unconformable. The lower part of the formation is described as similar to the Kootenay in appearance, in general rather dark sandstones and shales; toward the top greenish and gray sandstones and shales, with red shale bands, appear. No coal is present in the formation. The total thickness is 1850 feet.

Berry[5] has established two floras, a "Lower Blairmore" flora of Kootenay type with rare dicotyledonous angiosperms, which is considered as late Lower Cretaceous in age, and an "Upper Blairmore" flora which contains several

Upper Cretaceous dicotyledons. McLearn[33] describes a fresh water fauna having about the same range as the "Lower Blairmore" flora.

The work of J. S. Stewart[48] carried the name Blairmore northward through the foothills. He noted particularly the continuity of the basal conglomerate as a "marker bed" and the evidence of a discordance between it and the underlying Kootenay coal measures. North of Blairmore area the Crowsnest Volcanics evidently lens out, and the Blairmore is conformably overlain by the Lower Benton shale.

Bruce Rose[37] mapped Blairmore formation in the Highwood coal basin, and used the basal conglomerate as an horizon marker. D. D. Cairnes[6] had previously mapped the Moose Mountain area, and had given the formation name "Dakota" to what is, no doubt, the Blairmore formation. In fact, Hume[11] has recently re-described this formation and used the name Blairmore. Cairnes remarks upon the usefulness of the basal conglomerate in locating the coal seams of the Kootenay which lie immediately below it. The conglomerate is described as a continuous key bed from the Sheep river northward to within five miles of Bow river. Cairnes noted the Kootenay aspect of his "Dakota" flora and expressed the opinion that the lower part of the formation might be Kootenay in age. When the determinations of Hume's recent collections are published it will probably be shown that this is a "Lower Blairmore" flora, which closely resembles the Kootenay flora. The thickness in Moose Mountain area is approximately 1700 feet.

R. L. Rutherford[42] has mapped as Blairmore those beds underlying the Lower Benton shale along Bow river, but evidently the entire formation is not exposed.

In the work carried on by the writer south of Bow river, the upper part of the Blairmore has been mapped in the Highwood region, Bragg Creek and elsewhere and some study has been given to the lower part in the vicinity of Canyon creek, Moose Mountain area, where the basal conglomerate is, as elsewhere, a prominent member.

In 1927 exploratory work was carried northward from Bow river along the foothills belt. The Ghost river exposures show only the upper beds of the formation, which, as in the south, are massive grey sandstones with conglomerate lenses, and greenish shales with red bands. One or two carbonaceous shale seams occur, but these never develop into coal seams of any importance. The lower part of the formation does not appear until Red Deer river is approached, and from this stream northward large areas are underlain by the Blairmore rocks.

A 60 foot conglomerate bed marks the base of the formation. This massive bed appears to rest conformably on thinly bedded sandstones and shales, which belong in the Fernie formation. There is no Kootenay, (using the nomenclature of the south country) in the Brazeau range region. The lithological characteristics of the Blairmore on the Red Deer river section are very similar to those observed in the Moose Mountain area. The lower part contains more dark shale, and the sandstones are in general more thinly bedded and darker in color, though one horizon is marked by a light

gray quartzitic sandstone, possibly equivalent to the "Home sandstone" of Turner Valley. The upper part is made up of the usual gray and greenish, coarse or conglomeratic sandstones, with greenish or vari-colored shales near the top, and generally some reddish bands or mottlings. The contact with the overlying Lower Benton always appears to be conformable, the black marine shales in places resting directly on sandstones or, at a few localities, on a conglomerate, in other places showing gradation into greenish sandy shales of the Blairmore.

Coal seams are first noticed on Prairie creek, between Clearwater and Ram rivers, appearing about the middle of the formation. These coal measures rapidly assume importance to the north, and it is from these seams that coal is mined at Nordegg, Mountain Park, Cadomin, Luscar and, until recently, at Brule. To the writer's knowledge they extend as far north as the Berland river, where the seams are still of commercial importance.

As in the country south of Bow river, the basal conglomerate of the Blairmore continues to be an excellent "marker bed." It varies in thickness from a few feet to 75 feet, and consists of vari-colored chert and quartzite pebbles, averaging an inch in diameter, in a matrix of coarse sand. In its stratigraphic relationship to certain lithologic units and a fossil zone lying above it, this basal conglomerate seems to maintain a very constant position in the section. This is rather surprising considering the type of deposition which it probably represents, i.e., stream channel deposition.

The Blairmore is from 1100ft. to 1300ft. thick along Brazeau range, but in Bighorn and Nikanassin ranges attains a thickness of 1700 feet to 1800 feet.

Faunas and Floras

Between 200 feet and 300 feet above the basal conglomerate there occurs a zone wherein fine, black, flaky shales with ironstone bands and thin sandstone beds predominate. Individual black shale members, up to 75' thick, with small brown ironstone concretions and thin bands, give the zone a decidedly marine aspect. A small pelecypod which has been classed as Corbula sp. or Astarte sp. is very abundant in the fine shale in places, also occuring in the concretions and sandstone beds. The gastropod Pachymelania also is commonly found, and a small Cardium sp. was abundant in this shale at one locality. T. W. Stanton(54) examined a collection obtained by Malloch from this horizon in the Bighorn Basin and noted particularly its marine character.

The remains of a small dinosaur, determined by Sternberg to be a marine Plesiosaur, were found in this black shale at one locality on the Cardinal river.

R. L. Rutherford(40) has described these beds in full and commented upon their possible marine origin.

In sandstone beds a few feet below the dark shales Viviparus sp. and Unio sp. have been collected, indicative of the fresh-water conditions which were prevalent prior to the deposition of the shalier beds.

At only one locality have fossils been found in the upper part of the Blairmore and this was in the extreme

south in the Pekisko creek area, where a concretionary, calcareous bed contains Goniobasis sp., Viviparus sp. and pelecypods, a fresh-water assemblage.

The fauna described by McLearn[33] for the Blairmore area is evidently fresh-water in type.

Plant remains have been found in the Blairmore formation at several localities in the Brazeau range country and farther to the north-west. Horizons from which plants were obtained range from beds 75 feet above the basal conglomerate to the top of the coal series.

A list is given below of the plants identified and their approximate stratigraphic positions. These were collected between Clearwater and Gregg rivers.

Coal series 500' to 800' above conglomerate.	Pseudocycas unjiga (Dn)
	Withringtonites
	Taxodium
	Torreya dicksoniana Heer
	Nilsonia nigracollensis Ureland
	Sequoia

100' to 300' above basal conglomerate.	Pseudocycas unjiga (Dn)
	Torreya dicksoniana Heer
	Nilsonia nigracollensis Ureland
	Sequoia sp.
	Podozamites lanceolatus (Braun)
	Onychiopsis sp.
	Pterophyllum acutipennis (Heer)

A comparison of these floras with those which

have been established by McLearn[33] and Berry for the Blairmore formation of the Blairmore area brings out several points of interest. As previously noted, two distinct floras have been recognized in that region, a "Lower Blairmore" and an "Upper Blairmore" flora. The upper flora ranges as low as 260 feet below the top of the formation, the lower flora as high as 480 feet from the top. In the list given above, none of the species has been found higher than 800 feet below the top of the formation, i.e., the top of the coal-bearing series, hence the collection is in general representative of the lower part of the Blairmore. In general, the assemblage corresponds to Berry's lower Blairmore flora, with the exception of Pseudocycas unjiga, - which is one of his upper Blairmore types and a supposed index to that horizon, - and Podozamites lanceolatus, which, though generally found in the Kootenay flora, is known to range higher, and, to quote Berry, this species "lacks both botanical and chronological significance". The occurrence of Pseudocycas unjiga in beds as low as 200 feet above the basal conglomerate would tend to discount its value as an index to uppermost Blairmore beds, to which Berry attaches considerable importance. It is evidently true for the Blairmore region, but certainly is not the case farther north.

In such a transition series as the Blairmore formation represents, wherein the Lower Cretaceous grades upward, without any apparent break in deposition, into the Upper Cretaceous, there would naturally be much intermingling of the plant forms, and it is doubtful if confidence could be placed in any one species as an horizon marker.

McKay[17] has recently published a list of plants collected from the Brule coal beds, which, as already indicated, is the same series that is mined at Nordegg, Cadomin, Luscar and Mountain Park, and occurs in the middle of the Blairmore formation, as mapped by the writer. W. A. Bell has identified the flora as "lower Blairmore in age".

Berry[5] has pronounced the lower Blairmore flora to be distinctly late Lower Cretaceous in age and probably representing the Aptian and Albian of the standard European section. The upper Blairmore flora, he states, is definitely Upper Cretaceous in age, about equivalent to Cenomanian; that is, of about the age of the Cheyenne sandstone of Kansas, therefore older than Dakota. The use of the term "Dakota" for the upper part of the Blairmore formation would therefore be obviously incorrect.

Previous Work North of North Saskatchewan River.

Various formation names have been applied to the Blairmore in the territory north of North Saskatchewan river, the general tendency having been to class this formation as Kootenay, the presence of a commercial coal series indicating a possible correlation with the Kootenay of the region south of Bow river. It has herein been shown, however, that these coal measures of the north are much younger.

Allan and Rutherford have used the formation name Kootenay, and, in the Nordegg[38] area, placed the basal conglomerate within the Fernie formation. Farther north,[39,40] the Kootenay was sub-divided into the upper "McLeod member" and the lower "Coal-bearing member" and the conglomerate was included as the basal bed of the Kootenay.

MacKay*, working in the Nikanassin range country, has included the Blairmore in his Kootenay group, and divided the formation into three members, namely, the Cadomin conglomerate at the base, the Luscar formation in the middle, - which contains the coal seams, - and the Mountain Park sandstone at the top.

In the Bighorn basin, Malloch (54) named as Kootenay those beds from the top of the coal series down to the Fernie shale; the upper part of the formation he termed Dakota.

The sub-divisions which he worked out along Nikanassin range have been used by MacKay (17) in the Brule area, north of Athabaska river, though the Mountain Park sandstone is not so distinct a member as it is to the south.

Farther north, MacVicar (21) termed the upper part the Sunset sandstone, but classed as Kootenay all of the beds from the top of the coal series down to the Jurassic marine shales.

The correlation diagram herewith included indicates the synonomy of these various formation names and subdivisions. (Plate II.)

Lower Benton Formation

The Lower Benton formation comprises a series of finely bedded, dark marine shales lying conformably above the Blairmore and grading into the basal sandstone member of the Cardium formation above. Although the formation name "Benton" was used in the southern foothills by all of the earlier workers, Rutherford (42) was first to make the division into Upper and Lower Benton. Hume (10) has pointed out the misuse of the term "Benton"

* Personal communication.

as regarding its age significance.

The name Blackstone shale was applied to this formation by Malloch[54] in the Bighorn basin, after Blackstone river. Allan, Rutherford, Warren and MacKay have all used this formation name in the area between North Saskatchewan and Hay rivers. The writer has mapped this shale as Lower Benton throughout the territory, from Highwood river in the south to Berland river in the north, since the formation appears to undergo no change of importance in this distance, although in the extreme north end of the region the lithologic character gives evidence of gradation into a generally sandier type of deposit.

The formation may be subdivided into zones on the basis of lithologic changes as follows:-

100' Sandy, dark gray shale with small brown-weathering ironstone concretions along bedding planes, and few thin, fine ss. ribbons. Few Inoceramus cf. corpulentus.

200' Fine, dark gray to black shales, weather rusty, few concretions which weather yellowish brown or orange and are up to 3 feet across. Thin Bentonite seams occur. No fossils.

350' Finely bedded black clay shales with very thin ss. laminae. Upper part holds a few lens-shaped, gray calc. concretions. In middle, bands up to 2' thick of hd. fine sandstone or concty. limy material occur. These weather dirty yellowish color. Basal portion fine, fissile, black shales with few gray concretions. I. labiatus and Prionotropis sp. fairly common in basal part, but range to top of this zone. Band of bentonite up to 2' thick marks base in some localities.

250' Sandy, rusty weathering shale, thin ss. ribbons and few thin concty. bands, which may become large conctns. A platy to massive ss. bed, up to 4' thick occurs about 100' above base. Fish scales abundant at this horizon.

The thickness in the south end of the area is not more than 800 feet; there is evidence of a slight thickening in the northern areas, where the formation is close to 1000 feet thick.

Fauna

Reference will be made in the following remarks to the paper by Warren and Rutherford[52] concerning fossil zones in the Colorado shale. The present writer cannot subscribe to some of the statements therein, regarding such zones within the Lower Benton, though in general agreement with the conclusions set forth.

In the sandy, rusty weathering shale zone, some 250 feet thick, at the base of this formation, fossils are rare, excepting the fish-scale bed, near the base, which seems to be a persistent horizon marker. A large ammonite, classed as Mantelliceras sp. is of rare occurrence, also Inoceramus cf. corpulentus. The zone is well-named the "Barren Zone" by Warren and Rutherford.

Next above this Barren zone appears some 350 feet of fine, black shale with sandstone laminae and bands, as described above. This is the Inoceramus labiatus zone, and accompanying this species is Prionotropis woolgari Mantell, though the latter is generally difficult to find whereas I. labiatus is fairly abundant, particularly toward the base of the zone, in the fine, black, fissile shales. A small oyster resembling O. congesta also occurs. Warren and Rutherford make a separate, higher zone of the Prionotropis beds, but the results of field work done by the writer lend no support to

the establishment of such a zone. It may further be stated that I. labiatus and P. woolgari have not been found above or below the limits of this particular lithological zone.

The 200 feet zone of fine shale above the I. labiatus zone is barren of fossil remains.

In the concretion bearing shales extending for 100 feet below the Cardium formation a few specimens of I. cf. corpulentus have been collected.

As has been pointed out by Warren and Rutherford, the Barren zone may be tentatively correlated with the Thermopolis shale and the lower part of the Graneros shale of the Western Interior States, and with the so-called Benton shale of Manitoba. The I. labiatus zone correspondes to the Manitoba "Niobrara" - which is a misnomer, - and to the Greenhorn limestone of the central Great Plains. The presence of Prionotropis suggest that this zone is at least partly equivalent to the Carlisle shale, which is stratigraphically higher than the Greenhorn limestone.

All of the Lower Benton formation would seem to be of Lower Colorado age, grading into Upper Colorado at the top, in the transition to the Cardium formation.

There is much evidence to support a correlation of the Lower Benton with the Kaskapau[25] shale of Peace River area.

Cardium Sandstone Formation

In 1858 Dr. Hector applied the name "Cardium Shales" to the whole marine series of the Bow river section, on account of the persistent appearance of Cardia in certain sandstone beds within this series. Later, Cairnes[6] restricted the name to the sandstone members only, and was able to trace

this formation southward as far as Sheep river. He also observed that on the Bow river the formation is some 220 feet thick, containing several thick sandstone and conglomerate beds, whereas on Sheep river it is represented by about 50 feet of sandy beds and is not such a definite horizon marker. The Bighorn sandstone, originally defined by Malloch[54] for the Bighorn Coal Basin, and since that time mapped by Allan and Rutherford and McKay between North Saskatchewan and Athabaska rivers, has been traced southward by the writer from the former stream to Bow river and proved to be the same formation as the Cardium sandstone. Therefore the latter name has been used for the entire area.

On the Ghost river and northward along the central foothills for 200 miles or more, the formation is from 275 feet to 300 feet in thickness. It comprises a lower sandstone member, in places 75 feet thick, consisting of massive or thin-bedded, rusty-weathering, quartzitic sandstone, followed by 150 feet of sandy shale with ironstone concretions, then the upper sandstone member, which also may reach 75 feet in thickness, and is similar to the lower member but is generally capped by a few inches or as much as 10 feet of pebble conglomerate.

The upper contact is thus sharply defined by the dark marine shale of the Upper Benton resting conformably upon sandstone or conglomerate of the Cardium. The lower contact with the Lower Benton is entirdly a gradational one.

It has been noted above that the Cardium sandstone becomes thinner and of erratic occurrence to the south of

Bow river, and it likewise thins and finally disappears eastward, since sub-surface data from the plains do not record a sandstone from what would be the equivalent, in the plains region, of this stratigraphic horizon in the foothills.

To the north and west the formation is strongly developed. The most westerly section observed was on the upper Red Deer river, where there are several sandstone beds present and the total thickness is in excess of 350 feet, indicating a thickening to the west. In the Blackstone river area and northward, a thin lignitic shale seam appears within the Cardium formation, but does not develop into a true coal.

Fauna

Cardium pauperculum is fairly abundant in the upper sandstone member in most exposures, but becomes less common south of Bow river. In the northern part of the area several species of Inoceramı are persistently present in the lower sandstone member. Scaphites ventricosus has been found in the shale zone. The fossils of the Cardium formation are listed in the table below, with those of the Upper Benton formation. Warren and Rutherford[52] have shown that the Cardium sandstone does not represent a fossil zone in itself, since Cardium pauperculum has been found to occur in higher beds also. This formation does fall within the range of Scaphites ventricosus, however, so belongs in the Upper Colorado group and is of about Niobrara age.

The Cardium formation is, at least in part, the equivalent of the Badheart[25] sandstone, as recognized by McLearn in the Smoky river-Peace river region.

Upper Benton Formation

The Upper Benton formation consists of marine shales of varying lithological character, but all rather sandy and dark gray or black in color, in certain zones weathering to a rusty or greenish shade. This formation has been mapped along Bow river and to the south by various geologists, and when traced north-westward by the writer, was found to be the exact equivalent of the Wapiabi shale which has been mapped by various workers in the territory north of the North Saskatchewan river.

The name Wapiabi formation was first used by Malloch[54] in the Bighorn basin, and was there applied to the marine shales lying between the Bighorn (Cardium) sandstone at the base and the Brazeau (Belly River) formation above.

Allan and Rutherford and MacKay have made use of this formation name for the Upper Benton in the territory to the north and east. In this report the latter nomenclature will be retained, since it has been carried northward from the Bow river country during the course of the field work.

It seems probable that the Upper Benton is equivalent to the Smoky River[25] shale of Peace River area. The Upper Benton may be sub-divided into a number of zones based on the lithologic characteristics of the shales, as follows:

Overlying bed, green-gray, fairly coarse, basal Belly River sandstone.

100' Dark greenish-gray, fine-grained shale, with thin, fine ss. ribbons throughout. Conglomeratic band in base.

50' Massive to platy sandstone, weathers brown, grading into sandy shale at base. (Transition Zone)

350' Sandy shale, dark gray, in massive beds approaching sandstone in character, with thin zones of more finely bedded shale. Layers and "cannon-ball" concretions of brown-weathering ironstone common. Concretions have septarian structure, showing network of calcite veins. Baculites ovatus fairly common. (Upper Concretion Zone)

450' Thinly bedded shale, fine black clay shale with laminae of gray sandstone ⅛ inch to 2 inches thick, these ss. ribbons contain comminuted carbonaceous material in some places. Hard, fine grained calcareous, concretionary bands up to 3 feet thick occur throughout this zone; they weather a dirty yellowish color, but are dark gray on fresh surface, and in some places rather sandy. Few thin yellow bentonite layers. Brown-weathering ironstone concretions absent. The thin sand laminations give a platy character on weathered surface. Ostrea congesta, Anomia subquadrata, Scaphites and Inocerami occur. (Platy Shale Zone)

400' Sandy shales, dark gray, with many small, brown-weathering ironstone concretions present along bedding planes. Certain thin zones free of concretions contain fine, hard ss. ribbons. Few thin yellow bentonite seams. Scaphites and various Inocerami occur. (Lower Concretion Zone)

Underlying bed - upper ss. of Cardium formation.

The zones described, though entirely gradational into each other, are fairly well-defined units in the Upper Benton formation throughout the region from the Highwood to Berland river. There is some variation in the Transition Zone, which is to be expected, in that the massive sandstone bed is at some localities represented by sandy shales only, owing to lateral variation in the type of sediment deposited during the gradation from marine to fresh-water deposition.

The thickness of the formation has been measured at several places and was determined to be approximately 1350 feet, with very little variation from this figure along the foothills belt. Various estimates of the thickness of the

Upper Benton formation, or the Wapiabi shale, are found in the literature, most of which are excessively high. This tendency is undoubtedly due to the fact that usually there is much repetition of beds within the shales due to thrust-faulting.

Faunas

A list is herewith included of the fossils collected from the Upper Benton and Cardium formations, arranged under the separate lithological zones, with brief remarks on the ranges of certain genera.

It will be noted that two broad fossil zones may be established, the lower one being characterized by the presence of Scaphites ventricosus, and including beds from the base of the Cardium formation to the top of the Platy Shale Zone of the Upper Benton; the upper zone may be termed the Baculites ovatus zone, and includes all the beds from the top of the Platy Shale to the base of the Belly River formation.

Warren and Rutherford[52] noted the existence of these fossil zones and remarked upon the undoubted Niobrara age of the Scaphites fauna, and the Montana age of the Baculites ovatus fauna, this latter zone being about equivalent to the Telegraph Creek formation of the Montana area.

Lower Concretion Zone and Cardium Formation

Genera and Species	Vertical Range
S. ventricosus	Ranges from basal Cardium ss. up to top of Platy Shale Zone
S. ventricosus var. stantoni	In narrow zone 100-150' above Cardium ss. - not common
S. vermiformis	Lower Concretion Zone

Genera and Species	Vertical Range
I. deformis	From middle of Cardium to 300' above Cardium formation.
I. exogyroides	Middle to upper part of Lower Concretion Zone - rare
I. umbonatus	Lower Concretion Zone.
I. cf. pontoni	100 to 150' above Cardium formation in Lower Conctn. Zone.
I. cf. corpulentus	From 100' below Cardium to 200' above Cardium formation - common in basal Cardium
I. aff. flaccidus	Lower Concretion Zone.
I. selwyni	150' above Cardium formation
I. coulthardi	Lower ss. of Cardium and 150' above Cardium formation.
I. altus	Lower ss. of Cardium formation
I. cf. albertensis	Lower ss. of Cardium formation
I. fragilis	Lower ss. of Cardium formation
Exogyra sp.	Lower Concretion Zone - upper part
Pholadomya sp.	Cardium ss. and 200' above Cardium
Pteria cf. linguiformis	350' above Cardium at top of Lower Concretion Zone (rare)
Oxytoma (Pteria) nebrascana	Lower Concretion Zone - upper part
B. cf. asper	150' above Cardium to top of Platy Shale Zone
B. cf. anceps	150' above Cardium to middle of Upper Concretion Zone (?)
Cardium pauperculum	Fairly common in upper ss. member of Cardium formation

Genera and Species	Vertical Range
Anchura sp.	Middle of Lower Concretion Zone.
Anisomyon sp.	Middle of Lower Concretion Zone.
Platy Shale Zone	

Genera and Species	Vertical Range
Anomia subquadrata	Platy Shale Zone
Ostrea congesta	Platy Shale Zone and Lower
Scaphites ventricosus	Platy Shale Zone and Lower
Oxytoma (Pteria) nebrascana	Platy Shale Zone, upper Lower Concetn. Zone and Transition Zone
Baculites asper	Platy Shale Zone and Lower
Inoceramus n. sp.	Platy Shale Zone

Upper Concretion Zone and Transition Zone

General and Species	Vertical Range
Baculites ovatus Say	Upper Concretion Zone and Transition Zone Baculites cf. ovatus occurs in Lower Concretion Zone at one locality.
Oxytoma (Pteria) nebrascana	Transition Zone
Liopistha undata	Transition Zone
Pteria cf. linguiformis	Upper Concretion Zone
Pinna sp.	Upper Concretion Zone - upper part
Tancredia sp.	Transition Zone
Pholadomya sp.	Transition Zone
Inoceramus cf. lund-breckensis	Upper Concretion Zone

Genera and Species	Vertical Range
Cymella sp.	Upper Concretion Zone and Transition Zone.
Terebratula sp.	Upper Concretion Zone - Upper part
Lingula sp.	Upper Concretion Zone - Upper part
Nautilus sp.	Upper Concretion Zone - Upper part(rare)
Tellina sp.	Transition Zone
Placenticeras sp.	Upper Concretion Zone - Upper part(rare)

Belly River and Younger Formations

The name Belly River formation had its original application in the southern plains region, but was also applied by the early workers in the southern foothills belt to that series of fresh-water beds lying conformably above the Upper Benton shale and limited by a coal-bearing zone at the top. In the Turner Valley (10) and Highwood (47) areas this formation measures about 1800 feet to 1900 feet in thickness. It consists entirely of gray and green-gray, coarse and fine-grained sandstones, and dark greenish, sandy shales.

The coal-bearing series at the top is placed in the basal Edmonton formation. The dark shales of the coal series are singularly marine in aspect and carry a decidedly brackish-water fauna. These beds may represent the westward extension of the Bearpaw marine shale.

The Edmonton is in turn overlain by the Paskapoo sandstone formation. No satisfactory measurements of the thicknesses of these formations have been made.

In the Bow river area Rutherford[42] determined the following thicknesses:- Belly River formation, maximum thickness of 3000 feet, and Edmonton - Paskapoo series about 3500 feet (incomplete section).

North from Bow river very few localities were found where a measurement could be made of the beds overlying the Upper Benton, until the Blackstone river territory was reached. Here, a section of Belly River and younger rocks some 5000 feet in thickness was measured, the top of the Upper Benton defining the base of the Belly River formation.

The basal 2000 feet of beds would appear to correspond to the Belly River of the south, being chiefly massive green-gray sandstones and sandy green shales. A thick conglomerate was noted at many localities, about 500 feet above the base. The beds above this basal series are, in general, softer, containing thin coal seams at several horizons and commercial seams at the top; this upper series is probably Edmonton in age.

The commercial seams mentioned are believed to be equivalent to the beds mined at Saunders Creek and vicinity, and also in the Lovett, Coalspur and Mercoal areas.

Rutherford[38] uses the term Saunders formation for all of the beds above discussed, and sub-divides the formation into Lower Saunders, Saunders Coal series, and Upper Saunders; the middle member, - which is really the only recognizable and dependable dividing line, - being the commercial coal-bearing series mentioned above.

When Malloch[54] mapped the Bighorn Basin, he

applied the term Brazeau formation to the Belly River sandstones; MacKay has used the former name in his work farther north.

On general stratigraphic and paleontologic evidence, the Wapiti[25] formation of the far northern foothills is also equivalent to the Belly River formation.

Fauna

Fossils are very scarce in this series of beds. The occurrence of a brackish water fauna in the basal Edmonton in the southern part of the region has been noted. This includes Corbicula sp. and Ostrea sp. Beds containing Unio sp. occur higher in the succession, in the typically fresh-water sandstones.

An interesting collection was obtained on the North Saskatchewan and Ram rivers, the stratigraphic position being about 600 feet above the Saunders coal series, that is, some5500 feet to 6000 feet above the top of the Upper Benton formation.

The genera and species are listed below:-

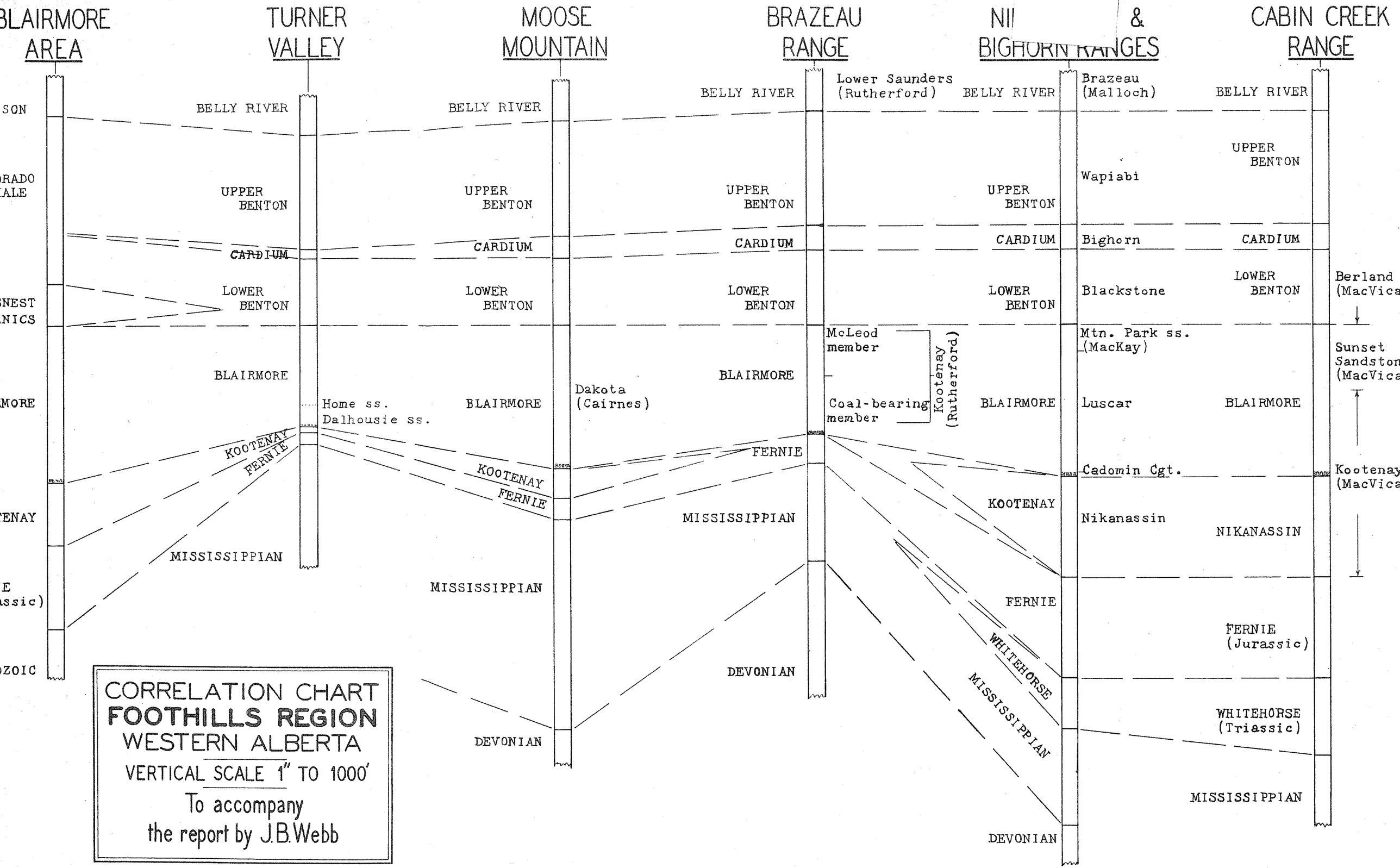
Unio cf. senectus
Unio danae
Thaumastus limnaeiformis tenuis (abundant)
Goniobasis tenuicarinata
Goniobasis tenuicarinata var. nov.
Viviparus sp.
Viviparus prudentius
Physa copei canadensis
Planorbus sp. nov.
Hydrobia recta

Viviparus zilaga (Dyer, new)

Viviparus leai

Sphaerium sp.

The age indicated is either Edmonton or Paskapoo but probably closer to the latter.



CORRELATION CHART
FOOTHILLS REGION
WESTERN ALBERTA

VERTICAL SCALE 1" TO 1000'

To accompany
the report by J.B.Webb

STRUCTURE

GENERAL STATEMENT

The structural conditions which are peculiar to the foothills belt have been produced by those same thrust forces, directed from the west toward the east, that caused the great Rocky Mountains uplift. That phase of western American orogeny has been termed the Laramide revolution. In the Alberta foothills it is evident that the major movements took place in post-Paskapoo time, that is, during the early Tertiary, but later than the earliest part of that period.

The compressive stresses, which were imposed upon the earth's crust in western Alberta by those laterally directed forces, were relieved largely within the area that now includes the Rocky Mountains and the foothills which lie immediately to the east. As the structural cross-sections herewith included will readily indicate, the early workers in the southern foothills were completely justified in applying the name "The Disturbed Belt" to this particular structural province. Relief of the stresses, to which the strata were subjected, came through folding followed by overthrust faulting. The folds are generally of the asymmetric type, with the steeper dips in the east flanks, which are in many cases, overturned to some degree. It can be stated, however, that extreme overturning on a large scale is not commonly found in the east flanks of foothills anticlines. It would appear that the tensile strain placed upon the east limb of any such overturned structure was relieved by faulting long before the

fold approached the recumbent state. There was, probably, a critical angle of overturned dip in the east flank, subject to variation, of course, at which overturning ceased and faulting took place. The writer would place this angle between 50° and 60°.

Foothills folds and fault blocks constitute very long, narrow, structural and topographic features, which roughly parallel each other and generally correspond in strike with the trend of the foothills belt. The abrupt nature of the plunge on the ends of such anticlines and fault blocks seems to be a structural characteristic peculiar to this type of folding. As stated above, foothills anticlines are generally found to be asymmetrical, on the basis of surface mapping, with the steeper dips in the east limbs. It follows that the axial planes of these folds would dip to the west. In the writer's opinion, this idea of the westward migration of the anticlinal axis at depth, is not supported by the subsurface data obtained in Turner Valley field. There are very few major anticlines in this region which do not exhibit faulting in the east flanks. The faults, in most cases, are a considerable distance east of the anticlinal axes at the surface, but, on the evidence of subsurface data, the fault planes dip to the west at angles which show a wide variation for different faults.

That a very great amount of fore-shortening of the earth's crust has taken place in the foothills, through overthrust faulting, is particularly evident from a study of the Sheep river cross-section (Plate III).

AREAL STRUCTURE

South of Bow river, the chief anticlinal structures in the outer foothills are, from south to north, the Highwood folds, Turner Valley, Bragg Creek (Two Pine Anticline) and the Jumpingpound anticline. These folds expose, in their axial portions, formations ranging from the Blairmore to the Upper Benton. The Moose Mountain dome is located in the inner foothills, west of the Bragg Creek anticline, from which it is separated by a broad syncline containing Belly River rocks. This uplift brings to the surface a thickness of some 2200 feet of Paleozoic strata (Mississippian formation). It is an unusual fold in that the east flank displays no evidence of faulting.

The geologic cross-sections along Highwood and Sheep rivers (Plate III) exhibit the extremely complicated nature of the folding in these areas, and show, also, certain structural interpretations that have been obtained through the use of sub-surface information. It will be observed that the fault-plane encountered by the Outwest and Weymarn wells, on the New Black Diamond anticline, has a rather low average inclination to the west, whereas the Turner Valley fault has a decidedly high average dip to the west. As indicated, it is believed that the dips along such fault planes become less with increasing depth, giving rise to the so-called "sleigh-runner" type of fault.

The latest information regarding the Turner Valley fault comes from the log of the Sterling Pacific well, which was drilled on the crest of the anticline in the south end of Turner Valley area. This well encountered the top of

the Mississippian limestone at a depth of 5000 feet, drilled to 6500 feet in this formation, then struck sandstone beds which have been definitely determined to belong in the Belly River formation.

The Turner Valley fault does not extend as far south as Highwood river, according to the present interpretation of outcrops on that stream. In fact, no large faults are in evidence in the east flank of the Highwood uplift. The Bragg Creek and Jumpingpound anticlines are known to be severely faulted.

In the Bow, Ghost and Little Red Deer river country, the outer foothills folds are severely faulted, for the most part, and do not expose strata older than the upper part of the Lower Benton. One fold, farther west, on Ghost river brings the upper part of the Blairmore formation to the surface. (Plate IV).

Toward the Red Deer river, a broad syncline containing Belly River rocks appears, which separates the outer foothills folds from an inner and more westerly line of folding. The eastern belt in this area contains minor folds and fault blocks, involving Belly River and the upper part of the Upper Benton formations. A fault of some 4000 feet stratigraphic displacement occurs at the east edge of the inner belt, where the uppermost beds of the Fernie formation, dipping steeply to the west, are in contact with the Belly River strata which dip eastward into the broad syncline mentioned above.

North of James river, two important anticlinal structures arise from the inner and outer lines of folding,

namely, the Clearwater and Brazeau range anticlines, both of which expose the Mississippian, and in places the Devonian, formations. (Plate V) Clearwater range reaches its greatest elevation and magnitude, structurally and topographically, just south of the Clearwater river, but plunges rapidly to the north-west, and on South Ram river is represented by minor folds only. Brazeau range, however, is continuous for many miles to the north-west, its total length being about 65 miles. This range is generally found to consist of two anticlines, separated by a syncline; the eastern, or outermost, anticline is tightly compressed and a fault of large displacement is present farther east. On the Saskatchewan river this fault shows a stratigraphic displacement of about 6000 feet.

North of Clearwater river the general trend of the foothills, that is, the strike of the strata, swings rather abruptly toward the west, becoming about N. 45°W. In the territory to the south, the strike gradually changes from N.0° W. in the south end of the Highwood area, to N. 25° W. in the Red Deer river country.

The region lying between Brazeau range and the front range of the Rocky Mountains, and extending from South Ram river to the North Saskatchewan is, broadly speaking, synclinal, with some anticlinal folding appearing along the western side. A major fault is present about one mile east of the front range.

North of the North Saskatchewan river and approximately 10 miles west of Brazeau range, the Bighorn range appears, and extends in a north-west direction for some

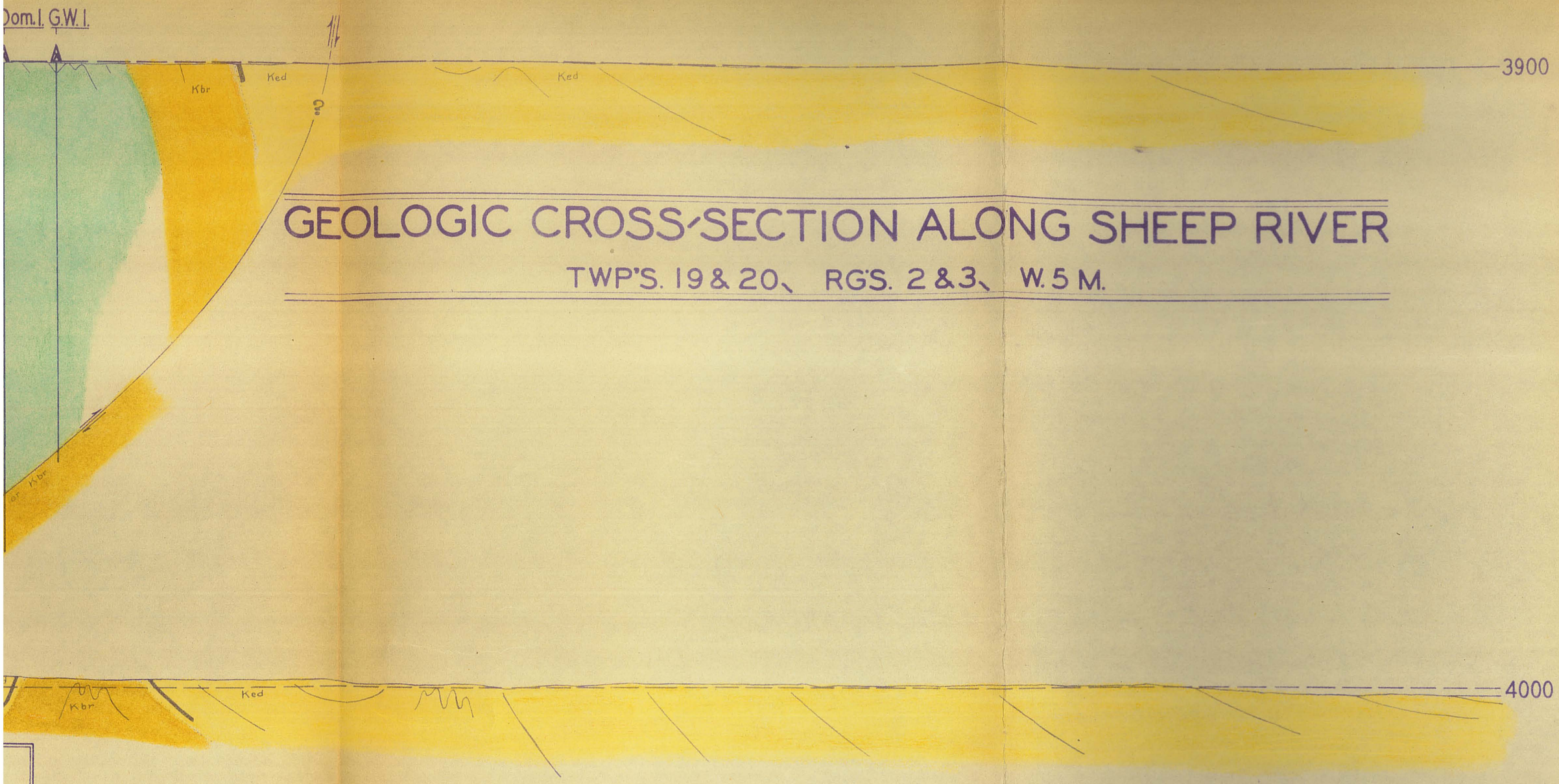
30 miles before the Paleozoic limestones of these mountains plunge under younger formations. On Blackstone river, which has cut a deep canyon through the Bighorn range, the west-dipping Paleozoic (Devonian) strata are evidently thrust upon Upper Benton shales, indicating a fault having a stratigraphic displacement of some 7000 feet. The Bighorn basin, lying west of Bighorn range, is, in general, a synclinal area, about 10 miles wide, bounded on the west by the great thrust fault which lies east of the front range of the Rocky Mountains.

The Paleozoic strata of the Brazeau Range fold plunge to the north-west beneath younger formations in the vicinity of Nordegg river, but this line of anticlinal folding persists, though varying in importance, for many miles to the north-west. In the Cardinal river country the folding again assumes major proportions for a distance of some 10 to 15 miles along this belt. It will be noted (Plate VI) that an unusual type of minor fault is present in this area, displaying a tendency toward over-thrusting directed from the east to the west.

Nikanassin range is similar structurally and topographically to Bighorn range, though it is of somewhat greater proportions. It lies in general strike alignment with the Bighorn fault block, but is separated from that uplift by a structural saddle about 18 miles long, in which the younger Cretaceous beds appear. The Brazeau and Cardinal rivers flow through this saddle. The Nikanassin fault block, like the Bighorn, exposes the Mississippian and Devonian formations, which are thrust upon the Cretaceous strata to the east.

In the outer foothills of this region, the only fold of importance is the northwestward continuation of that anticline which was previously noted as being an important feature in the Cardinal river area. On McLeod river, west of the mouth of MacKenzie creek, the structure indicated is simply a west-dipping fault-block of Lower Benton shale, which lies in contact with Belly River sandstones that form the west limb of a broad syncline. A general northwestward plunge in the whole of the outer foothills belt carries the Colorado formations below the Belly River formation in the territory lying north of McLeod river.

In the Athabaska river country and northwestward as far as this investigation was carried, the only important folds are those which are situated immediately east of the Rocky Mountains. The anticlinal structure known as Folding mountain lies in this belt, and extends southward from the Athabaska river. It exposes the upper beds of the Mississippian formation. A similar, but sharper, fold is present north of Berland river, in the Cabin creek area, and the name Cabin Creek range has been applied to the minor mountain range that forms the topographic expression of this structural feature.



GEOLOGIC CROSS-SECTION ALONG SHEEP RIVER

TWP'S. 19 & 20, RG'S. 2 & 3, W. 5 M.

GEOLOGIC CROSS-SECTION ALONG HIGHWOOD RIVER

TWP. 18, RG'S. 2 & 3, W. 5 M.

Outwest 1. Weymarn 2. Strat. Disp. 2500+ ft. Roy. 2 Roy. 4 Roy. 1. Br. Dom. 1. G.W. 1.

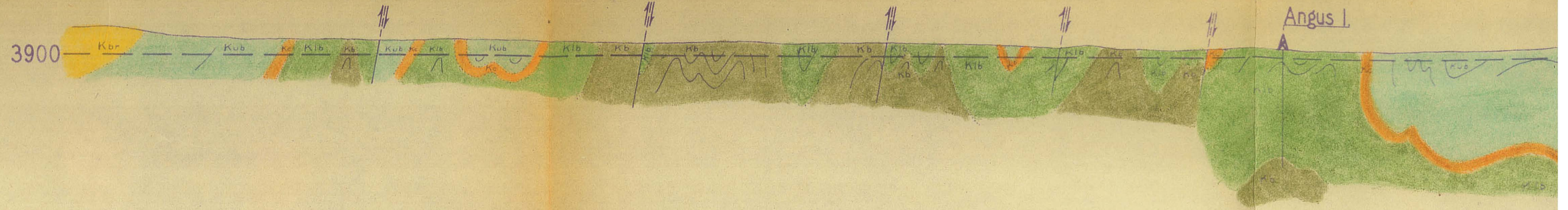
N.W.C.&E. 1. Imp. Highwood 1.

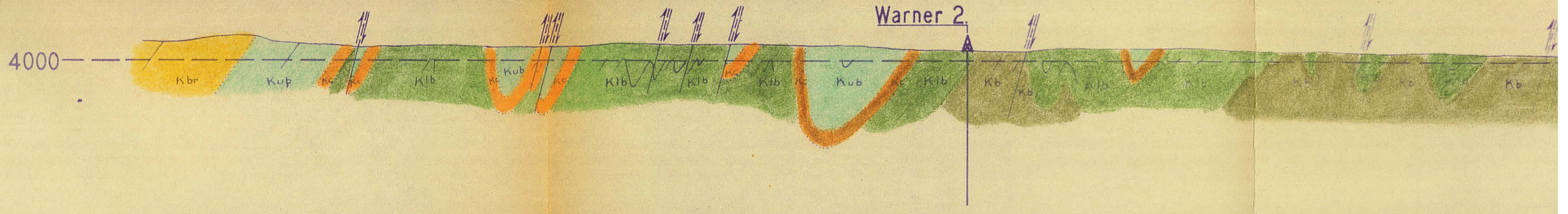
-LEGEND-

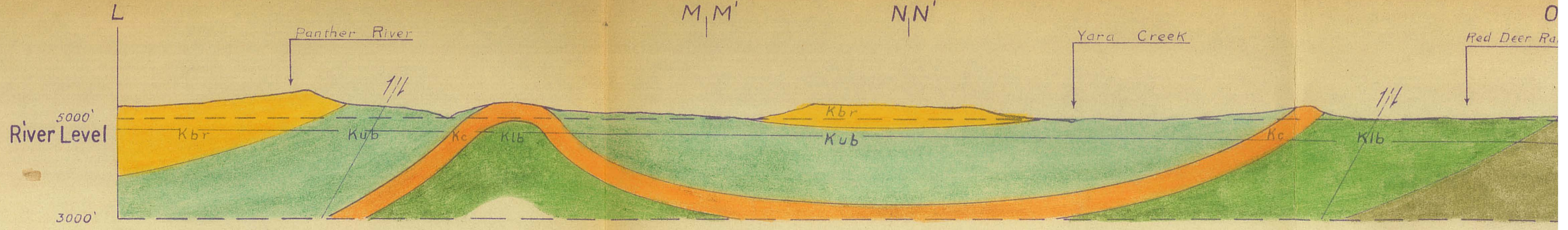
- Edmonton
- Belly River
- Upper Benton
- Cardium
- Lower Benton
- Blairmore
- Kootenay
- Fernie
- Mississipian

Scale: 4 inches = 1 mile.

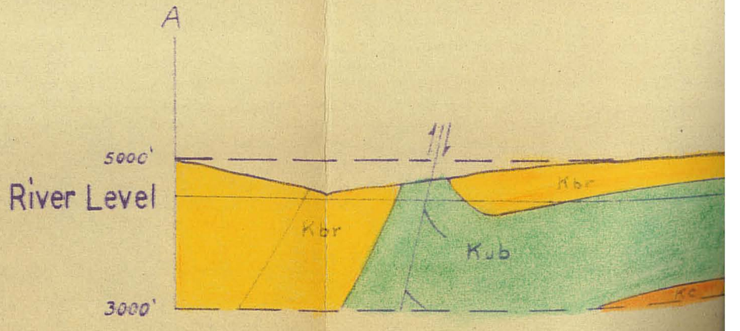
Geology by J. B. Webb, 1929

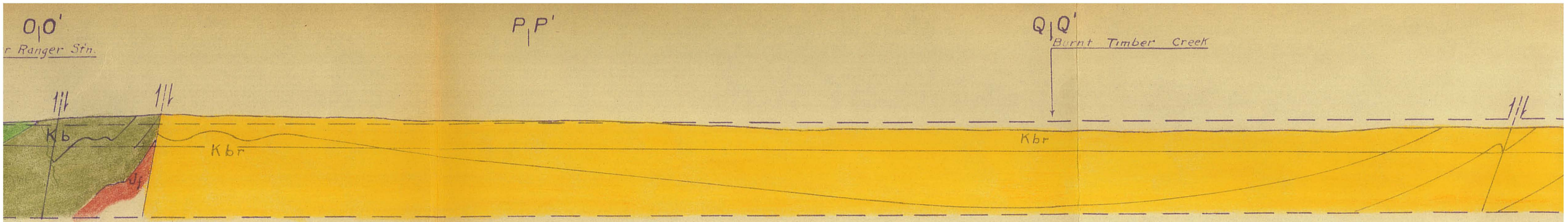

3900
Kbr
Kub
Kc
Klb
Kb
Angus 1.
A


4000
Kbr
Kub
Kc
Klb
Kb
Warner 2.
A


L
M M'
N N'
O
Panther River
Yara Creek
Red Deer Ra
1/4
1/4
5000'
River Level
3000'
Kbr
Kub
Kc
Klb
Kbr
Kub
Kc
Klb

SEC


A
1/4
5000'
River Level
3000'
Kbr
Kbr
Kub



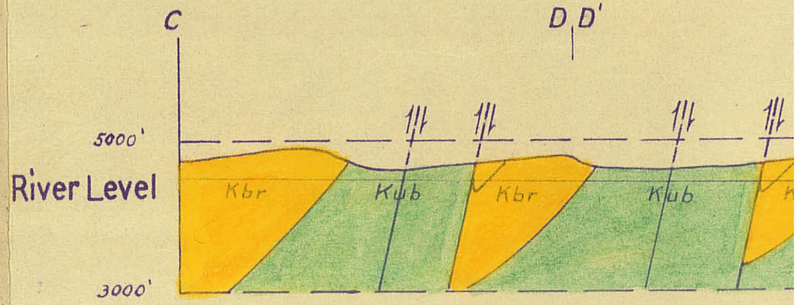
SECTION ALONG RED DEER RIVER TWP. 31, RGS. 6 TO 10, W.5M.

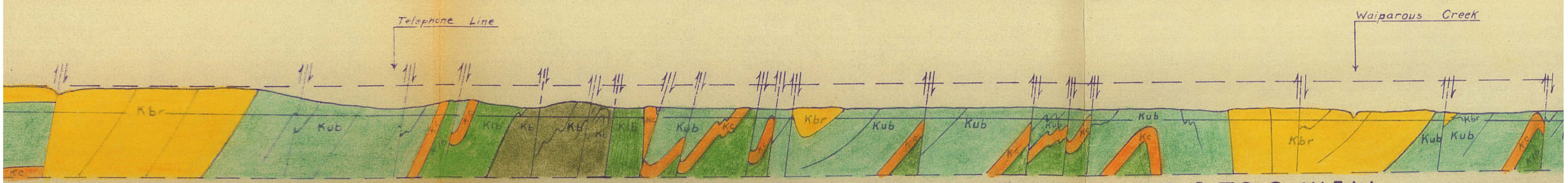
LEGEND

- Belly River
- Lower Benton
- Upper Benton
- Blairmore
- Cardium
- Kootenay
- Fernie

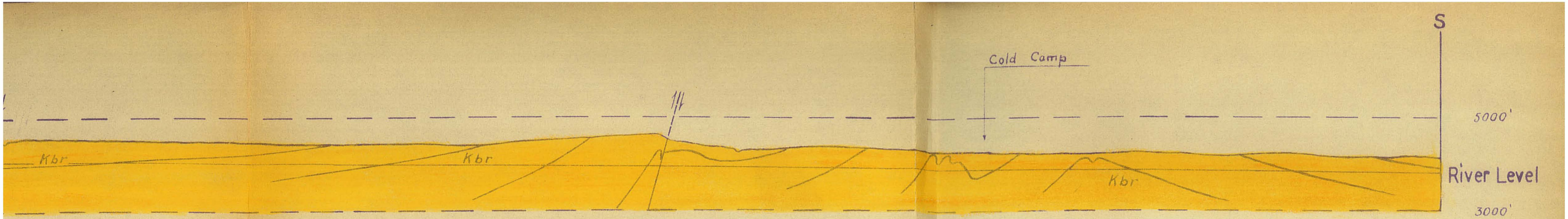
Scale: 1" to 2000'

Geology by J.B. Webb, 1927

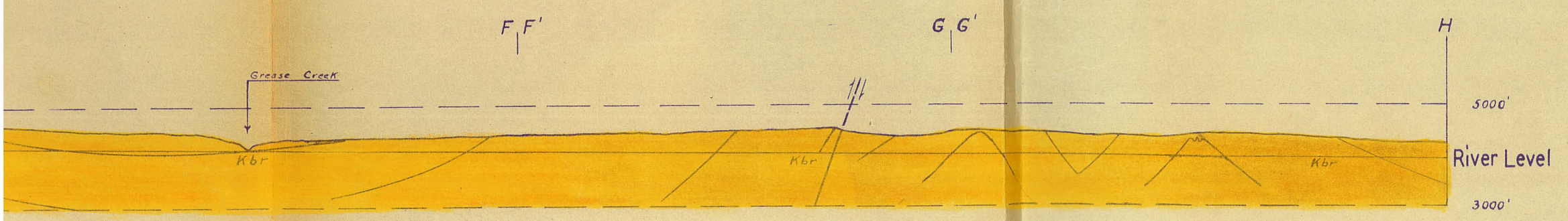




SECTION ALONG GHOST RIVER TWP. 27, RGS. 6 TO 8, W.5M.

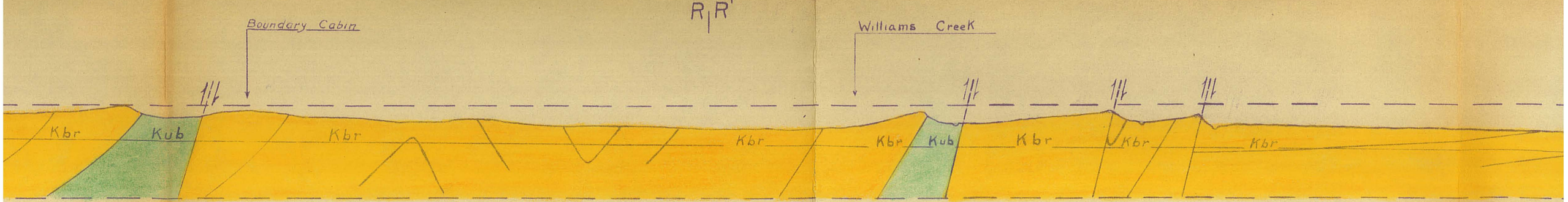


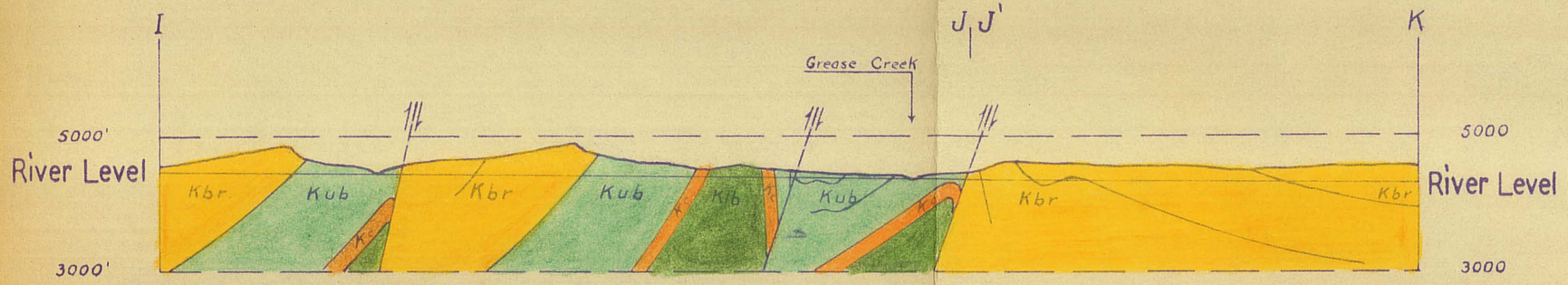
vel



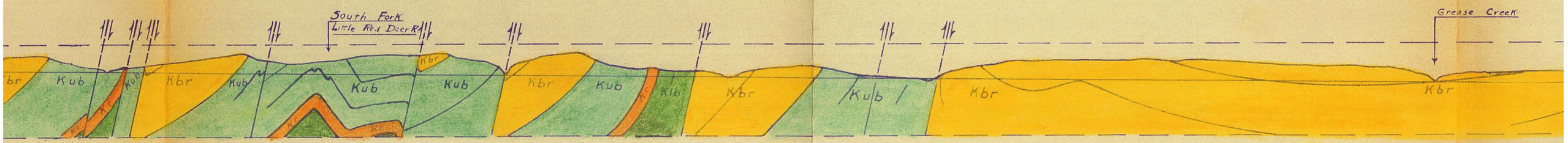
TWPS. 28 & 29, RGS. 5 TO 7, W.5M.

PLATE IV

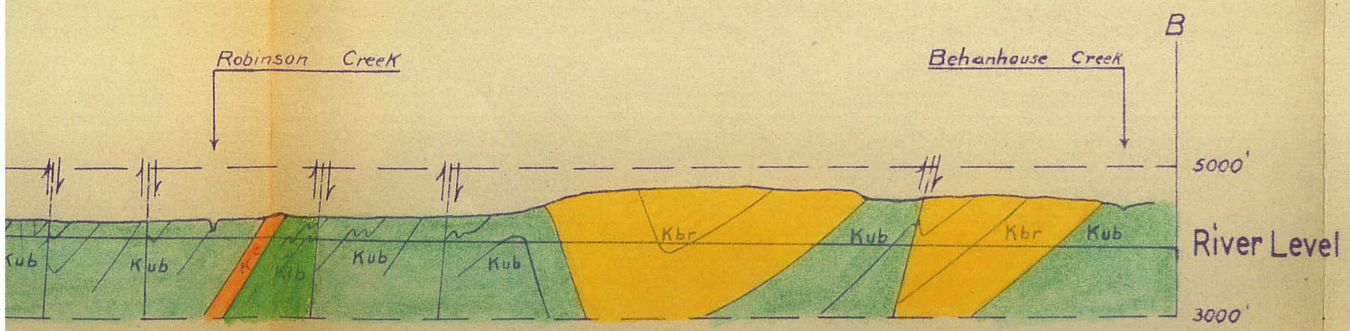


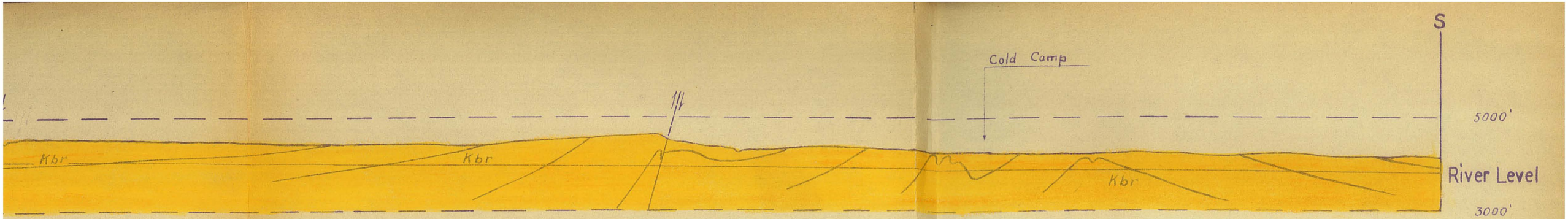


SECTION ALONG HAROLD CREEK TWP. 29, RGS. 6&7, W.5 M.

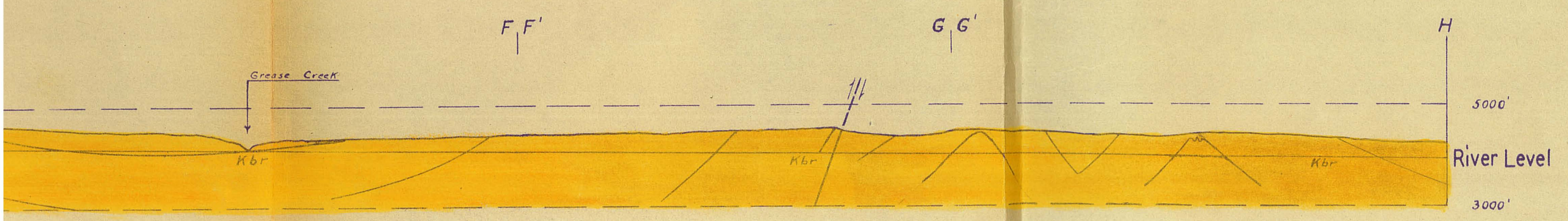


SECTION ALONG LITTLE RED DEER RIVER TWP.S. 28&29, RGS. 5



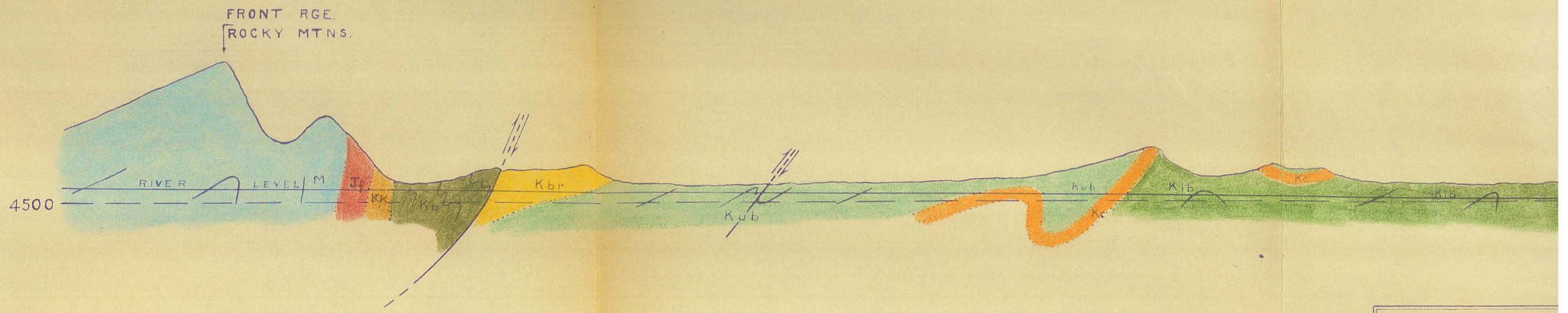


vel



TWPS. 28 & 29, RGS. 5 TO 7, W.5M.

PLATE IV

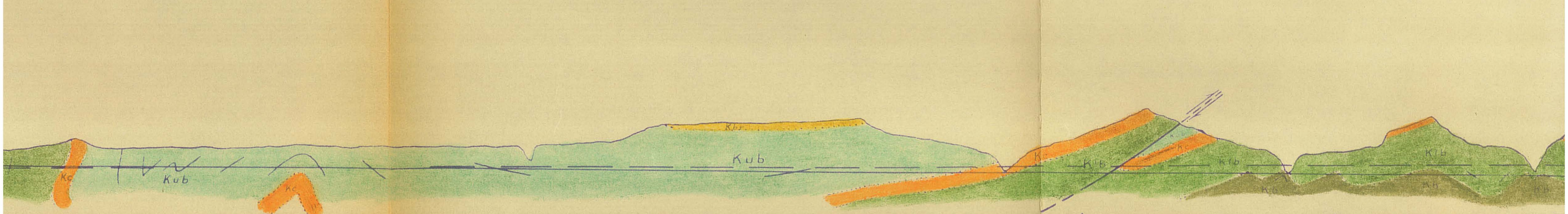


LEGEN

- Belly River
- Upper Benton
- Cardium
- Lower Benton
- Devoni

Scale: 1" to

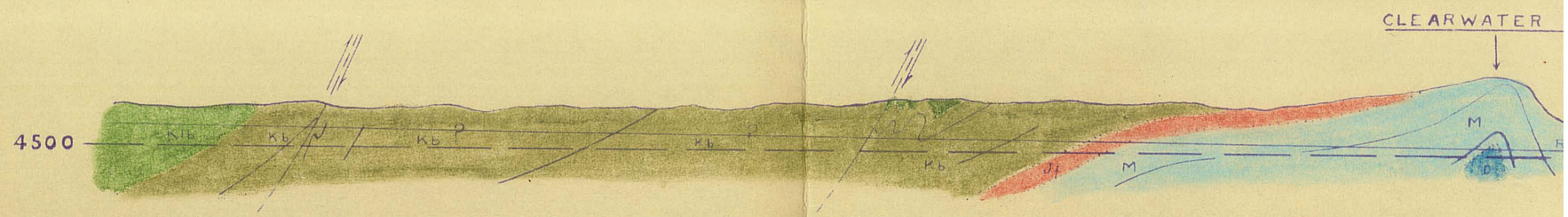
Geology by J. B. W



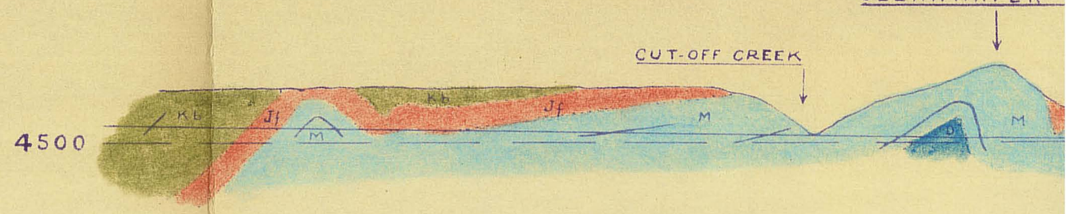
SECTION ALONG SOUTH RAM RIVER TWP'S. 36 TO 38, RG'S. 11 TO 14, W.5

ND
Blairmore
Kootenay
Fernie
Mississipian
an

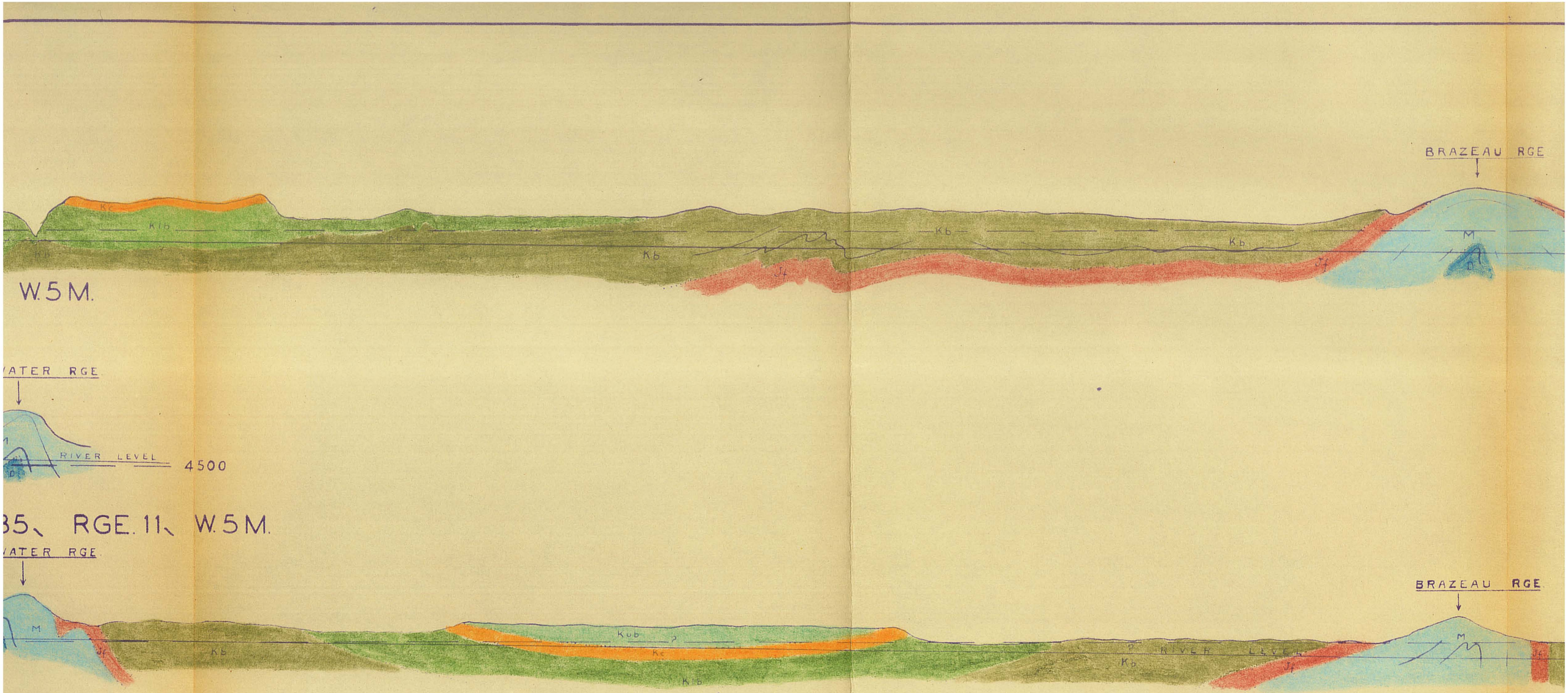
2000'
Webb, 1927



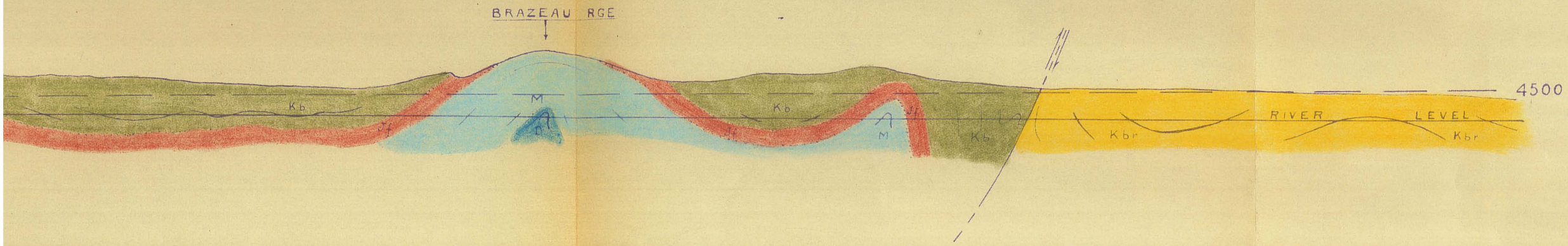
SECTION ALONG CLEARWATER RIVER TWP. 35,



SECTION ALONG CUT-OFF CREE



REEK & CLEARWATER RIVER TWP. 35、 RG'S. 9 TO 11、 W.5 M.


BRAZEAU RGE
Kb
Jf
M
Kb
Jf
M
Kb
Kbr
RIVER LEVEL
Kbr
4500

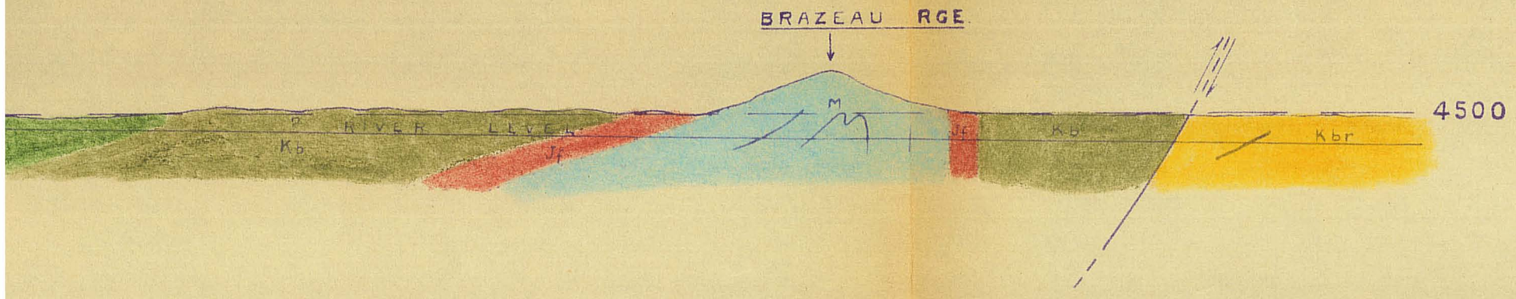
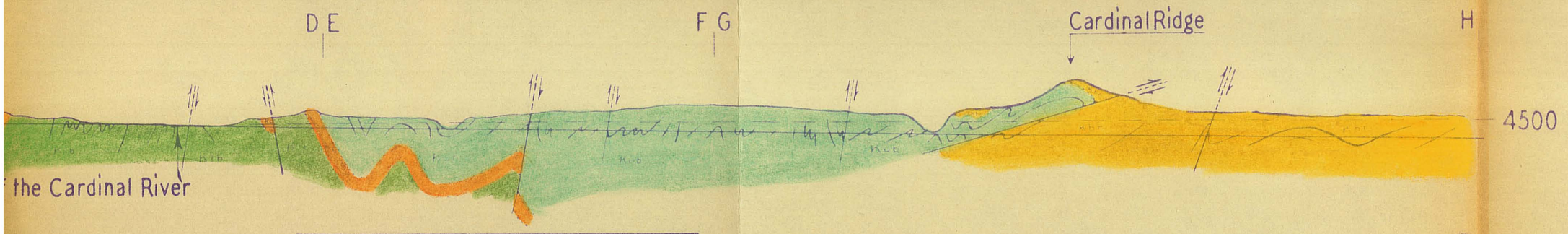

BRAZEAU RGE
M
Kb
Jf
Kb
Kbr
4500

PLATE V.

GEOLOGIC CROSS SECTION ALONG THE CARDINAL RIVER



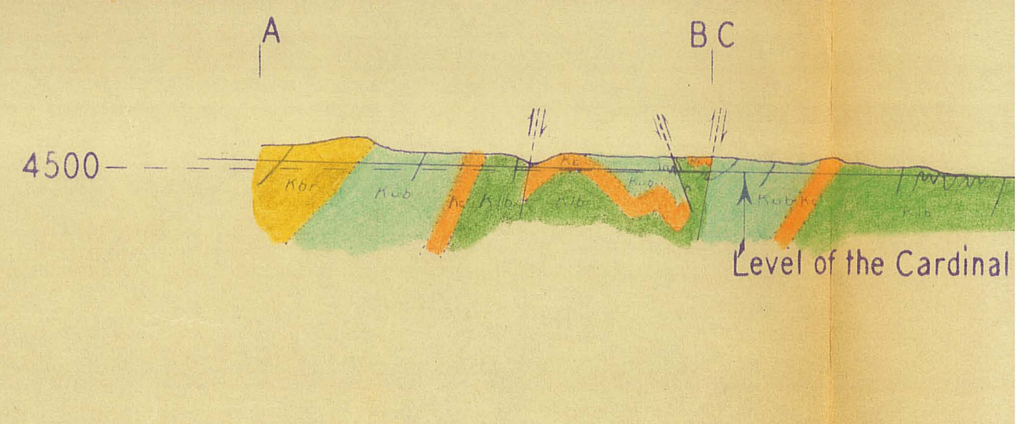
LEGEND

- Belly River
- Cardium
- Upper Benton
- Lower Benton

Scale: 1" – 2000'

Geology by
J. B. Webb,
September, 1929.

HUDSON'S BAY OIL & GAS COMPANY LIMITED


A
B C
4500
Level of the Cardinal

Looking southeast along the axis of the Cardinal anticline, between Cardinal and Brazeau rivers. The dotted line connects the outer rims (Belly River sandstone) of the fold. The intervening hills are composed of Cardium sandstone.

Extreme crumpling in the crest of an anticline on Cardinal river. The strata shown are sandstones and shales in the Transition zone at the top of the Upper Benton formation.

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