BULLETIN 53

THE OXFORDIAN BEDS OF THE JURASSIC FERNIE GROUP, ALBERTA AND BRITISH COLUMBIA

Hans Frebold, E. Mountjoy, and Ruth Reed

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By

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PREFACE

A systematic study of the Jurassic of Western Canada was begun in 1950 by the Geological Survey of Canada. Initial work was concentrated on the Fernie group which forms a belt along the eastern Rocky Mountains and Foothills. The results of this study were presented in GSC Memoir 287.

Part of the Fernie group consists of the distinctive Green beds of Oxfordian age. These were found to be much more extensive than heretofore known and have also been recognized as an important and widespread horizon marker, easily recognizable in oil well samples.

In this paper all available information on these beds is assembled, the general nature and fauna by Frebold, the stratigraphy of the northern exposures by Mountjoy, and the subsurface information by Miss Reed of the Shell Oil Company of Canada, Limited.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, November 25, 1958

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THE OXFORDIAN BEDS OF THE JURASSIC FERNIE GROUP ALBERTA AND BRITISH COLUMBIA

Abstract

The Oxfordian beds of the Jurassic upper Fernie group occur at many places in the Foothills and eastern Rocky Mountains between the International Boundary in the south and the Peace River country in the north. Their lower part (unit *a*) consists of glauconitic silt or sandstone and shale (Green beds), their upper part of dark shale with rusty weathering bands and concretions (unit b^1) or dark shale with sandstone bands (unit c^1=lower part of Passage beds). Unit b^1 is the northern equivalent of unit c^1 which is characteristic of the south.

The Green beds are normally underlain by the lower Callovian Grey beds but locally they lie on the middle Bajocian Rock Creek member. They form an excellent horizon marker, both where they outcrop and in the subsurface. In the southern sections they are 50 to 60 feet thick. In the north (Rocky River sections) they consist of two glauconite beds, separated from each other by 50 to 60 feet of shale with concretions. These beds contain Cardioceratids of early Oxfordian age. Unit b^1 and the uppermost part of unit *a* in the south contain *Buchia concentrica* (Sowerby) which indicates a late Oxfordian or early Kimmeridgian age.

In the western interior of the United States and in the southern plains of Canada the equivalent of the Oxfordian part of the Fernie group is the Swift formation.

The Oxfordian beds of the Fernie group were deposited in the Logan Sea, which transgressed over parts of Western Canada after the late Callovian period of regression. The Canadian part of the Logan Sea was probably connected with the sea in British Columbia, and through it, with the Pacific Ocean. After the time of the late Oxfordian or early Kimmeridgian the sea began to retreat in the western interior of the United States, where the non-marine beds of the Morrison formation were deposited. During this time marine conditions still prevailed in the Canadian part of the former Logan Sea and there the final regression took place not earlier than in late Portlandian time.

Résumé

Les couches oxfordiennes de la partie supérieure du groupe Fernie, d'âge jurassique, se rencontrent en bien des endroits des avant-monts et de l'est des montagnes Rocheuses, entre la frontière internationale, au sud, et la région de la rivière de la Paix, au nord. La partie inférieure de ces couches (subdivision *a*) se compose de siltstone glauconieuse ou de grès et schiste argileux à glauconie (couches Vertes); la partie supérieure est formée de schiste argileux foncé dont quelques couches et concrétions ont pris la teinte de la rouille dû à l'action des agents atmosphériques (subdivision b^1), ou de schiste argileux foncé renfermant des bancs de grès (la subdivision c^1 correspond à la partie inférieure des couches Passage). La subdivision b^1, située au nord, équivaut à la subdivision c^1, qui caractérise les couches situées au sud.

D'une façon générale, les couches Vertes recouvrent les couches Grises du Callovien inférieur, mais, en certains endroits, elles reposent sur le membre Rock Creek du Bajocien moyen. Elles constituent un excellent repère d'horizon, sous la forme soit d'affleurements soit de roche de fond. Dans les sections du Sud, elles sont épaisses de 50 à 60 pieds. Dans le Nord (sections de la rivière Rocky), elles se composent de deux couches glauconieuses séparées l'une de l'autre par 50 à 60 pieds de schiste argileux à concrétions. Ces couches contiennent des ammonitidés du genre Cardioceras qui remontent au début de l'Oxfordien. Dans le Sud, la subdivision b^1 et la partie la plus élevée de la subdivision *a* contiennent des fossiles de l'espèce *Buchia concentrica* (Sowerby), qui indiquent soit le sommet de l'Oxfordien soit la base du Kimméridgien.

Dans l'Ouest central des États-Unis et dans le Sud des Plaines du Canada, la formation Swift équivaut à l'Oxfordien du groupe Fernie.

La mise en place de ces couches oxfordiennes eut lieu dans la mer Logan, qui envahit certaines portions de l'Ouest canadien à la suite de la période de régression de la fin du Callovien. La portion canadienne de la mer Logan rejoignait probablement la mer en Colombie-Britannique et, par là, l'océan Pacifique. A la fin de l'Oxfordien ou au début du Kimméridgien, la mer se mit à reculer dans l'Ouest central des États-Unis, où se produisit la mise en place des couches d'origine non marine de la formation Morrison. Au cours de cette époque, un régime marin continuait de régner dans la portion canadienne de l'ancienne mer Logan, où cette mer ne recula pour de bon que vers la fin de l'âge portlandien.

STRATIGRAPHY

(H. Frebold)

Rock Units

The Fernie group comprises all Jurassic rocks in the Canadian Rocky Mountains and Foothills except for the upper Portlandian beds, which are included in the lower Kootenay sandstone (*see* Table I). A comprehensive account of the Fernie group has recently been published by the Geological Survey of Canada (Frebold, 1957)[1].

That part of the Fernie group, which on the basis of distinctive fossils could be determined as Oxfordian, consists of three rock-units (*see* Table II). These are: *a,* the Green beds, consisting mainly of glauconitic silt and sandstones and shale; b^1, lower part of dark shale with rusty weathering siltstone bands and concretions; c^1, lower part of the Passage beds. Units b^1 and c^1 are equivalent to each other and overlie *a*.

Units b^2 and c^2 which are stratigraphically above and more sandy than units b^1 and c^1 are probably of Kimmeridgian age. No diagnostic fossils have yet been found in these beds. Unit c^2 forms the upper part of Passage beds.

Unit *a*, the Green Beds

The Green beds were first mentioned by F. H. McLearn (1916, p. 111) as occurring at Blairmore and on the "Castle River (south fork, Oldman)"[2], and were described in more detail by the same author (McLearn, 1929, pp. 84, 85, 87, 100) from the same southern Alberta localities.

These beds, previously misinterpreted as tuffs, were found by McLearn to be about 50 feet thick and overlain by the thin-bedded sandstones and shales of the Passage beds (McLearn, 1929, p. 84). Belemnites, a rib and neural spine of an ichthyosaur, and probably some plesiosaur bones were found at Carbondale River, and belemnites and *"Turbo"* sp. in the brickyard quarry south of the railway tracks in Blairmore (op. cit., p. 87). At this locality, too, the Green beds are overlain by the Passage beds.

An exact determination of the age of the Green beds was not possible on the basis of the fossils known at that time and McLearn (1929, p. 100) concluded that "The fauna of the Green beds is probably Jurassic, but no exact correlation can be made . . ."

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[1] Names and dates in parentheses are those of references cited at the end of this report.
[2] Now Carbondale River.

Figure 1. **Distribution of the Fernie group in Western Canada. (By H. Frebold)**

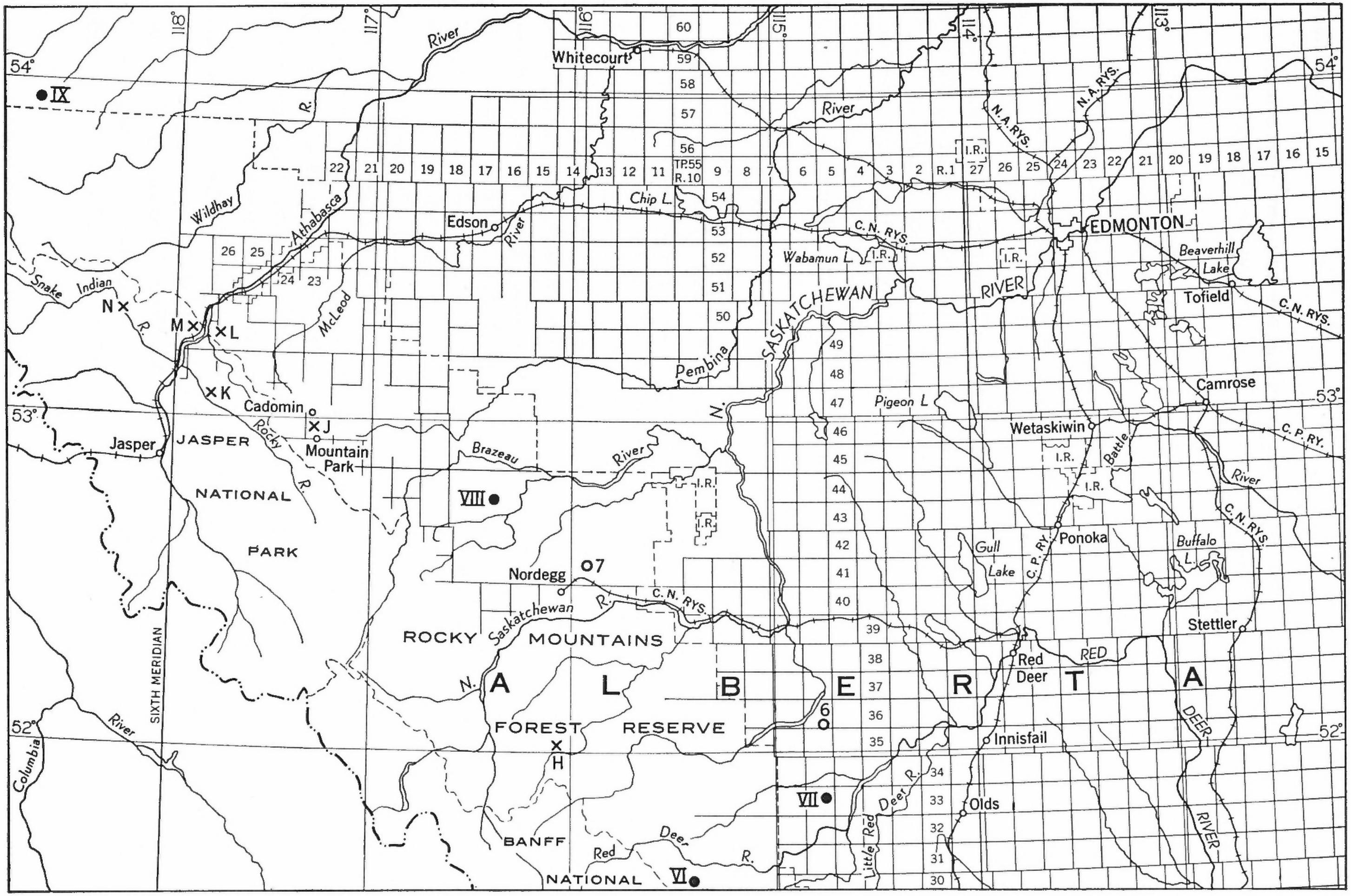
A section on the Adanac stripmine road (about half-way between Carbondale River and Blairmore) was measured in detail by Clow and Crockford (1951, p. 20). Below the Passage beds they found:

"Sandstone, bright emerald green, glauconitic; two or more lenses of hard rusty weathering shale	10.00
Shale, brown, blocky	6.6
Shale, sandy, yellowish-green to green in color, one band one foot wide, pistachio green (glauconitic)	9.8
Shale, green and brown layers generally blocky but in places quite plastic; crumbly weathering; very sandy near top	41.00"

The Green beds have a maximum thickness of about 66 feet at this locality and are there underlain by greyish and brownish shales below which is the lower Callovian *Gryphaea* bed (Frebold, 1957, p. 74). Clow and Crockford (1951, pp. 21, 22) pointed out that the microscopic examination of the green sand shows it to be composed largely of glauconite. The lithological development of the Green beds at other localities, as for instance Carbondale River, is very similar to that described by Clow and Crockford (1951, p. 20).

Subsequent detailed and systematic field studies of the Jurassic Fernie group in the Canadian Rocky Mountains and Foothills (Frebold, 1953, chart; 1954, chart; 1957, pp. 71, 73, 75, 78) have fully confirmed McLearn's findings on the stratigraphic position of the Green beds immediately below the Passage beds. They have also shown that the Green beds are generally about 50 feet above the lower Callovian *Gryphaea* bed which forms the top of the lower Callovian *Corbula munda* beds. Furthermore, the occurrence in the Carbondale River section of *Buchia concentrica* (Sowerby) (=*B. bronni* Rouiller) in the uppermost part of the Green beds, 9 feet below the contact with the lower Passage beds, permitted the age of this part of the Green beds to be determined as late Oxfordian or possibly early Kimmeridgian (Frebold, 1953, p. 1238; 1957, pp. 27, 28). The Green beds were at that time known to be present at the following localities: Carbondale River, Tent Mountain (Corbin area), Adanac, Blairmore brickyard quarries, Daisy Creek summit, and Alexander Creek. At all these localities except Daisy Creek summit, where no fossils were found, belemnites, *"Turbo" ferniensis,* and fossil wood are abundant. In the Grassy Mountain section north of Blairmore, the Green beds are very thin. Their local presence in disturbed parts of the section may indicate that they are structurally suppressed.

The Green beds were believed to pinch out northward and to be replaced by dark shales (Frebold, 1953, chart; 1954, chart; 1957, pp. 28, 29). The discovery of Green beds in the Miette (*see* pp. 30-38), Snake Indian River, Moosehorn Creek and Cadomin areas and in the subsurface as far north as the Peace River area shows however that this excellent marker bed has a much wider



ALBERTA
EDMONTON
Whitecourt
Edson
Jasper
Cadomin
Mountain Park
Nordegg
Tofield
Camrose
Wetaskiwin
Ponoka
Red Deer
Innisfail
Olds
Stettler
JASPER NATIONAL PARK
ROCKY MOUNTAINS FOREST RESERVE
BANFF NATIONAL
SASKATCHEWAN RIVER
N. Saskatchewan R.
Athabasca
Brazeau River
Pembina
McLeod
Wildhay
Snake Indian R.
Rocky R.
Red Deer R.
Little Red Deer R.
RED DEER RIVER
Battle River
Columbia River
Chip L.
Wabamun L.
Pigeon L.
Gull Lake
Buffalo L.
Beaverhill Lake
C.N. RYS.
C.P. RY.
N.A. RYS.
I.R.
SIXTH MERIDIAN
TP.55
R.10
R.1
54°
53°
52°
113°
114°
115°
116°
117°
118°
IX
VIII
VII
VI
H
J
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M
N
6
7

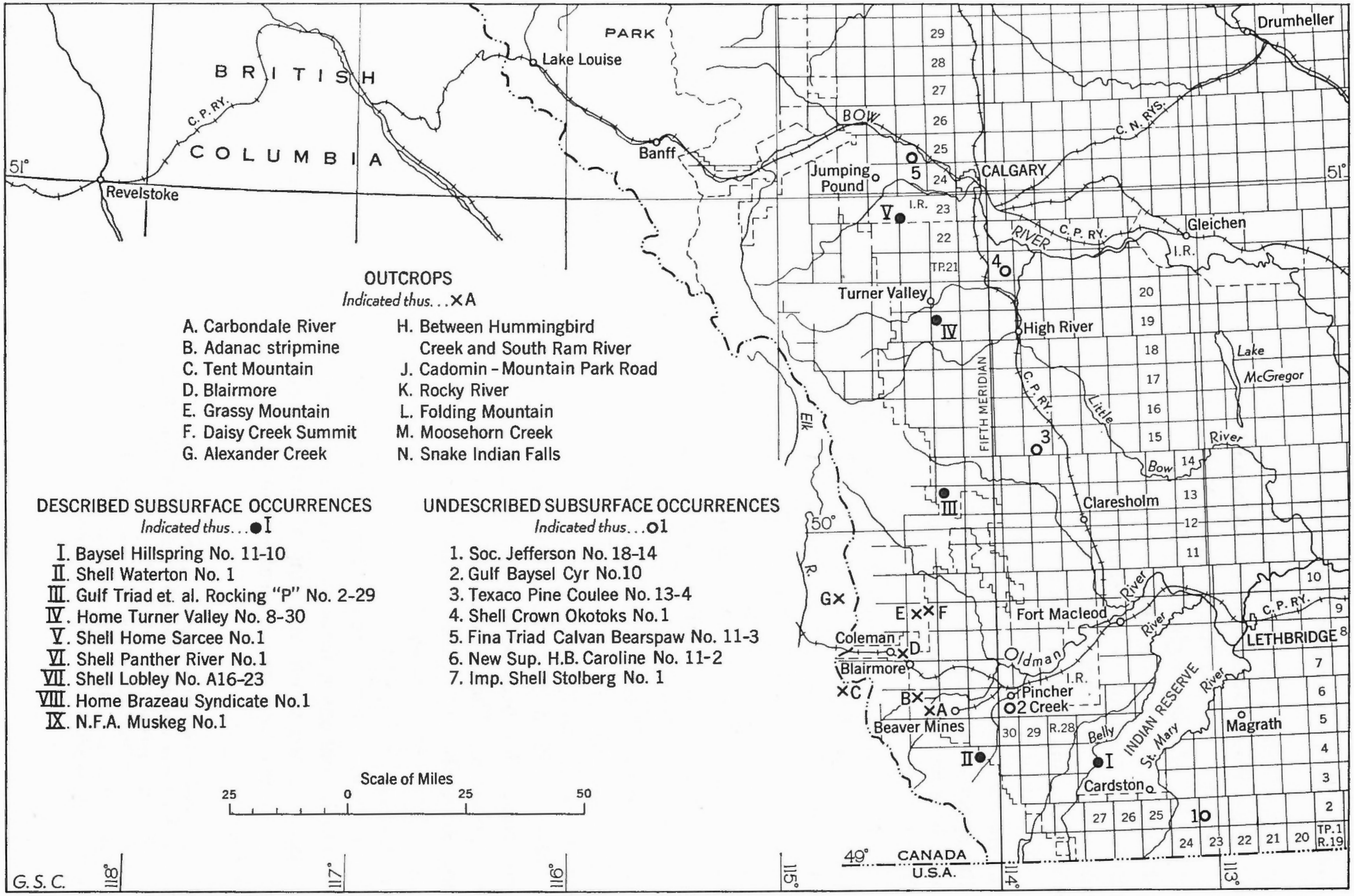

Figure 2. Distribution of the Oxfordian Green beds in the outcrops and subsurface in southern central parts of the Rocky Mountains and Foothills. Subsurface information by Ruth Reed.

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distribution than previously thought. Occurrences in the southern and central parts of the Rocky Mountains and Alberta Foothills are shown in Figure 2, p. 5.

The Green beds at Rocky River, Miette area consist, according to Mountjoy (*see* p. 33), of a lower glauconite bed, approximately 5 feet thick, 50 to 60 feet of shale with concretions and an upper glauconite bed, 6 inches thick. Cardioceratids[1] are frequent in the shale which is probably equivalent to shales with Cardioceratids of other areas, as for instance Cuthead Creek, between Lake Minnewanka and Panther Creek.

According to Mountjoy (*see* p. 33) the Green beds of Rocky River, Miette area, are underlain by a 25-foot-thick bed with large concretions, which may be the upper part of the lower Callovian Grey beds. A bed with large concretions is also present below the Green beds in the Carbondale River section and at Cadomin.

In the Cadomin area the Green beds were found by the author in a cut in the road from Cadomin to Mountain Park, a few hundred yards north of its junction with the Prospect Creek road. The locality is illustrated in GSC Memoir 287 (Frebold, 1957, Pl. XIII, fig. A), but when the picture figured was taken the Green beds were covered and could not be seen. The "Upper Jurassic dark shales with thin hard bands" illustrated are immediately on top of the Green beds which have since been exposed in the road-cut in the far right corner of the picture. The thickness of the Green beds is 5 feet. Exposed underneath the Green beds are 2 feet of brownish shale with concretions and grey shales that may be equivalent to the lower Callovian Grey beds. The Green beds yielded belemnites and plant fragments.

Weir (1949, p. 557) described, from the subsurface of the southern Alberta plains, glauconitic beds with black chert pebbles as forming the basal part of the Swift formation. These glauconitic beds were correlated with the Green beds in the Foothills and Rocky Mountains (Frebold, 1953, p. 1241, chart; 1957, p. 30). They are overlain by a unit whose lithology is similar to that of the lower Passage beds (unit c^1). A possible representative of the Green beds is the middle member of the Vanguard formation of Milner and Thomas (1954, pp. 264, 265) which contains glauconite, black chert pebbles, and water-worn belemnites, and occurs in the southern plains of Saskatchewan. All these indications suggest that the Green beds are traceable lithologically over wide regions in Western Canada.

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[1] The presence of Cardioceratids in the Fernie group has been mentioned before. *Cardioceras canadense* Whiteaves was described (Whiteaves, 1903, pp. 65-67) from the Fernie area but its locality and stratigraphic position are doubtful (Frebold, 1957, p. 63). Spivak (1949, p. 544) in his stratigraphic chart mentions *Quenstedtoceras* from Cadomin and *Cardioceras* from both Cadomin and Nordegg, but no further information is given as to the beds in which these ammonites were found or as to which species they may belong.

The Green beds are also present in many parts of the western interior of the United States, where they form part of Cobban's (1945, pp. 1281-1286) Swift formation.

Unit b^1, Lower Part of Dark Shales with Rusty Weathering Siltstone Bands and Concretions

Unit b^1 is present in many places in the central and northern Foothills. It is well exposed for instance at Shale banks in Snake Indian valley and at Rocky River in the Miette area. At Rocky River it overlies the Green beds (*see* Plates X, XI, XII). About 60 to 90 feet above the top of the Green beds *Buchia concentrica* (Sowerby) was found. The same *Buchia* was found in Snake Indian valley and in Kvass Flats area, there associated with specifically indeterminable Cardioceratids. Unit b^1 is also present in the Cadomin-Mountain Park region and in Fiddle River, northeast of Jasper. At the latter locality unit b^1 seems to overlie the middle Bajocian Rock Creek member and both the lower Callovian Grey beds and the Oxfordian Green beds seem to be absent. *Buchia* was found in various levels at this locality. It is believed that this facies extends through the northern Foothills up to the Pine Pass-Peace River region.

Towards the top dark shales of unit b^1 grade into similar shales with an increasing number of silt and sandstone bands (unit b^2) which in turn are overlain by the lowermost sandstone of the Nikanassin formation.

Some Buchias, probably indicating the presence of upper Kimmeridgian and Portlandian species, have been found in the upper part of this shale at various places in the northern Foothills.

Unit b^1 resembles in some general particulars the lower part of the Passage beds (unit c^1) in the south. The Passage beds, too, consist of dark shales, with silty and sandy interbeds in greater number and thickness in the upper part (unit c^2), which is overlain by the lower Kootenay sandstone, the probable equivalent of the lower Nikanassin sandstone.

The general similarity of the entire unit *b* to the Passage beds, unit *c*, and the similar stratigraphic position they occupy between the Green beds and lower Kootenay or Nikanassin sandstone, suggest that the two units are merely different facies of the same beds.

The lower part of unit *b* (unit b^1) which has yielded *Buchia concentrica* (Sowerby), may be equivalent to the upper part of the Green beds in the Carbondale River section, in which the same *Buchia* was found.

	STAGES	FERNIE GROUP	
UPPER JURASSIC	Purbeckian		Part of Kootenay Formation
	Portlandian	UPPER FERNIE	Lowermost Kootenay fm.
	Kimmeridgian		Passage beds and equivalents
	Oxfordian		Green beds
	Callovian		
			Grey beds
MIDDLE JURASSIC	Bathonian	MIDDLE FERNIE	
			Locally represented?
	Bajocian		
			Rock Creek member
LOWER JURASSIC	Toarcian	LOWER FERNIE	Paper shale
	Pliensbachian		
	Sinemurian		Nordegg member
	Hettangian		

G. S. C.

Table I. Subdivision of the Fernie group. For details *see* Memoir 287 (Frebold, 1957) and Table II, p. 9.

	STAGES			SOUTHERN CANADIAN ROCKY MOUNTAINS AND FOOTHILLS	CENTRAL AND NORTHERN CANADIAN ROCKY MOUNTAINS AND FOOTHILLS		MONTANA (after Imlay, 1952, 1956)	
UPPER JURASSIC	PORTLANDIAN			Lower part of Kootenay formation *Titanites occidentalis*	Lower part of Nikanassin formation			
UPPER JURASSIC	KIMMERIDGIAN	UPPER PART OF FERNIE GROUP		Unit c²: Upper Passage beds	Unit b²	Dark shale with rusty weathering bands	MORRISON FM.	
UPPER JURASSIC	KIMMERIDGIAN	UPPER PART OF FERNIE GROUP	DEPOSITS OF LOGAN SEA	Unit c¹: Lower Passage beds	Unit b¹: *Buchia concentrica* '*Turbo*' *ferniensis*		SWIFT FORMATION	*Buchia aff. concentrica*
UPPER JURASSIC	OXFORDIAN	UPPER PART OF FERNIE GROUP	DEPOSITS OF LOGAN SEA	Unit a: Green beds. Upper part with *Buchia concentrica*. '*Turbo*' *ferniensis*, *Belemnites*, Wood	Unit a: Green beds. Locally 2 glauconitic beds separated by shale with concretions. *Scarburgiceras* and other Cardioceratids. *Belemnites*		SWIFT FORMATION	*Cardioceras cordiforme* *Quenstedtoceras collieri*
UPPER JURASSIC	UPPER CALLOVIAN	UPPER PART OF FERNIE GROUP		NOT IDENTIFIED	PROBABLY ABSENT			
UPPER JURASSIC	LOWER CALLOVIAN	UPPER PART OF FERNIE GROUP		Shale	Shale with large concretions	Dark shale with thin yellowish brown bands	RIERDON FM.	*Kepplerites* *Gowericeras* *Arctioceras*
UPPER JURASSIC	LOWER CALLOVIAN	UPPER PART OF FERNIE GROUP		*Gryphaea* bed. *Kepplerites*, *Lilloettia*, *Gr. impressimarginata* etc.	Grey beds. *Kepplerites*, *Arcticoceras*, *Cadoceras*, etc.			
UPPER JURASSIC	LOWER CALLOVIAN	UPPER PART OF FERNIE GROUP		*Corbula munda* bed. *Cadoceras*, etc.				

G. S. C.

Table II. **Subdivision, index fossils and correlation of the upper Fernie group.** **(*By* H. Frebold)**

Unit c^1, Lower Part of Passage Beds

In the southern part of the Canadian Rocky Mountains and Foothills the Green beds are overlain by the very distinctive lower part of the Passage beds (unit c^1) which consists of dark shale with thin sandstone interbeds. A few belemnites and some pelecypod fragments, none of them diagnostic, occur in these beds. The contact between the Green beds and the lower Passage beds has been observed at many places.

The upper part of the Passage beds (unit c^2), which is more sandy and grades into the overlying Kootenay sandstone, is probably younger than Oxfordian. As mentioned in the foregoing, the lower part of the Passage beds is considered to be an equivalent of unit b^1.

The relationship of the various rock-units is summarized in Table II on page 9.

Age and Correlation

The age of the various units of the Oxfordian part of the Fernie group and their correlation with strata in other regions are mainly based on the contained fossils.

The distribution of the faunas in the rock-units and at the various localities is summarized as follows (*see also* Table II, p. 9):

Fauna 1. In unit *a,* Green beds, particularly in the shale with concretions between lower and upper glauconite bed; Miette area: *Cardioceras* (*Scarburgiceras*) *alphacordatum* Spath, *C.* (*S.*) aff. *alphacordatum* Spath and *gloriosum* Arkell, *C. mountjoyi* n. sp., *C. mountjoyi* var. *robusta* n. sp. et n. var., *C.* (*S.*) sp. indet. (large forms), *Goliathiceras* cf. *crassum* (Reeside), *Gryphaea nebrascensis* Meek and Hayden.

This fauna indicates the presence of the *Cardioceras cordatum* and part of the *Quenstedtoceras mariae* zones of the lower Oxfordian of Europe. It is also probably equivalent in age to the *Cardioceras cordiforme* zone of Imlay (1948, p. 17) in the western interior of the United States. The index fossil of this zone, *C.* (*S.*) *cordiforme* Meek and Hayden, has, however, not yet been found in the Canadian Green beds.

Fauna 2. In the upper part of unit *a,* Green beds, Carbondale River section; and in unit b^1, dark shale with rusty weathering bands and concretions, Rocky River, Fiddle River, and Snake Indian River: *Buchia concentrica* (Sowerby).

This fauna is stratigraphically higher and younger than fauna 1 and belongs to the upper Oxfordian and/or lower Kimmeridgian. The vertical distribution of *B. concentrica* has recently been discussed by Imlay (1955, p. 83) and he shows that the highest occurrence of this species is in the zone of *Amoeboceras alternoides.*

Fauna 3. In a dark shale of uncertain stratigraphic relation to the Green beds, unit *a,* Cuthead Creek: *Cardioceras* (sensu lato) div. sp. indet., *"Turbo" ferniensis* Frebold.

This shale may be equivalent to the shaly part of unit *a,* or to part of b^1. *"Turbo" ferniensis,* which is locally common in the Green beds and was also found in dark shales in Pocaterra Creek, Cascade Valley near Banff, and Fiddle River, seems to be a comparatively long-ranging form, as it occurs both in units *a* and b^1.

Fauna 4. In unit c^1, lower Passage beds, southern Rocky Mountains and Foothills: Non-distinctive pelecypods and belemnites.

Table II illustrates the position of the Oxfordian beds within the upper part of the Fernie group, its index faunas and subdivision, and its correlation with the Montana succession and European stages.

Equivalents of the Oxfordian beds of the Fernie group are widespread in parts of British Columbia, but most of the faunas are still undescribed. Locally, beds with *Cardioceras* (*Scarburgiceras*) and beds with *Buchia concentrica* are known to be present. Marine Oxfordian beds are known to occur at the following localities: west coast of Vancouver Island, Harrison Lake area, Tyaughton Lake area, McConnell Creek area, Terrace area, Groundhog area, Stikine area.

The presence of Oxfordian in the southern plains of Alberta and Saskatchewan was mentioned above. It is possible that part of the upper Sundance formation of Manitoba includes Oxfordian beds (*see* Francis, 1957, p. 379).

THE LOGAN SEA

(H. Frebold)

The Oxfordian sedimentary rocks of the Fernie group dealt with in this paper were deposited in the Logan Sea. W. N. Logan (1900) described some of the Jurassic occurrences in the United States and Canada that he believed to be characterized by only one fauna whose index fossil was *Cardioceras cordiforme*. The age of the beds concerned was determined accordingly as Oxfordian. The areal extent and age of the Logan Sea was defined in Schuchert's map (1923, fig. 14) which is reproduced in Figure 3. In Canada the term Logan Sea is restricted to the sea that occupied the region of the Rocky Mountains and Foothills and part of the plains of Alberta, Saskatchewan, and perhaps Manitoba. The sea in the western part of the Cordilleran geosyncline, and the hypothetical connections with the Pacific and Arctic Oceans via Yukon and Mackenzie River valley respectively were not included in the term Logan Sea. The time of the transgression of the Logan Sea was "early Upper Jurassic" (Schuchert, 1923) and as Schuchert follows Logan's ideas about the time, it is obvious that he was referring to the Oxfordian.

Crickmay (1931, p. 50) and Stille (1940, pp. 167, 252) have used the name Logan Sea according to this definition and it is used here in much the same way. However, the beds with *Buchia concentrica* (Sowerby), which were deposited in the last stage of the Logan Sea transgression, are included. These are somewhat younger than the beds with *Scarburgiceras* and may be in part of early Kimmeridgian age.

It is an interesting fact that, as far as Canada is concerned, there was no actual faunal evidence for the presence of the Logan Sea. Neumayr's (1885, map II) palæogeographic map illustrating his idea of an extensive early Upper Jurassic transgression was not supported by any fossils in the region later called the "Logan Sea" or in other Canadian regions that in his opinion were covered by seas. Logan (1900, p. 272) stated that Neumayr's palæogeographic map was not supported by facts and rightly denied the connection of the west Canadian sea with the Arctic through the Mackenzie River valley. However, Logan himself was in error when he considered that all the Jurassic faunas in Canada known to him belonged to the Oxfordian *Cardioceras cordiforme* fauna. In reality none of the Canadian faunas he mentioned in his paper (1900, pp. 258, 259) is of Oxfordian age; they are all older and most of them belong to the Bajocian. Crickmay (1931, p. 49) refers to *Cardioceras canadense* Whiteaves, which was supposed to have been found near the town of Fernie, British Columbia, but the origin of this specimen is questionable (*see* Frebold, 1957, pp. 27, 63). Spivak's (1949, p. 544) mention of *Cardioceras* and *Quenstedtoceras* from the Cadomin and Nordegg areas was the first evidence of the actual presence of Logan Sea deposits in Western Canada.

The discoveries made since 1951, described in GSC Memoir 287 (Frebold, 1957), and in this report, have shown that deposits of the Logan Sea are widely distributed in the Canadian Rocky Mountains and Foothills. Thus a reliable basis for the extent and nature of this sea can now be established much more accurately. The extension of the sea into the plains of Saskatchewan and Manitoba is indicated by beds probably equivalent to those of the Logan Sea to the west, but no reliable guide fossils have yet been found.

The eastern boundary of the Canadian part of the Logan Sea followed a general southeast trend to a point about midway between Calgary and Lethbridge. From there it swung into an easterly direction in the southern plains of Alberta, Saskatchewan and part of Manitoba. This coast-line followed, in general, the coast-line of most of the Jurassic seas in Western Canada (*see* Figure 4). In Manitoba the coast-line bends south again and continues southward through the eastern parts of North and South Dakota and Nebraska (Imlay, 1950, map 6; Peterson, 1957, p. 432, fig. 17).

The Logan Sea was for a long time believed to be bordered on the west by "mountains" (Schuchert, 1923, p. 226, fig. 14), by a coherent landmass "Jurozephyria" (Crickmay, 1931, p. 89, map 10) or by the "Central Cordilleran geanticline" (Schuchert, 1939, pp. 64, 65). The existence of this land, which was considered to have separated the Logan Sea from the Pacific geosyncline, cannot be supported by any known facts (Frebold, 1957, pp. 37-41). This, however, does not mean that islands or belts of islands, probably of volcanic origin, may not have been present in the Jurassic seas of British Columbia. It was suggested recently (Frebold, 1959) that such volcanic islands were present in the geosyncline in Nelson and Salmo areas, particularly for the *Arnioceras* time of the Early Jurassic. They are indicated by the presence of near-shore deposits (coquina beds) that rapidly grade into deeper water sediments.

The presence of thick marine Jurassic deposits in more northerly parts of British Columbia (McConnell Creek, Groundhog, and Stikine areas), which are close to or coincide directly with the position of the supposed "geanticlinal landmass" amply demonstrates the absence of this landmass in these regions also. This is particularly true of the deposits of Oxfordian age, during which time thick marine beds were deposited over wide areas. The Oxfordian sea in those parts of British Columbia is believed to have been connected, on the west, to the

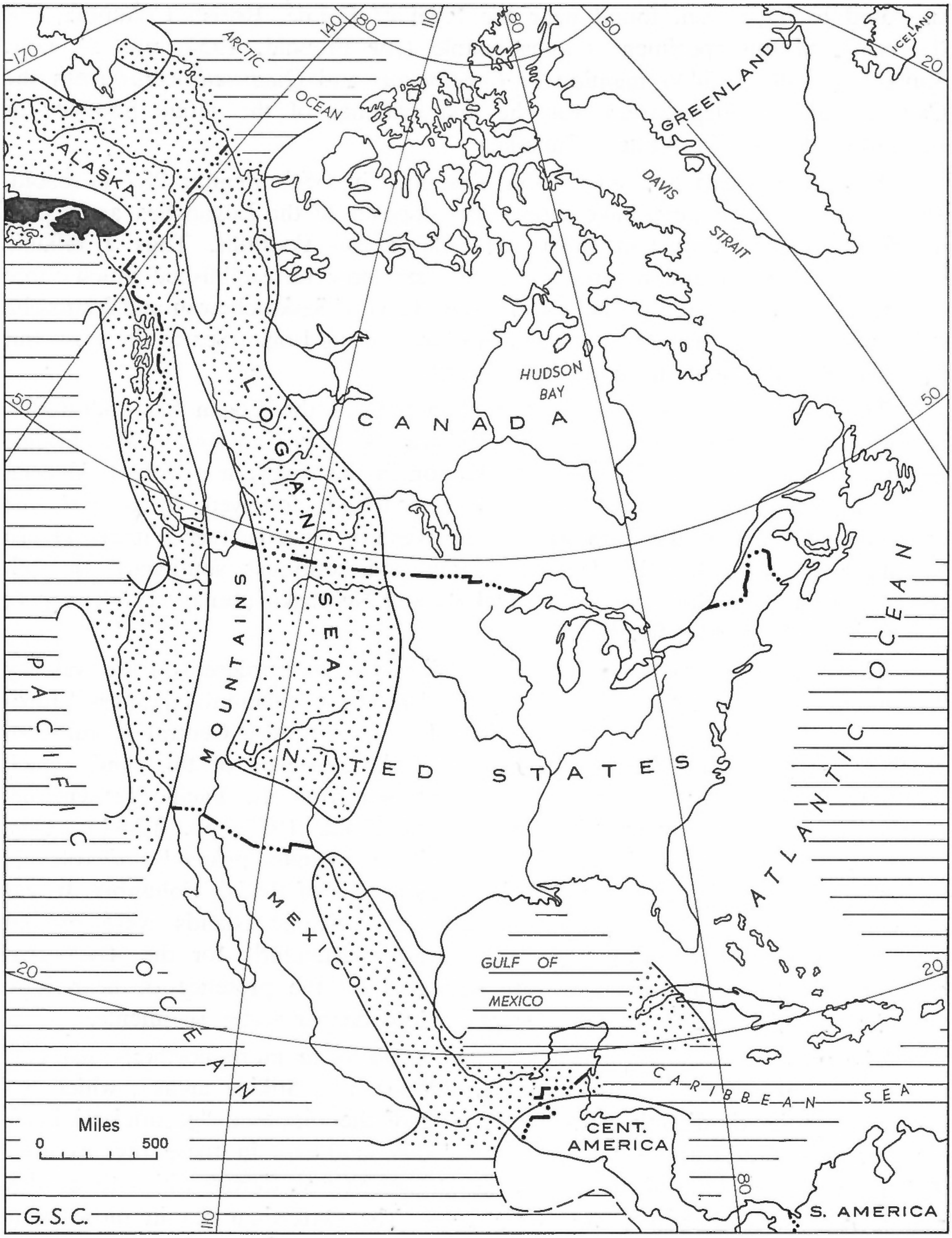

Figure 3. **The extent of the Logan Sea as defined by Schuchert (1923, p. 226, fig. 14).**

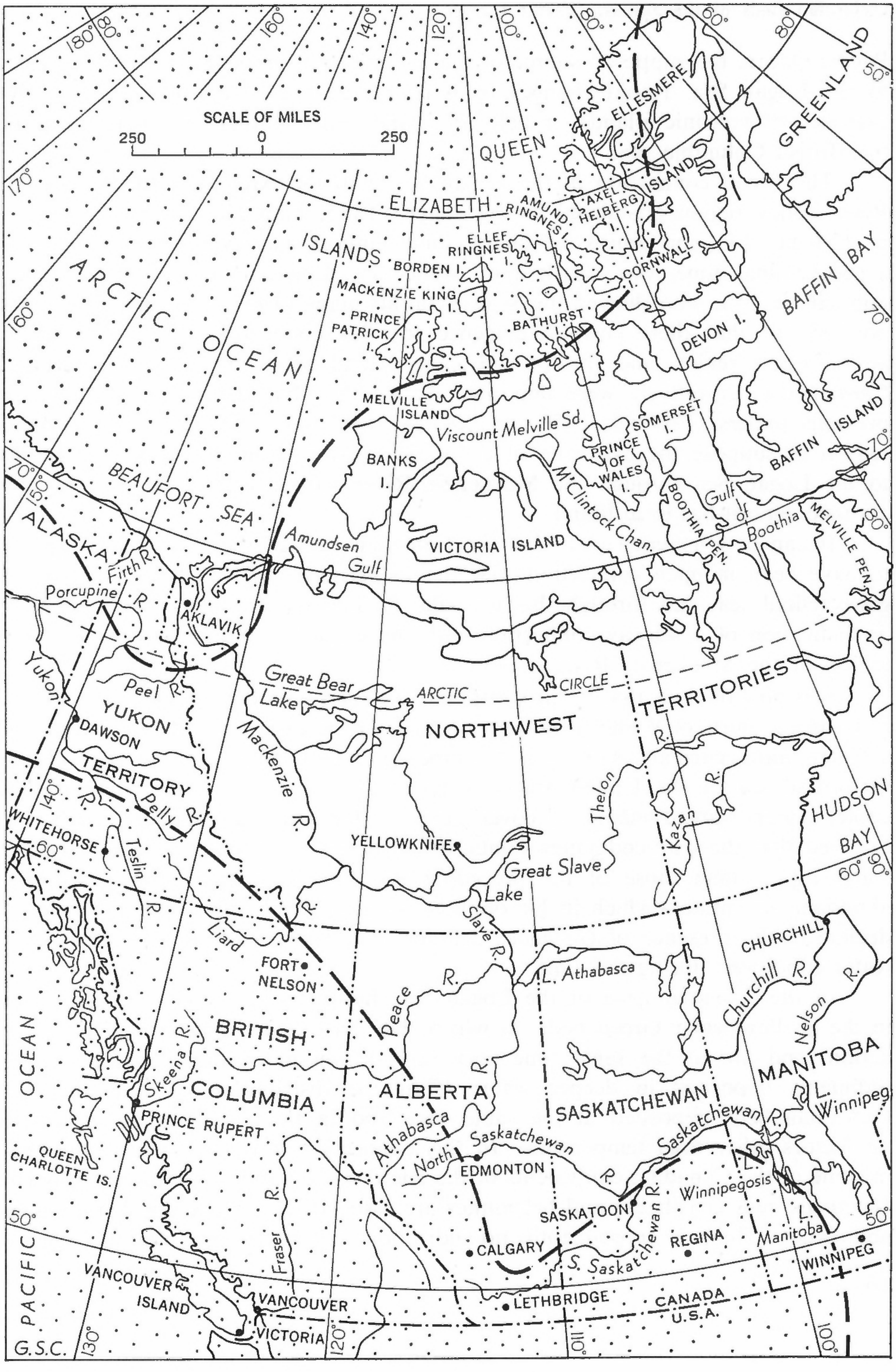

Figure 4. **Regions of marine deposition, shown by stipple pattern, in Western and Northern Canada during Jurassic time. (By H. Frebold)**

Pacific Ocean, the supposed source of the Jurassic transgressions, and on the east, to the Logan Sea. Rapid changes from coarse to fine facies may indicate the presence of volcanic islands or belts of islands also in these northern parts of the British Columbia sea.

The broad connection of the Logan Sea with the Arctic via the Mackenzie River valley region postulated by Neumayr (1885, map II), Schuchert (1923, p. 226, fig. 14) and others, which by some authors was even considered to be a geosynclinal zone, was clearly pure conjecture. Logan (1900) and Crickmay (op. cit., p. 15), who showed this seaway on his maps (1931, pp. 83, 84, 86-90), pointed out that there was no evidence for this connection. In the Canadian Arctic coast region and in Axel Heiberg Island sediments with *Buchia* and *Cardioceras* respectively were deposited during the Oxfordian, but as shown in previous papers (Frebold, 1957, pp. 38, 44; 1958a, p. 29), there is no sound reason to suppose the existence of a Jurassic seaway from these Arctic regions to the Logan Sea through the Mackenzie River valley, where no trace of any Jurassic deposit has been found.

It can be concluded then that the Canadian part of the Logan Sea appears to have been in open connection with the western part of the British Columbia geosynclinal sea, and through this with the Pacific. On the other hand, there is no indication of a seaway connection with the Canadian Arctic Sea through the region of the Mackenzie River valley.

It is now obvious that in the comparatively long time during which the Logan Sea covered parts of Western Canada, changes in the extent and depth, fauna and sedimentation, currents, salinity and temperature took place. Of the part of the Oxfordian sea in the United States, Peterson (1957) was of the opinion that cooler waters spread inland to cover areas as far south as southern Utah. He believed that the ostracod fauna contained in deposits of that time has a cooler water aspect than those of the preceding Rierdon (Callovian) time. Also the abundant belemnites, which in his opinion preferred cool water, and the marked decline in the presence of *Gryphaea* are considered by Peterson to indicate cool water conditions during this time.

In the Canadian part of the Logan Sea, however, belemnites are abundant in the shallow-water Green beds, in which they have been concentrated by wave action, and are at the same time very rare or absent in the equivalent shaly sediments deposited in deeper water. Thus the distribution of belemnites in Oxfordian beds deposited at the same time and in the same sea is dependent on factors other than temperature. In this connection it is also noteworthy that in some of the Canadian equivalents of the Rierdon formation, the lower Callovian *Gryphaea* bed, Gryphaeas and belemnites are associated with one another in great abundance. There is consequently no indication in this instance that Gryphaeas preferred warm and belemnites cool water. Similar assemblages, in which both Gryphaeas and belemnites are abundant, occur in the middle Bajocian Rock Creek member of the Fernie group.

Because of these facts no attempt is made here to discuss the possible presence and direction of cool or warm currents in the Canadian part of the Logan Sea.

There are, however, enough facts known to permit some comment upon the varying extent of the Logan Sea at different times during the Oxfordian, and about changes in its depth and in the sediments deposited in it. Three different periods of time can be recognized, as indicated by the succession of distinct faunas. The oldest is characterized by *Quenstedtoceras,* the next by Cardioceratids, including the subgenus *Scarburgiceras*, and the youngest by *Buchia concentrica* (Sowerby).

As there are no fossils that indicate the presence of upper Callovian sediments, a hiatus between the lower Callovian and the base of the Oxfordian is postulated. The absence of most of the upper Callovian has also been established for the western interior of the United States (Imlay, 1952, chart). This interval may be regarded as a time of total regression of the sea, or at least a time of non-deposition and interruption of all connections so that no fauna could immigrate.

The transgression of the Logan Sea, following this interval, occurred in the earliest Oxfordian, characterized by representatives of the genus *Quenstedtoceras.* This first advance of the sea, which reached into the western interior of the United States, is not well indicated in the Canadian part of the Logan Sea.

During the following time interval, that of *Scarburgiceras* and other Cardioceratids, various types of sediments were deposited in the Canadian part of the Logan Sea, comprising the glauconitic sandstones, siltstones and shales of the Green beds (unit *a*). The shaly facies indicates deeper water conditions than the glauconitic sandstone and siltstone facies of the Green beds. A significant feature of the shaly facies is the scarcity of belemnites, so abundant in the glauconitic sandstone beds. *"Turbo" ferniensis,* one of the index fossils of the glauconitic beds, and Cardioceratids are, however, present.

The glauconitic sandstones in the western interior of the United States, which were deposited over wide areas as indicated on the palæogeographic maps of Imlay (1950, p. 6) and Peterson (1957, map, fig. 17, p. 432) and which are equivalent in age to the Canadian Green beds, were considered by Imlay (1950, p. 91) to be very shallow-water deposits. This shallow-water character is indicated, according to Imlay (loc. cit.), by abundant ripple-marks and crossbedding, and locally by wood impressions, oolites, and such organisms as *Ostrea* and *Gryphaea.* A shallow-water origin was also postulated (Frebold, 1957, p. 31) for the glauconitic Canadian Green beds, which locally have abundant wood and belemnites. Some equivalents of the Green beds were deposited in the southern plains of Alberta and Saskatchewan; there also with many rolled belemnites.

During the last stage of the Logan Sea, i.e., the time of the deposition of beds with *Buchia concentrica* (units b^1 and c^1) marine conditions are indicated in the eastern parts of the Rocky Mountains and in the Foothills. In the northern parts of this region shales with silt and sandstone intercalations (unit b^1) were deposited, and in the south, the uppermost part of the Green beds and the lower part of the Passage beds (unit c^1). The new discovery of *Buchia* of the *concentrica* group in the western interior of the United States (Imlay, 1956, p. 595) proves the continued presence of the sea in that region, but its extension into Manitoba and the eastern parts of Saskatchewan is uncertain.

The regression of the Logan Sea began in the south, probably in the Kimmeridgian, when in the western interior of the United States non-marine beds of the Morrison formation were deposited. In the southern parts of the Canadian Rockies and Foothills the sea was shallow, as is indicated by the increase of sandy material in the upper Passage beds (unit c^2). The sea retreated there definitely during the late Portlandian, its last manifestation being the lower Kootenay sandstone, which contains the large ammonite *Titanites occidentalis.*

Marine conditions seem also to have persisted in the northern part of the sea, as indicated by the presence in the northern Foothills of younger *Buchia* faunas of late Kimmeridgian or Portlandian age. However, too little is known about these faunas for a definite conclusion to be reached.

The source of the sediments in the Canadian part of the Logan Sea is uncertain. As long as the hypothesis of the existence of a bordering land in the west, Jurozephyria, was regarded as valid, much of the Oxfordian sediments in the Rocky Mountains and Foothills was thought to have originated from this "Central Cordilleran geanticline". It has, however, been shown that there is no reason to accept the existence of this land for most of Jurassic time, although some of the sediments may have come from the volcanic islands believed to have existed in this region during the Jurassic. It is more probable that the sediments came from lands that bordered the Logan Sea on the north and east and it is obvious that at least the deposits in the northern and eastern border zones of the Logan Sea, including the southern plains of Saskatchewan, came from this source. Some American authors (Peterson, 1957) favour a western source for the sediments in the southern parts of the Logan Sea, the western interior of the United States.

The deposits in the Canadian part of the Logan Sea reach a thickness of about 200 feet in the south and 300 feet in the north. The amount of subsidence in the Logan Sea during the Oxfordian was accordingly extremely small, particularly when compared with the estimated thicknesses in the geosynclinal areas of British Columbia. In the Harrison Lake area the Agassiz series attains a thickness of about 8,000 feet (Crickmay, 1930, p. 37) and the Oxfordian deposits in northern British Columbia are estimated to be several thousand feet thick. The comparison of these thicknesses with those in the Logan Sea shows clearly that the latter was a non-geosynclinal area during the Oxfordian and that it formed a border zone between the geosyncline in the west and the land in the east. The same conclusion has been reached for the other Jurassic deposits in the Rocky Mountains and Foothills (Frebold, 1957, pp. 41, 42).

During the time of the Oxfordian neither orogenic movements nor igneous activity took place in the regions covered by the Logan Sea. In parts of the British Columbia geosyncline, however, orogenic movements have apparently taken place during the late Callovian. Crickmay (1931, p. 45) believed that the conglomerates of the Agassiz series near Harrison Lake, which are about 3,000 feet thick and which are supposed to be Oxfordian in age, prove that an uplift took place between the lower Callovian and Oxfordian. Crickmay (op. cit., p. 46) stated rightly that probably no strong folding occurred and that no definite trends of mountain structure are discernible during this "Agassiz orogeny". The magnitude of this movement has occasionally been overestimated in recent years. The author's field observations in the type area near Agassiz did not reveal any angular disconformity between the Agassiz series and the underlying lower Callovian, but the lithological change from Callovian shales to the coarse conglomerates of the Agassiz series indicates at least an epirogenetic uplift of considerable magnitude. As the Agassiz conglomerate is only known from the immediate neighbourhood of Agassiz, the movement seems to have been local. The Agassiz orogeny coincides with the regression during the late Callovian in the region of the Logan Sea, but is not necessarily the cause of it.

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SYSTEMATIC DESCRIPTION OF FOSSILS

(H. Frebold)

Cardioceras (Scarburgiceras) alphacordatum Spath

Plate I, figures 1*a, b*

Cardioceras cordatum var. A. de Loriol, 1898, pp. 15, 16, Pl. 2, figs. 1, 2, 3.
cf. *Cardioceras alphacordatum* Spath, 1939, p. 94, Pl. 6, fig. 10.
cf. *Cardioceras alphacordatum* Arkell, 1946, pp. 302-304, text fig. 106, Pl. 69, figs. 8*a, b.*

The specimen illustrated on Plate I, figures 1*a, b,* is septate almost to the end of the last whorl, only the most anterior part of which belongs to the body chamber. The maximum diameter is not measurable because of the fragmentary preservation of the last whorl. The measurements in millimetres taken at a smaller diameter are as follows:

Dm.	Width of umbilicus	Height of whorl	Thickness of whorl
87	19 (.22)	44 (.51)	30 (.34)

At this diameter the ribs begin to disappear, but there are still some primary ribs and faint secondaries visible in the anterior part of the last whorl. The absence of ribs is also partly caused by the fragmentary preservation of this part of the specimen. In the posterior part of the last whorl all primaries are present at the umbilical edge, some of them are faintly indicated on the steep umbilical wall, where they are inclined backwards. Some of the primaries are entirely straight, others somewhat bent, some are higher than others, and the space between them varies. At the point of bifurcation, which is a little below half the height of the flanks, the ribs form fairly sharp bullae. All secondaries, including the intercalated ribs, are of about equal strength, they are bent very sharply forward, running below the high keel and eventually ending forwardly in one of its strong denticulations.

Part of the deeply incised suture line is visible in the anterior part of the last whorl. The ventral lobe and the first lateral saddle are not preserved but part of the deep and slender, apparently trifid first lateral lobe is recognizable. The second lateral lobe is trifid and shorter than the first lateral. There are some auxiliary lobes. The saddles are broad, the second lateral much higher than the third.

This specimen shows the same general type of ribbing as de Loriol's *C. cordatum* var. A (1898, Pl. 2, fig. 1, 1*a*), and Spath's *C. alphacordatum* (1939, p. 94, Pl. 6, fig. 10). Arkell's *C. alphacordatum* (1946, pp. 302-304, text fig. 106, Pl. 69, figs. 8*a, b*) also seems to agree fairly well with the Canadian specimen.

This specimen was found at locality *F* (*see* Figures 5 and 6) on Rocky River, Miette map-area, west half, in unit *a*.

C. (*S.*) *alphacordatum* Spath occurs in the Jura bernois in the *praecordatum* beds of the *Quenstedtoceras mariae* zone, and in England in the *praecordatum* subzone of the upper Oxford Clay (lower Oxfordian).

Cardioceras (Scarburgiceras) aff. *alphacordatum* Spath and *gloriosum* Arkell

Plate II, figure 1

The last whorl of this imperfectly preserved specimen does not show any sculpture except for some fine striae visible on a restricted area where part of the shell is preserved. The posterior part of the whorl is still septate; the anterior part forms part of the living chamber. No keel is preserved on the last whorl. The umbilical wall is high and overhanging at this stage of the ontogenetic development.

The visible part of the preceding whorl (after removal of part of the living chamber) has a high overhanging umbilical wall. Only on the posterior part of this whorl are primary ribs present. The point of division into the secondaries is faded, no bullae are present. In the anterior part of this whorl only secondaries are visible. These are fairly sharply bent forward and end in the strong denticulations of the high keel. These secondaries continue in the lower half of the flanks in the form of very fine striae. In the most anterior part of this whorl the sculpture has faded.

As the inner whorls of this specimen could not be exposed it is uncertain if the specimen represents a later stage of ontogenetic development than that of *Cardioceras* (*Scarburgiceras*) *alphacordatum* Spath described above. The type of sculpture resembles both that of *C. alphacordatum* Spath (Spath, 1939, pp. 94, 95, Pl. 6, fig. 10) and *C. gloriosum* Arkell (Arkell, 1946, p. 304, Pl. 69, fig. 20) but on account of the unsatisfactory preservation no positive identification can be made.

This specimen was found at locality *F* on Rocky River, Miette map-area, west half (*see* Figures 5 and 6), in unit *a*.

Cardioceras mountjoyi n. sp.

Plate III, figures 1*a, b,* 2*a, b,* 3*a, b;*
Plate IV, figures 1*a, b*

The measurements in millimetres of the holotype (Plate IV, figures 1*a, b*) of this new species, named for Dr. E. Mountjoy, Geological Survey of Canada, are as follows:

Dm.	Width of umbilicus	Height of last whorl	Thickness of last whorl
103	17 (.17)	49 (.48)	41 (.40)

The cross-section at the end of the last whorl is high cordate, the fairly narrow umbilicus has at this stage a high perpendicular wall, which is absent on the inner whorls. The specimen is septate almost to the end, most of the living chamber is missing.

On the posterior part of the last whorl there are straight, fairly strong, widely spaced primary ribs that terminate at half the height of the flanks in bullate tubercles. At this point the primaries are divided into two or three secondary ribs that, together with intercalated secondaries, are sharply bent forward and cross the very high keel. Some of the intercalated secondaries are also faintly indicated in the lower part of the flanks. On the anterior part of the last whorl both the primaries and secondaries fade out.

This species is similar to the *Cardioceras* (*Scarburgiceras*) *alphacordatum* Spath described above, but is more robust and has stronger bullae at the point of the division of the primaries.

The specimen Plate III, figures 1*a, b* of this new species has about the same size as the holotype; there are some slight differences in the sculpture, some of the primaries being subdivided a little below half the height of the flanks. This specimen is septate almost to the end of the last whorl, but details of the suture line are not recognizable.

Both specimens were collected at locality *F* on Rocky River, Miette map-area, west half, in unit *a.*

Another, broken specimen of about the same size as those described above, shows the venter and the upper part of the flanks of an inner whorl between 7 and 9 mm high. The whorl section at this stage is oval, the keel well developed. The ribs on the flanks (the point of division is not visible) are all equal in size, strongly bent forward. They cross the keel, each forming a denticulation.

Between this stage and the stage characterized by the larger specimens already described, this species passes through a stage with a more quadrate whorl section and comparatively flat venter. In the specimen under discussion this stage is very faintly recognizable.

Two specimens figured on Plate III, figures 2*a, b,* 3*a, b* which are probably young specimens of *C. mountjoyi* illustrate these younger ontogenetic stages. At a diameter of 37 mm the smaller of the two specimens (Plate III, figures 2*a, b*) has, at the beginning of the last whorl, an oval shape, at its end it is more rectangular. At a diameter of 51 mm the cross-section is almost quadrate and the venter flat.

The same conditions are present in the other specimen (Plate III, figures 3*a, b*) which has a diameter of 58 mm. The shape of the whorl at this stage is similar to that of representatives of the subgenera *Cardioceras* sensu stricto, *Subvertebriceras,* and *Vertebriceras.* Both of the small specimens have strong straight primary ribs with high tubercles at the point of bifurcation which up to a diameter of 37 mm is at the half-height of the flanks. The point of bifurcation is somewhat higher when the venter becomes flatter. The secondaries are strongly bent forward, cross the venter forming a denticulation of the keel. Generally there is one intercalated secondary between two pairs of secondaries originating from a primary rib in the flat venter stage and two or more in the preceding stage with oval cross-section.

These two small specimens were found in the Green beds (unit *a*) at locality *H* on Rocky River in the Miette area.

No decision is made here as to the subgeneric position of this species. As stated above, the holotype is similar to *C.* (*Scarburgiceras*) *alphacordatum* Spath with which it was found associated in the same bed at the same locality. The shape of the inner whorls of *C. mountjoyi,* however, does not agree with that of known *Scarburgiceras* species.

Cardioceras mountjoyi var. *robusta* n. var.

Plate IV, figures 2*a, b*

The measurements of this specimen are as follows:

Dm.	Width of umbilicus	Height of last whorl	Thickness of last whorl
88	19 (.22)	48 (.55)	46 (.52)

The cross-section at the end of the last whorl is cordate, the umbilical wall of the last whorl is high and perpendicular. The living chamber is missing, the specimen being septate at the end of the last whorl.

There are about eight straight primary ribs on the umbilical wall that continue to a point at about half the height of the flanks where they terminate in bullate tubercles and are subdivided generally into two secondaries that are moderately bent forward and cross the keel. Other secondaries that are not connected with primaries are equal in size and shape, they fade out below the half-height of the flanks. In the anterior part of the last whorl all the ribs are fading out.

This specimen is very similar to *Cardioceras mountjoyi* n. sp. but it is distinguished from it by a wider cross-section, more rounded venter, and a lower keel. Furthermore, the secondaries are bent forward much less than in *C. mountjoyi.* More specimens from the beds concerned may indicate a gradual transition from *C. mountjoyi* to the present form, which is here considered to be a variety of that species.

The specimen was collected at locality *F* on Rocky River, Miette area, in unit *a.*

Cardioceras (Scarburgiceras ?) **sp. indet.**

Plate VII, figure 2; Plate VIII, figures 1*a, b;*
Plate IX, figure 1

Several specimens of large ammonites with high whorls and a narrow umbilicus were found in the Miette area. The specimen illustrated on Plate VIII, figures 1*a, b* consists of a fragment of a large whorl (figure 1*a*) and part of one of the inner whorls (figure 1*b*). At a diameter of about 46 mm this inner whorl has primary ribs which end in elongated bullae from which usually two fairly strong secondaries arise. One other secondary is generally intercalated between the pairs of secondaries that originate from the primaries. The secondaries are bent forward and cross the high keel. The cross-section at this diameter is high oval. The fragment of the larger whorl (figure 1*a*) has a very high cross-section. On the flanks are fine radial striae which are strongly bent forward and end in the denticulations of the keel. The whorl is septate to the end.

The cross-section figured on Plate VII, figure 2, belongs to the penultimate whorl of a fragmentary specimen still larger than the specimen described above. An inner whorl fragment of about the same size as that figured on Plate VIII, figure 1*b,* has apparently the same type of ribbing and the same high cross-section. At a diameter of approximately 140 mm, the width of the umbilicus is about 19 mm, the height of the last whorl 72 mm, and the thickness of the last whorl 44 mm. The cross-section is high oval. The remnant of the last whorl preserved has still a very high oval cross-section and is septate to the end.

Except for a few faint ribs and striae, the last whorl of the large specimen illustrated on Plate IX, figure 1, is entirely smooth.

The large indeterminate specimens described here seem to be closely related to one another and may belong to the same species. The few, fragmentary inner whorls available for study seem to indicate that they belong to the subgenus *Scarburgiceras* but there is also a certain similarity with some species of the subgenus *Scoticardioceras* Buckman. All these large specimens are distinguished from *C. mountjoyi* n. sp. and *C.* (*Scarburgiceras*) *alphacordatum* Spath by higher whorls and an earlier disappearance of the ribs.

The specimen figured on Plate VIII, figures 1*a, b* was found at locality *E* on Rocky River, the others are from unit *a,* at locality *F* on Rocky River, Miette area.

Goliathiceras cf. *crassum* (Reeside)

Plate V, figure 1; Plate VI, figure 1;
Plate VII, figures 1*a, b*

This specimen has a maximum diameter of about 190 mm but some shell remnants on the last whorl preserved indicate that it was still larger. The shell is stout; the greatest thickness is close to the umbilical shoulder. The whorls are involute, the umbilicus fairly narrow and deep, the height of the umbilical wall increases considerably with the growth of the specimen. The umbilical wall of the last whorl is steep, the umbilical shoulder rounded. The transition from the flanks into the venter is gradational; in the anterior part of the last whorl the venter is much narrower and sharper than at the beginning of the last whorl. A weak keel is visible where the shell is removed.

The cross-section of the last whorl, taken at a diameter of about 187 mm (Plate VI, figure 1), shows that the whorl becomes considerably higher towards the end. The approximate measurements at this diameter are: width of umbilicus 41 mm (.22), height of whorl 96 mm (.51), thickness of whorl 75 mm (.40). As the anterior part of the whorl is slightly crushed, accurate measurements are not possible. A constructed cross-section, lying between the two figures with a whorl-height of about 68 mm and an approximately equal thickness, is rounded-triangular with a sharper venter.

Strong, almost straight, broad primary ribs with rounded cross-section are present in the posterior part of the last whorl. They bifurcate somewhat below the middle of the flanks. The ribs are bent slightly backward on the flanks and somewhat forward on the venter which is crossed with a very oblique angle. Some secondaries are intercalated between the pairs of secondaries that originate from the primaries. These intercalated secondaries do not extend downward beyond the middle of the flanks. Towards the end of the last whorl the ribs are much weaker. On the penultimate whorl the visible part of the rounded and widely spaced straight primaries is very strong. The ribs are also straight and regularly spaced on two more preceding whorls.

Up to a diameter of about 180 mm parts of the suture line are visible, the remaining part of the last whorl belongs probably to the body chamber. The ventral and first lateral lobes are of about equal length and fairly deeply incised. The shape of the apparently short second lateral lobe is not clearly defined.

This specimen is similar to *"Cardioceras" crassum* Reeside (1919, p. 23, Pl. 12, figs. 3, 4; Pl. 13, fig. 1; Pl. 14, figs. 1, 2), which is also stout and has similar ribs. The cross-section of the here-described specimen, at a diameter of 187 mm, shown in Plate VI, figure 1, does not agree with the cross-section of one of Reeside's specimens (Reeside, 1919, Pl. 14, fig. 2) taken at a diameter of 141 mm, but a constructed cross-section of the Canadian specimen at about the same diameter is essentially the same. The suture line of Reeside's specimen (Reeside, 1919, Pl. 12, figs. 3, 4) differs from that of the Canadian specimen mainly in the ventral lobe that appears to be shorter than the first lateral (in the here-described specimen they are of equal length) and in the shape of the first lateral lobe, that seems to be more regular in the Canadian specimen. Accurate comparisons of the two suture lines are difficult as both are unsatisfactorily visible. Because of these uncertainties the here-described specimen is not directly identified with Reeside's species.

"C." bellefourchense Reeside, also, is morphologically related, both in its general stoutness and the type of sculpture, but as none of the specimens of this species described by Reeside reaches the size of the Canadian specimen, no direct comparisons can be made. *Cardioceras* (?) *incertum* Reeside (1919, p. 36, Pl. 20, figs. 17-20; Pl. 21; Pl. 22, figs. 1, 2) is also related, but Reeside's cross-section of a large specimen is wider than that of the Canadian specimen, the last whorl of which is much higher than wide. Furthermore, Reeside's large specimen (1919, Pl. 21), which has about the same diameter as the Canadian specimen, is almost smooth.

Imlay (1947, p. 264) and Arkell (1956, p. 548) have assigned Reeside's *"Cardioceras" crassum* to the genus *Goliathiceras* Buckman of the subfamily Cardioceratinae. As the here-described Canadian specimen is closely related and possibly identical with *crassum* Reeside, it is placed into the same genus.

This specimen was found at locality *F* on Rocky River, Miette area (*see* Figures 5 and 6) in unit *a*.

Cardioceras (?) (sensu lato) sp. indet. 1

Among some ammonite fragments collected in the beds with *Buchia concentrica* (Sowerby) on Llama Mountain, Kvass Flats area, is an imprint of a small form about 10 mm in diameter with fairly widely spaced primary ribs that are subdivided into secondaries bent slightly forward. The point of division is about at half the height of the flanks. On part of the venter a finely denticulated keel seems to be present. This small ammonite is probably a *Cardioceras* but neither subgenus nor species can be determined.

Cardioceras (sensu lato) sp. indet. 2

Plate VIII, figure 2

The small specimen (diameter about 32 mm) figured on Plate VIII, figure 2, is from the black shale with ironstone stringers on the Cuthead Creek road. This poorly preserved specimen has straight primary ribs that, at half the height of the flanks, are divided into two forwardly bent secondaries that fade out before reaching the finely denticulated keel. The point of division of the primaries is marked by a tubercle.

Among the North American Cardioceratids described by Reeside the young specimen of *C. wyomingense* Reeside (1919, pp. 34, 35, Pl. 15, fig. 17) has a similar type of ribbing, but the unsatisfactory preservation of the Canadian form prohibits detailed comparison. The young forms of *Cardioceras mountjoyi* n. sp. and related forms found in the Miette area are clearly distinguished by differences in the type of ribbing and by a higher keel.

Cardioceras (sensu lato) sp. indet. 3

Plate I, figure 2

The poorly preserved fragment from Cuthead Creek illustrated on Plate I, figure 2, has two rows of spines on the flanks and the keel is finely serrate. The nature of the ribs is not discernible. This form was apparently fairly wide umbilicate. None of the North American Cardioceratids described by Reeside (1919) is comparable.

Other Cardioceratids

Besides the two forms from Cuthead Creek described here, there are others from the same locality that belong to different species, one of them with very strong ribs. All are too poorly preserved to warrant description.

Ammonites gen. et sp. indet.

Plate VIII, figure 3

Two ammonite fragments that deserve special attention were found in large, grey, hard, splintery concretions immediately below the Green beds in the Carbondale River section. The smaller fragment is the partial imprint of a whorl with part of the left flank and part of the venter preserved. Both flank and venter are moderately convex. The almost straight ribs cross the venter without interruption. The point of division of the ribs is probably on the lower part of the flank, which is not preserved. There is no keel on the venter.

The larger fragment (Plate VIII, figure 3) is the venter of an ammonite, gently convex and with ribs similar to those in the small specimen, but slightly bent forward. There is no keel. Both fragments may belong to the same genus.

The shape of the venter and of the ribs is similar to that of some representatives of "*Quenstedtoceras*" described by Reeside (1919) from the western interior of the United States, as for instance, *Q. hoveyi* and *Q. suspectum*, but the palæontological evidence is not strong enough to justify their identification.

Buchia concentrica (Sowerby)

Plate VIII, figures 4, 5

For synonyms *see* Imlay, 1955, p. 83.

This species, usually described under the name *Buchia bronni* Rouiller [1] (*see also* Frebold, 1957, p. 68, Pl. 38, figs. 4*a*, *b*), is represented in Mountjoy's collections by some fragments found at Rocky River, half a mile southwest of Nashan Creek, Miette area, in unit b^1, 60-90 feet above the Green beds. All these fragments agree very well with *Buchia* ex gr. *bronni* Rouiller, described from the uppermost Green beds in the Carbondale River section, and with Imlay's (1955, p. 83, Pl. 9, figs. 11-16) *Buchia concentrica* (Sowerby) from southwest Alaska.

Other specimens (*see* Plate VIII, figures 4, 5) that belong to this species were found in Kvass Flats area on Llama Mountain associated with *Cardioceras* (?) sp. indet. (Frebold *in* Irish, 1954, pp. 23, 24; Frebold, 1957, pp. 29, 95) at Shale Banks, Snake Indian River, and in the Fiddle River sections.

Gryphaea nebrascensis Meek and Hayden

Plate VIII, figure 6

Gryphaea nebrascensis Meek and Hayden. Imlay, 1948, pp. 18, 19, Pl. 5, figs. 7, 8. For complete list of synonyms *see* Imlay, 1948, p. 18.

The adult specimen illustrated on Plate VIII, figure 6, has an elongated shell that distinguishes this species from *Gryphaea impressimarginata* McLearn, which is abundant in the lower Callovian *Gryphaea* bed of the Fernie in southern

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[1] Waterston (1951, pp. 40, 41, Pl. 1, figs. 2*a-c*) has shown that the species was first described by Sowerby (1827, p. 113, Pl. 559, fig. 1) as *Plagiostoma concentrica* (*see also* Imlay, 1955, p. 83).

Alberta. This specimen shows a well-developed sulcus in the posterior part of the shell. The distinct radiating striae in the umbonal region mentioned by Imlay (1948, p. 18) cannot be seen on this specimen. The only partly preserved beak is strongly incurved.

Imlay stated (1948, p. 19) that in the western interior of the United States this species ranges from the lower Callovian *Gowericeras subitum* zone to the top of the marine Jurassic and (Imlay, op. cit., p. 17) that it is abundant in his *Quenstedtoceras collieri* zone, i.e., immediately below the *Cardioceras cordiforme* zone. Specimens of this species were also recognized by the author from some oil wells in Saskatchewan. The present specimen was found associated with *Goliathiceras* cf. *crassum* (Reeside) at locality *F* on Rocky River opposite Makwa Ridge (*see* Figures 5 and 6) in the uppermost part of unit *a*.

OCCURRENCES AND STRATIGRAPHY OF THE OXFORDIAN BEDS, MIETTE AREA, ALBERTA

(E. Mountjoy)

Miette map-area lies between lat. 53°00′ and 53°15′ and long. 117°30′ and 118°00′, about 20 miles northeast of Jasper in Jasper National Park (*see* Figure 5).

Jurassic beds that outcrop along Fiddle River have been thoroughly examined and described by a number of geologists, (Dowling, 1912; Collet, 1931; and Frebold, 1953, 1957). Lang (1947) reported briefly on the Fernie group in Brûlé area immediately north of Miette area. Spivak (1949) summarized the then known stratigraphic evidence from the Foothills and gave several stratigraphic and well sections, including one from Folding Mountain in the northeast corner of Miette area.

In 1957, most of the west half of Miette area was examined by the author and a preliminary examination was made of the outcrops on Folding Mountain. The Fiddle River (11) (*see* Figure 5) and the Morris Creek (39) Fernie sections (Frebold, 1957) were used as standards and sections A and B, along strike to the south were examined. West of Miette Range, Fernie beds were found to outcrop along two zones: one on the east side and near the base of Makwa Ridge (Figure 5, C) and again along strike to the southeast (Figure 5, D), the other along Rocky River from Nashan Creek to Dromore Creek (*see* Figures 5 and 6, E, F, G, H).

Rocky River, for a stretch of 4 miles between Dromore and Nashan Creeks, has cut through thick deposits of gravel and sand to expose Jurassic rocks. In these upper Fernie shales (unit *b*), Green beds (unit *a*), the lower Callovian Grey beds, the middle Bajocian Rock Creek member, the Toarcian Paper shales and the Sinemurian Nordegg member are all present.

This region can be reached by a rough horse-trail, not marked on the present topographic maps, that begins at the camp grounds near highway 16, crosses Rocky River, and thence follows the east bank of the river and canyon. One or two campsites suitable for small pack outfits (10 to 14 horses) are present along the route.

The major structures are shown on Figure 6, but time did not permit detailed mapping. Zones of folding and crumpling are therefore not shown and possibly some minor faults were overlooked. Three stratigraphic sections were measured: from E to F, at G, and at H. All are disturbed by faulting. In addition to the above, other good exposures exist that deserve attention.

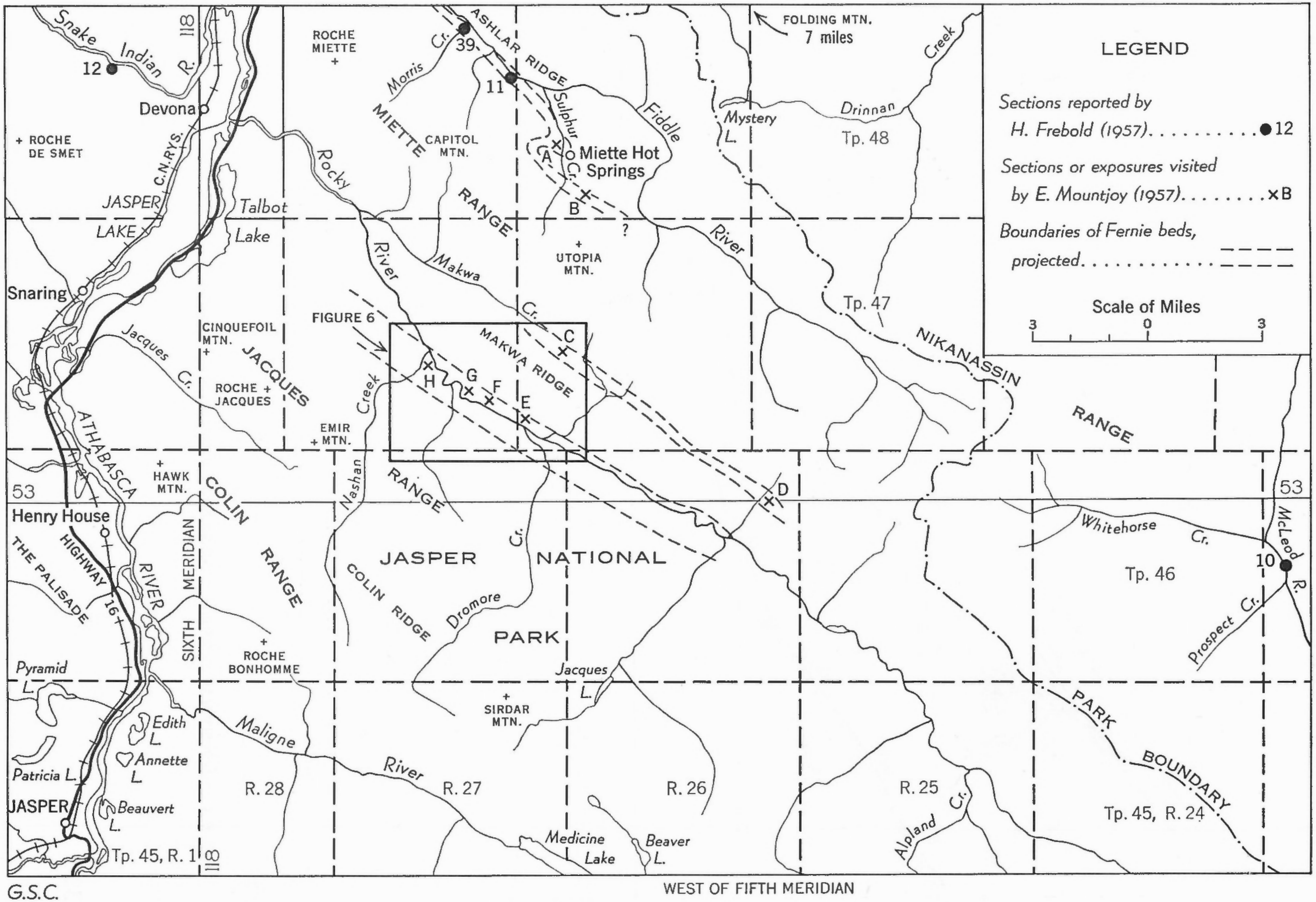

Figure 5. Distribution of Fernie group, Miette area, Alberta. (By E. Mountjoy)

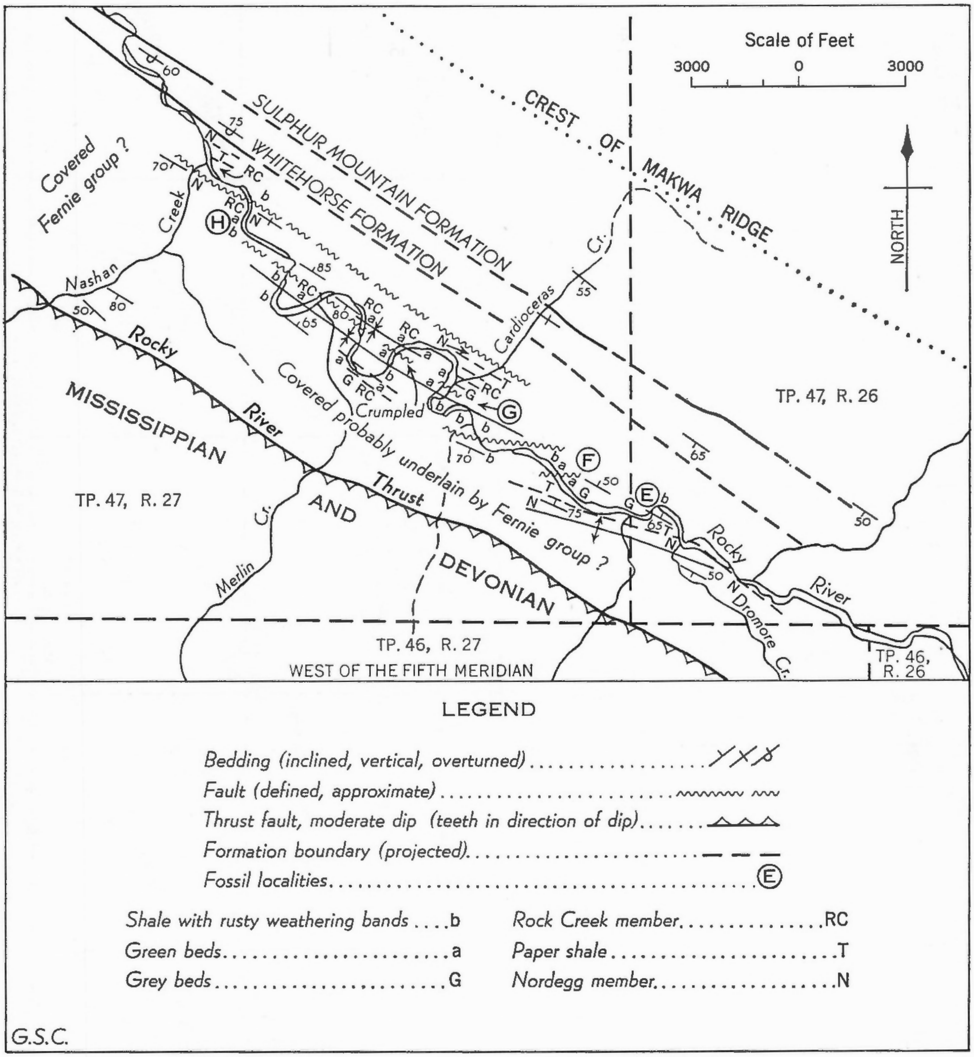

Figure 6. Generalized geological map of Rocky River region, Miette area, Alberta. (By E. Mountjoy)

In general, the Green beds (unit *a*) in this area consist from bottom to top of: glauconitic, argillaceous, green siltstone and fine-grained sandstone, about 5 feet thick; 50 to 60 feet of shale with *Cardioceras;* and an upper glauconitic bed, 6 inches thick. Unit *a* is overlain by a thick sequence of dark grey shales with thin interbeds of rusty weathering siltstone (unit b^1), and is underlain by 20 to 25 feet of dark grey shales containing numerous large concretions. These shales are in turn underlain by grey and greenish grey indurated shales and mudstones (lower Callovian Grey beds). Unit *a* belongs to the lower Oxfordian, *b* to the upper Oxfordian and possibly lower Kimmeridgian (*see* pp. 9-11). (The beds below unit *a* are probably older than Oxfordian.)

The excellent exposures of the Green beds along Rocky River will be discussed first, followed by brief descriptions of other relevant Jurassic outcrops in the Miette area.

Detailed Stratigraphy

Locality *H*—Rocky River (*see* Figure 6)

At locality *H* the pre-Oxfordian shale with large concretions is about 24 feet thick. It consists of dark grey, fissile shale with large siltstone concretions that vary from 2 to 5 feet in diameter and possess calcite cores. These concretions are unfossiliferous. The beds stratigraphically below are of unknown age, but are not of the Grey bed lithology as seen at localities *G* and *F*. They, in turn, are underlain by disturbed sandstones of Rock Creek member lithology.

Five feet of glauconite (base of unit *a*) occur above the shale with large concretions. These beds consist of dark greyish green, fine-grained sandstone with interbedded dark grey, silty shales, and contain a few belemnites and concretions an inch to 2 feet in diameter. A thin section revealed rounded fragments of shale and glauconite grains with associated pyrite in a brown matrix of very fine-grained sand, silt, and carbonate mud. The glauconite consists of well-rounded pale green grains of silt size (0.02-0.10 mm) which show aggregate polarization. This glauconite horizon (base of unit *a*) weathers greenish grey to green, in part rusty, due to the presence of pyrite. Two Cardioceratids were collected from it. The upper thin glauconite horizon was not observed.

The Green beds are overlain with apparent conformity by 250 to 300 feet of fissile to thin-bedded, dark grey to black shales and mudstones with concretions at the base and with thin (½- to 2-inch) interbeds of rusty weathering siltstone that become more frequent upwards. A few belemnites were found in the lower part and a few concretions towards the middle of this unit. Several specimens of *Buchia concentrica* (Sowerby) were collected 115 feet above the 5-foot glauconite bed.

Locality *G*—Rocky River

The exposure at locality *G* occurs about 1½ miles farther upstream on Rocky River, immediately above the point where the river is joined by Cardioceras Creek. This section is rather poor as beds are repeated by more than two thrust faults.

In shales of lower Callovian Grey bed lithology at the top of the section, squashed, fragmentary ammonite remains, possibly *Kepplerites* (*Seymourites*) sp. indet., were observed. There the Grey beds appear to be 100 to 150 feet thick, depending on structural interpretation. They consist of indurated grey, silty shales, mudstones, and siltstones that weather grey and are thin bedded. A thin section of a rock specimen from the lower part of the Grey beds revealed numerous plant seeds of silt size (0.01-0.005 mm) in a matrix of calcareous mud. Another thin section from a different part of the Grey beds consists of a few very fine silt grains in a calcareous mud matrix.

As at locality *H*, the lower part of the Green beds (unit *a*) are 5 feet thick. They are underlain by the bed with large concretions, which is about 30 feet thick. Specimens of *Cardioceras* were collected approximately 50 feet above the lower glauconite zone (lower part of unit *a*). Another glauconite horizon, 6 inches thick, occurs about 60 feet above the lower. A poorly preserved and pyritized, indeterminable ammonite was collected from shales with thin ribbons of rusty weathering siltstone and ironstone concretions (unit b^1) some 150 to 200 feet above unit *a*.

Localities *E* to *F*—Rocky River (*see* Plate X)

Locality *F* is about a mile upstream from locality *G*, on the northeast bank of the river. At this locality, the Green beds appear to be repeated two or three times within a distance of several hundred feet by east-dipping thrust faults of small displacement. In each slice the lower part of the Green beds consists of about 5 feet of glauconitic, argillaceous, green siltstone or very fine-grained sandstone, generally with numerous belemnites. Stratigraphically below is the shale with large concretions, which consists of 15 to 20 feet of dark grey to greenish shales with numerous concretions up to 5 feet in diameter. The lower glauconite zone (lower part of unit *a*) is overlain by about 50 feet of dark grey shale and mudstone with occasional concretions. Large and excellently preserved Cardioceratids are present in the upper half of this shale. Another 6-inch glauconite zone is present above this shale.

Unit *a* is overlain with apparent conformity by dark grey silty shales with thin interbeds of siltstone and ironstone concretions (unit b^1). Poorly preserved pelecypod (?) fragments, possibly including *Buchia,* were collected approximately

60 to 90 feet above the Green beds. The next 100 feet of beds of similar lithology is contorted and thrust against isoclinally folded fine-grained sandstones that probably belong to the lower Nikanassin formation. The northern extension of this fault across the river may be seen in Plate XI. The transition zone (?) or change from the upper Fernie shales and siltstones to the Nikanassin sandstones was not observed in this section of the Rocky River exposures.

Farther upstream, about 85 to 100 feet of lower Callovian Grey beds were measured directly beneath the zone with large concretions. These beds consist of grey, partly indurated shales, in places with a greenish tinge, weathering grey, fissile to very thin bedded and breaking along bedding planes with a very smooth surface. The green coloration of these strata seems to increase in intensity upwards as the Green beds are approached. Some *Kepplerites* (*Seymourites*) sp. indet. fragments were collected from near the base.

At locality *E,* one *Cardioceras* was collected from dark grey shales with occasional concretions. These and the shales above are lithologically like the upper Fernie beds. Near the base of the section the shales have a slightly green colour. This shale is probably the shaly part of unit *a*.

Upstream from locality *E* the Toarcian Paper shales and the Sinemurian Nordegg member are well exposed. Still farther upstream Rocky River is just beginning to erode its channel into bedrock, and outcrops are scattered and poor. No Green beds were observed, though one outcrop revealed dark grey shales (unit b^1) with numerous small, spherical, 'ball concretions'. At Tent Mountain in the Crowsnest Pass similar beds of small concretions occur immediately above the Green beds in the lower Passage beds (unit c^1).

Locality *C*—East side of Makwa Ridge

The only other known occurrences of the Green beds (unit *a*) are on the northeast slopes of Makwa Ridge (*see* Figures 5, 6) beneath the Makwa thrust and its southern extension (Figure 5, D). There tightly folded Fernie beds are well exposed in the small creeks that drain the east side of the ridge.

At that point there are from 2 to 3 feet of green to greenish brown, glauconitic siltstone and very fine-grained sandstone, with numerous belemnites which may be the stratigraphic equivalent of the upper or lower glauconite horizon in the Rocky River outcrops. In this section the glauconite occurs in subrounded grains of silt size (0.01 mm) associated with pyrite in a matrix of carbonate mud and fine silt. The glauconite beds are overlain by about 30 to 40 feet of dark brown siltstone and silty shale, and some black shales, before the Makwa thrust is reached. They are underlain by about 20 feet of dark grey to black, silty shales containing large concretions ranging from about a foot to 4 feet in diameter.

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A thorough search for fossils was made but none was found. No typical grey shales, only dark grey to black shales, were observed below the zone with large concretions.

Locality *D*

A nearly complete section of the Fernie group appears to be exposed at locality *D* about 6¼ miles southeast of locality *C* (*see* Figure 5), but the exact stratigraphic relationships are unknown, because of structural complications and some drift cover. However, 250 to 300 feet of upper Fernie shales with thin rusty weathering siltstone bands (unit *b*) were seen and are underlain by 5 to 10 feet of green, argillaceous, very fine-grained sandstones (Green beds?). The above sandstones are in turn underlain by black, silty shales with some concretions. Farther upstream and stratigraphically below the above units, exposures of the middle Bajocian Rock Creek member, the Toarcian Paper shales, and the Sinemurian Nordegg member were seen.

Sparse outcrops of Fernie strata were found in the creeks between localities *C* and *D*.

Locality *B*

Miss R. Reed, Dr. Frebold, and the writer visited this locality in 1957, which is on a small tributary of Sulphur Creek near the base of the northeast slope of Utopia Mountain (*see* Figure 5). Miss Reed found a very poorly preserved impression of a *Cardioceras* some 200 feet below the assumed base of the Nikanassin sandstones. The beds lower in the succession were concealed.

Locality *A*

Locality *A* is on the first creek tributary to Sulphur Creek immediately northwest of the Miette Hotsprings (*see* Figure 5).

Jurassic strata, from the base of the Toarcian Paper shales to the lower part of the Nikanassin, are almost continuously exposed though structurally disturbed. No Grey beds, the bed with large concretions, or Green beds (unit *a*) were observed. Poorly preserved Gryphaeas were collected from about 60 feet above the probable top of the middle Bajocian Rock Creek member.

Localities 11 and 39

These two sections on Fiddle River and Morris Creek (Frebold, 1957, pp. 90, 91) do not contain the Grey beds, shales with large concretions or Green beds (unit *a*) rock types or faunas.

Folding Mountain and Drystone Creek

Fernie strata are poorly exposed on the eastern slopes of Folding Mountain but are relatively well exposed in Drystone Creek, on the west side of Folding Mountain, though outcrops are not continuous. Spivak (1949, p. 539) reported 245 feet of grey shales in a tributary of Drystone Creek.

This locality was visited by the writer and the following were found, exposed below Nikanassin sands and shales: 200 feet of upper Fernie (unit *b*), 6 inches of glauconite (possibly upper part unit *a*), 36 feet grey shale and mudstone, 64 feet covered interval to Rock Creek member, the upper fossiliferous member of which is not present and appears to be covered. Cuttings from the Solomon Creek well, about 10 miles to the north, were examined but are very poor and glauconite was not observed.

Extent and Correlation of the Green Beds in Miette Area

From the above data it is readily apparent that in Miette area the Green beds (unit *a*) and black shales with siltstone bands (unit *b*) are extensively developed in the Rocky River valley and along the east side of Makwa Ridge and related structures to the southeast. In the Snake Indian valley rocks of unit *a* have not yet been found, although *Buchia concentrica* (Sowerby) (=*bronni* Rouiller) was found there in the dark shales with rusty weathering bands (unit *b*) (Frebold, 1957, pp. 29, 93). Approximately 25 feet of glauconite and glauconitic shales were found directly overlying the Rock Creek member in a tributary of Moosehorn Creek near lat. 53°15′. Elsewhere in the area, except possibly at Folding Mountain, the Green beds are absent but they are present at Cadomin, on strike southeast with the Fiddle River outcrops. They were also found immediately southeast of Harlequin Creek in the northwest corner of the Mountain Park area.

The seemingly sporadic occurrence of the Green beds may be accounted for in several ways:

1. The unit is relatively thin.
2. The green colour seems to be in part dependent on the weathering characteristics of a particular outcrop, which in turn depends on its content of clay, glauconite, and pyrite.
3. Most Fernie rocks are poorly exposed, particularly the more shaly zones.
4. The beds may be faulted out as the shales are very incompetent and dislocations and bedding-plane slips numerous.
5. Nondeposition due to a lack of suitable source material and local topographic highs.

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They seem to be completely absent along Fiddle River where exposures are excellent, and relatively little structural deformation was observed. Possible facies changes may occur between Miette area and Cadomin, and between Snake Indian River and Rocky River. Even in Crowsnest Pass where Green beds are thick and well developed, local variations can be seen. Thus the section though thick in the Blairmore brickyards is very thin at Grassy Mountain, a distance of only 5 miles (Frebold, 1957, p. 28).

The development of glauconitic sands appears to be the result of the presence nearby of a suitable source and special environmental conditions. It is therefore probable that locally this facies was never deposited. Certainly it seems unlikely that the beds were eroded in the Fiddle River and Snake Indian River outcrops, as they contain a *Buchia concentrica.*

Present data suggest that the Green beds may in part be a near-shore deposit which overlaps the Grey beds in an easterly and northeasterly direction, as the Green beds overlie the Rock Creek member in the Moosehorn Valley, and possibly at Folding Mountain. South of Folding Mountain and along the lower Fiddle River the upper Fernie shales (unit *b*) were found disconformably over Rock Creek sandstones.

THE OXFORDIAN GREEN BEDS IN THE SUBSURFACE

(Ruth Reed)[1]

During a systematic study of Jurassic subsurface sections in parts of the Alberta Foothills, it became apparent that the Oxfordian Green beds of the Fernie group, which were known from a few surface sections only, were present almost everywhere in the Foothills subsurface. The recognition of these beds in the subsurface is valuable because they form an excellent, easily recognizable, marker bed and give a better understanding of the actual extent of these beds than the surface outcrops can offer. As mentioned by E. Mountjoy (p. 37) the seemingly sporadic occurrence of the Green beds in surface outcrops may be accounted for by their locally small thickness, by poor outcrop conditions, and by the fact that the green colour seems to be dependent on the weathering characteristics of a particular outcrop.

The Green beds are known in the Foothills subsurface from the International Boundary in the south to the Peace River country in the north. The region dealt with in this report is limited in the west by those wells which penetrated a complete Jurassic section east of the McConnell and Lewis overthrusts, in the north by the regions north of Jasper, in the east by the approximate edge of the disturbed belt, and in the south by the International Boundary.

In the following discussion Frebold's (1957 and this paper) terminology of the subdivisions of the Fernie group is used.

As no distinctive fossils have yet been found in the Green beds of the subsurface, the question as to their identity with the Oxfordian Green beds in surface outcrops might arise. Considering the fact that some of the subsurface occurrences are geographically very close to surface occurrences of the Green beds, their correlation with one another appears justified. Still better evidence for the correctness of the correlation of subsurface and outcrop Green beds is that the subsurface Green beds are found in the same stratigraphic position as the Green beds in outcrops, i.e., below the Passage beds or their equivalents and above the Callovian Grey beds. In the northern part of the subsurface under consideration, however, these Grey beds seem to pinch out and the strata on which the Green beds rest are probably the Bajocian Rock Creek member. These strata contain sandstones which are entirely unknown in the Grey beds, but are well known from the Rock Creek member in eastern Foothills sections, where they appear in the neighbourhood of the eastern shoreline of the Fernie Sea (Frebold, 1957, p. 17 and Fig. 3).

[1] Geologist, Shell Oil Company of Canada, Limited, Calgary, Alberta.

Frebold (loc. cit.) has also mentioned the absence of the Callovian Grey beds in some of the eastern Foothills outcrop sections (Moose Mountain, Fiddle River). The stratigraphic position of the subsurface Green beds is thus in accordance with that in surface outcrops.

The thickness of the subsurface Green beds ranges from 5 to 30 feet, but in most of the region it averages 5 to 10 feet. The upper limits of the range are found near the International Boundary, which is in agreement with conditions in outcrops. The small thickness of the Green beds in most of the other subsurface sections here described in comparison with larger thicknesses to the south may be accounted for by partial facies replacements. Frebold (*see* Table II) is of the opinion that locally the facies of the Green beds is replaced partly or entirely by his unit *b*, the shale with rusty weathering siltstone bands. Such facies replacements of the Green beds by other rocks are also indicated in some of the subsurface sections (e.g., Husky Phillips Savanna Creek No. 1), in which no Green beds have been found, and where shales with fragments of ironstone occur in a similar stratigraphic position to the Green beds.

In subsurface sections the Oxfordian Green beds are recognized in ditch cuttings and cores by the presence of emerald green (5 G 4/6)[1] rounded to subrounded, fine- to medium-sized glauconite grains. The glauconite may be extremely abundant with a very dark grey or dark grey-brown (5 YR 2/1-1/2) shale matrix, or it may occur as scattered grains in the shale. Pyrite and ironstone are often associated. The ironstone is occasionally glauconitic. In almost every case where the Green beds are recognized in ditch cuttings the Electrical and Gamma Ray-Neutron Logs have shown a characteristic development (e.g., Shell Panther River No. 1 interval 5,959-5,970 feet). The resistivity curve of the electrical log usually indicates a low resistivity, however, the self-potential curve has no apparent consistent character. The Gamma ray curve of the Gamma Ray-Neutron Log indicates a marked increase in radiation whereas the neutron curve indicates a marked decrease in radiation.

Figure 2 shows the general distribution of the Green beds in the subsurface and in the outcrops of parts of the southern and central Foothills and the Rocky Mountains. Descriptions of some of the subsurface occurrences follow.

[1] Rock Colour Chart, published by G.S.A. 1951, New York.

I. Baysel Hillspring #11-10

11-10-4-27-W4M [1]

In this well the Green beds, approximately 12 feet thick, consist of a glauconitic sandstone, emerald green in colour, medium- to fine-grained, pyrite cement, non-calcareous. Rare ironstone fragments, angular, dark brown (5 YR 2/4), with scattered grains of emerald green glauconite occur. These fragments probably represent nodules. Some shale, dark grey-brown (5 YR 3/2) with buff to light grey-brown streak is associated with the glauconitic sandstone, or the shale may be so abundant that only a few grains of glauconite may be present.

The Green beds are overlain by approximately 110 feet of sandstone, fine grained, grading to siltstone, light brown (10 YR 6/4-5/4); slightly calcareous, micaceous, pyritic, siliceous, occasionally glauconitic, with quartz grains being the predominate constituent. Shale, dark brown-grey (5 YR 3/1-2/1) increases in quantity towards the base of the unit. This is the lithology of the Passage beds which normally overlie the Green beds.

The Green beds are underlain by shales, medium brown (10 YR 2/2), soft, platy, calcareous, micaceous. This is the general lithology of the Grey beds (Rierdon) which normally underlie the Green beds.

II. Shell Waterton #1

4-21-4-1-W5M

In this well the Green beds consist of a glauconitic sandstone, dark emerald green, fine grained, non-calcareous; with shale, dark grey-brown, associated with the glauconite in various amounts, generally acting as the matrix. Traces of angular fragments of medium to dark brown (5 YR 3/4-2/4) ironstone occur. The thickness of 41 feet may be in excess of true thickness due to dip or contortion of the strata.

The Green beds appear to be overlain by strata with lithology typical of the Passage beds, approximately 220 feet thick.

The Green beds are underlain by shale, medium to dark grey (N 3-2), fairly hard, blocky, with few bands of medium brown (10 YR 4/2-3/2) limestone, and occasional shell fragments. This is the lithology typical of the Grey beds in the facies as found in the outcrops of the southern Foothills (*see* Frebold, 1957).

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[1] The numbers indicate the location of this and the following wells on official Government maps, e.g., Legal subdivision 11, sec. 10, tp. 4, rge. 27, W. 4th mer.

III. Gulf Triad et al. Rocking "P" #2-29

2-29-13-2-W5M

In this well the Green beds, approximately 10 feet thick, consist of a glauconitic sandstone, emerald green, fine and medium grained, slightly calcareous. Few angular fragments of light to dark brown ironstone are found with occasional glauconite grains. Shale, dark grey-brown with a buff to light brown streak, and glauconite are intimately associated in various amounts.

The Green beds appear to be overlain by the typical lithology of the Passage beds. They are underlain by Grey beds consisting essentially of shale, medium to dark grey, calcareous, fairly soft, blocky to platy.

IV. Home Turner Valley #8-30

8-30-19-2-W5M

In this well the Green beds consist of dark grey-brown shale, occasionally slightly silty with abundant fairly dark emerald green, fine to medium glauconite grains. Some light brown angular fragments of ironstone are present in the interval; the ironstone may be slightly glauconitic.

The Green beds are overlain by the Passage beds in the typical facies of the southern outcrop area. The Green beds are underlain by dark brown-grey shales, fairly soft, platy, light grey streaks, with occasional bands of limestone. This unit may be equivalent to the Grey beds.

V. Shell Home Sarcee #1

12-6-23-3-W5M

In this well the Green beds are approximately 17 feet thick and consist of a glauconitic sandstone, light to dark emerald green, fine grained, and non-calcareous. Angular fragments of silty ironstone, occasionally glauconitic, occur. Shale, dark grey-brown with a light to medium brown streak occurs in various amounts with the glauconite.

The Green beds are overlain by beds with the typical lithology of the Passage beds. The character of the underlying beds is doubtful, owing to poor samples. However, nearby subsurface information indicates a lithology that suggests the presence of the Rock Creek member. This would indicate the absence of the Grey beds.

VI. Shell Panther River #1

5-19-30-10-W5M

In this well the Green beds, approximately 12 feet thick, consist of shale, fairly dark grey (N 3-4) with a light grey-brown streak. It contains dark emerald green glauconite grains, in fine- to medium-sized grains, in various amounts. This unit is difficult to recognize in this well, due to slickensiding. Ironstone fragments, glauconitic in part, angular, light and fairly dark brown, calcareous, also occur, which may represent nodules.

The Green beds are overlain by shales, dark to very dark grey (5 YR 2/1-1/1) with a slight brownish tinge, blocky, fairly soft, with a light brown streak. Several bands of siltstone, light to medium brown, occur. This lithology is similar to that in the N.F.A. Muskeg No. 1 well. These beds may be equivalent to the Passage beds of the southern Fernie development.

The Green beds are underlain by shale of unknown age. It is medium grey-brown (5 YR 3/1), blocky, fairly soft, calcareous.

VII. Shell Lobley #A16-23

16-23-33-6-W5M

In this well the Green beds, approximately 3 feet thick, consist of fine- to medium-, emerald green glauconite grains in shale. This shale is dark grey-brown, with an abundant amount of pyrite.

The Green beds are overlain by light brown sandstones, fine grained, with various amounts of dark grains which do not exceed 25 per cent. This sandstone is siliceous with only an occasional trace of calcareous material. The sandstone is interbedded with dark grey-brown shales, fairly soft, tending to be blocky. The amount of shale increases gradually as the Green beds are approached. This unit may be equivalent to the Passage beds.

The Green beds are underlain by a sandstone, very light grey (N 8-9), very fine grained, calcareous, pyritic. The age is questionable but is possibly that of the Rock Creek member.

VIII. Home Brazeau Syndicate #1

5-17-43-17-W5M

In this well the Green beds, approximately 10 feet thick, consist of shale, dark grey (N 2-3), blocky, fairly hard with various amounts of emerald green, fine and medium glauconite grains. A few fragments of belemnites were found.

These Green beds are overlain by the Passage beds, or their northern equivalents, and underlain by sandstone, light grey to white, very fine to fine grained, with various amounts of calcareous material, slightly pyritic. The age of this unit is probably that of the Rock Creek member.

IX. N.F.A. Muskeg #1

24-57-6-W6M

In this well the Green beds, approximately 10 feet thick, consist of a glauconitic sandstone, fairly dark emerald green, fine grained, non-calcareous, pyritic, with rare chert pebbles and plant fragments. Shale, grey-brown with a light grey-brown streak, occurs in various amounts.

The Green beds are overlain by dark grey shales with a slight brownish tinge, containing bands of light to medium brown siltstone. This lithology is that of the northern equivalents of the Passage beds.

Below the Green beds are dark grey shales with a brown streak, fairly hard, blocky. There are also minor occurrences of calcareous shale, fairly dark grey with a brownish tinge. The age of this unit is questionable.

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PLATES I TO XII

PLATE I

(All figures natural size)

Specimens in collections of the Geological Survey of Canada

Figures 1a, b. *Cardioceras* (*Scarburgiceras*) *alphacordatum* Spath (p. 20). 1a, lateral view and suture line; 1b, venter and cross-section. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F.*[1] Hypotype, GSC No. 13892.

Figure 2. *Cardioceras* (sensu lato) sp. indet. 3 (p. 27). Lateral view; Oxfordian; Cuthead Creek. GSC No. 13893.

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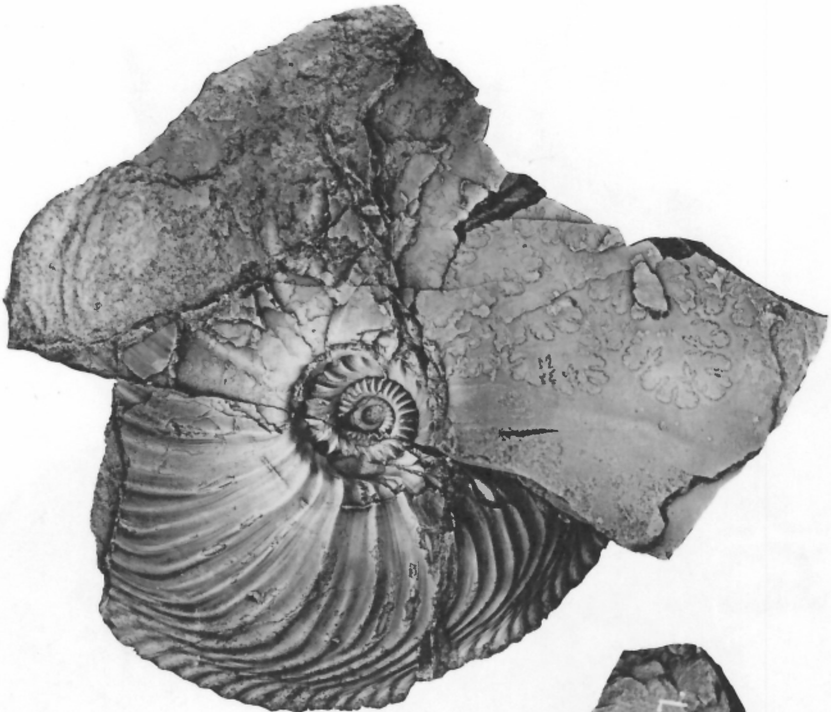
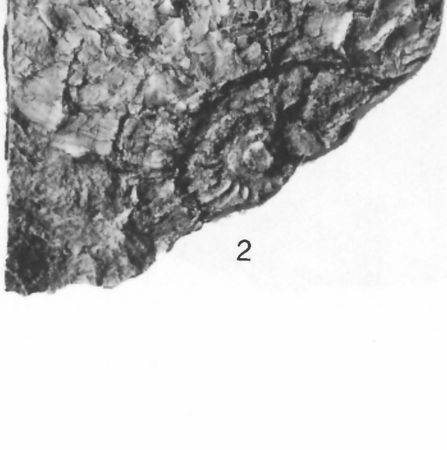
[1] The position of the localities in the Miette area is indicated in Figures 5 and 6.



1a



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1b

PLATE II

1

Plate II

(Natural size)

Specimen in collections of the Geological Survey of Canada

Figure 1. *Cardioceras* (*Scarburgiceras*) aff. *alphacordatum* Spath and *gloriosum* Arkell (p. 21). Lateral view. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F.* GSC No. 13894.

PLATE III

(All figures natural size)

Specimens in collections of the Geological Survey of Canada

Figures 1a, b. *Cardioceras mountjoyi* n. sp. (p. 22). 1a, lateral view; 1b, venter and cross-section. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F*. Paratype, GSC No. 13896.

Figures 2a, b. *Cardioceras mountjoyi* n. sp. (p. 22). 2a, lateral view; 2b, venter. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *H*. Paratype, GSC No. 13897.

Figures 3a, b. *Cardioceras mountjoyi* n. sp. (p. 22). 3a, lateral view; 3b, venter. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *H*. Paratype, GSC No. 13898.

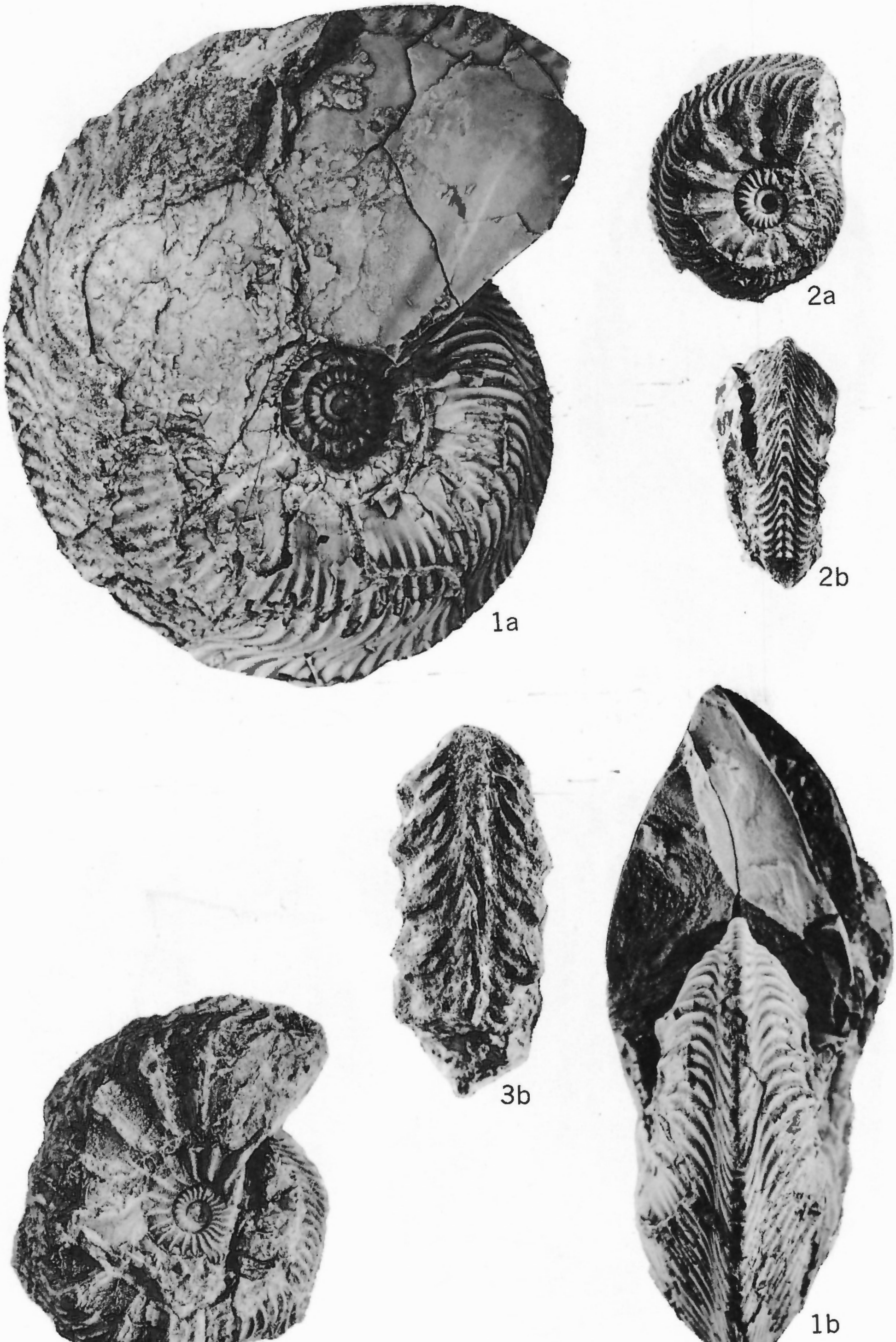

2a
2b
1a
3b
1b
3a

Plate IV

1b

1a

2a

2b

PLATE IV

(All figures natural size)

Specimens in collections of the Geological Survey of Canada

Figures 1a, b. *Cardioceras mountjoyi* n. sp. (p. 22). 1a, lateral view; 1b, venter and cross-section. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F*. Holotype, GSC No. 13895.

Figures 2a, b. *Cardioceras mountjoyi* var. *robusta* n. var. (p. 23). 2a, lateral view; 2b, venter and cross-section. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F*. Holotype, GSC No. 13899.

Plate V

(Natural size)

Specimen in collections of the Geological Survey of Canada

Figure 1. *Goliathiceras* cf. *crassum* (Reeside). Same specimen as Plate VI, fig. 1, and Plate VII, figs. 1a, b (p. 25). Lateral view. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F.* GSC No. 13900.

1

PLATE VI

1

PLATE VI

(Natural size)

Specimen in collections of the Geological Survey of Canada

Figure 1. *Goliathiceras* cf. *crassum* (Reeside). Same specimen as Plate V, fig. 1, and Plate VII, figs. 1a, b (p. 25). Cross-section. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F. GSC* No. 13900.

Plate VII

(All figures natural size)

Specimens in collections of the Geological Survey of Canada

Figures 1a, b. *Goliathiceras* cf. *crassum* (Reeside). Same specimen as Plate V, fig. 1 and Plate VI, fig. 1 (p. 25). 1a, venter; 1b, part of suture line. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River. GSC No. 13900.

Figure 2. *Cardioceras* (*Scarburgiceras* ?) sp. indet. (p. 24). Cross-section of penultimate whorl of fragmentary large specimen. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F*. GSC No. 13901.

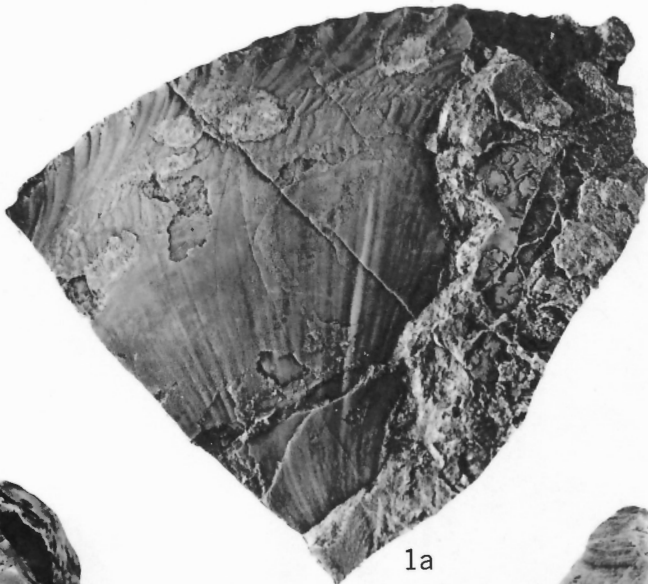
PLATE VII

1a

1b

2

PLATE VIII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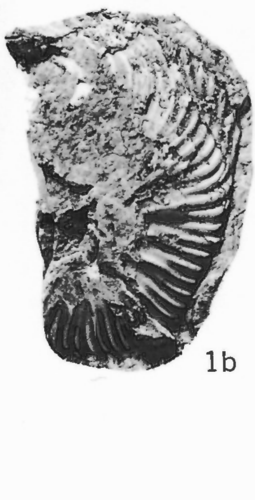
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Plate VIII

(All figures natural size)

Specimens in collections of the Geological Survey of Canada

Figures 1a, b. *Cardioceras* (*Scarburgiceras* ?) sp. indet. (p. 24). 1a, lateral view of whorl-fragment; 1b, inner whorl of same specimen. Lower Oxfordian; Miette area, Rocky River, locality *E*. GSC No. 13902.

Figure 2. *Cardioceras* (sensu lato) sp. indet. 2 (p. 27). Lateral view; Oxfordian; Cuthead Creek. GSC No. 13903.

Figure 3. Ammonites gen. et sp. indet. (p. 27). Ventral view. Shale with large concretions below Green beds; Carbondale River. GSC No. 13904.

Figures 4, 5. *Buchia concentrica* (Sowerby) (p. 28). 4, left valve; 5, impression of right valve. Upper Oxfordian or lower Kimmeridgian; Llama Mountain, Kvass Flats area. GSC No. 13905.

Figure 6. *Gryphaea nebrascensis* Meek and Hayden (p. 28). Left valve. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F*. GSC No. 13906.

Plate IX

(Natural size)

Specimen in collections of the Geological Survey of Canada

Figure 1. *Cardioceras* (*Scarburgiceras* ?) sp. indet. (p. 24). Lateral view. Green beds, unit *a;* lower Oxfordian; Miette area, Rocky River, locality *F*. GSC No. 13907.

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PLATE X

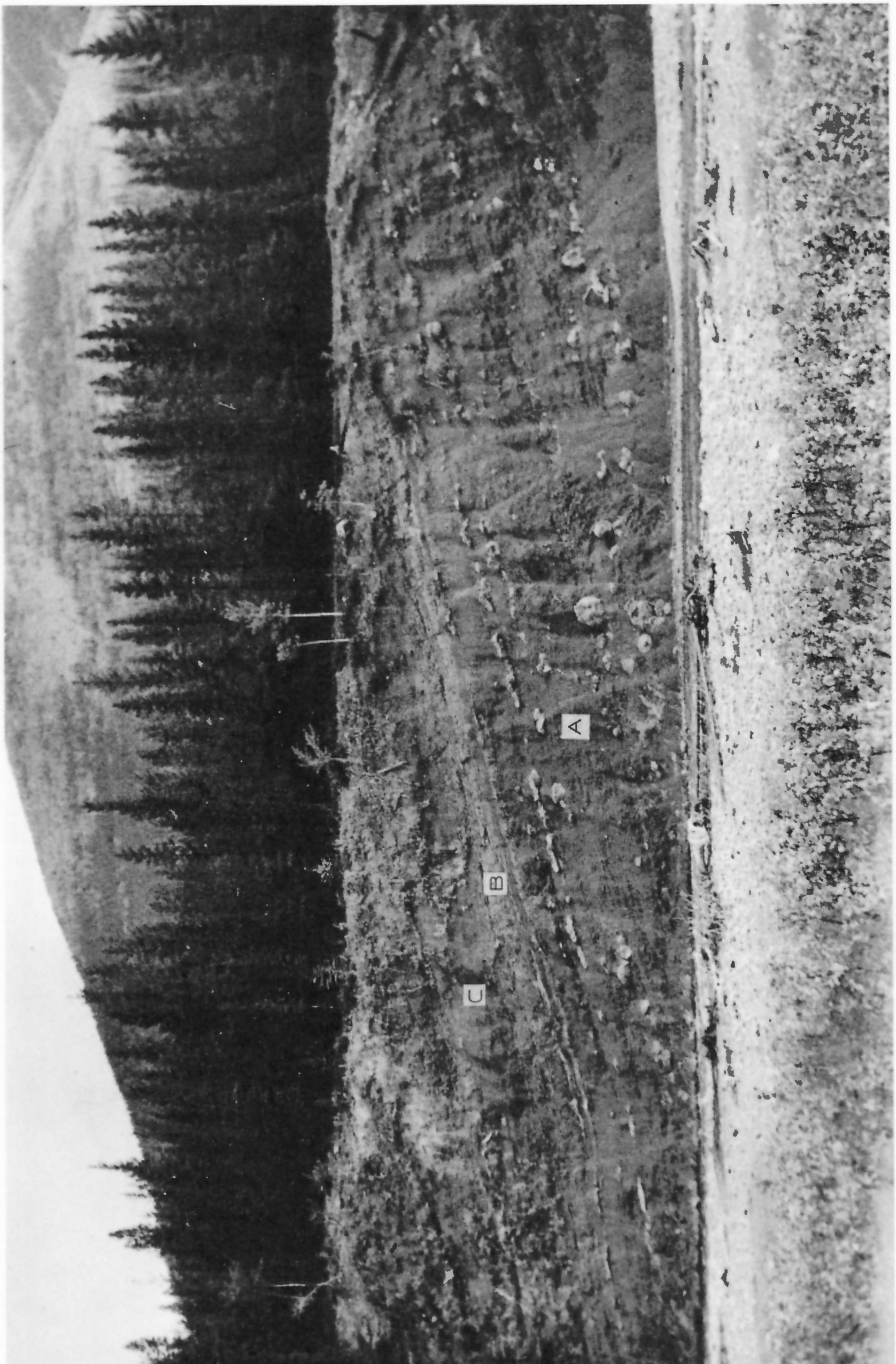

PLATE X

Mountjoy's locality *F* on Rocky River, Miette area. (A) Shale with large concretions; (B) unit *a*, lower part, Green beds, 5 feet thick; (C) dark shales with concretions (middle part unit *a*).

PLATE XI

Rocky River, Miette area, downstream and across river from Mountjoy's locality *F*. (C) Dark shale with rusty weathering bands (unit *b*) faulted over (?) (N) isoclinally folded Lower Nikanassin (?) sandstone beds.

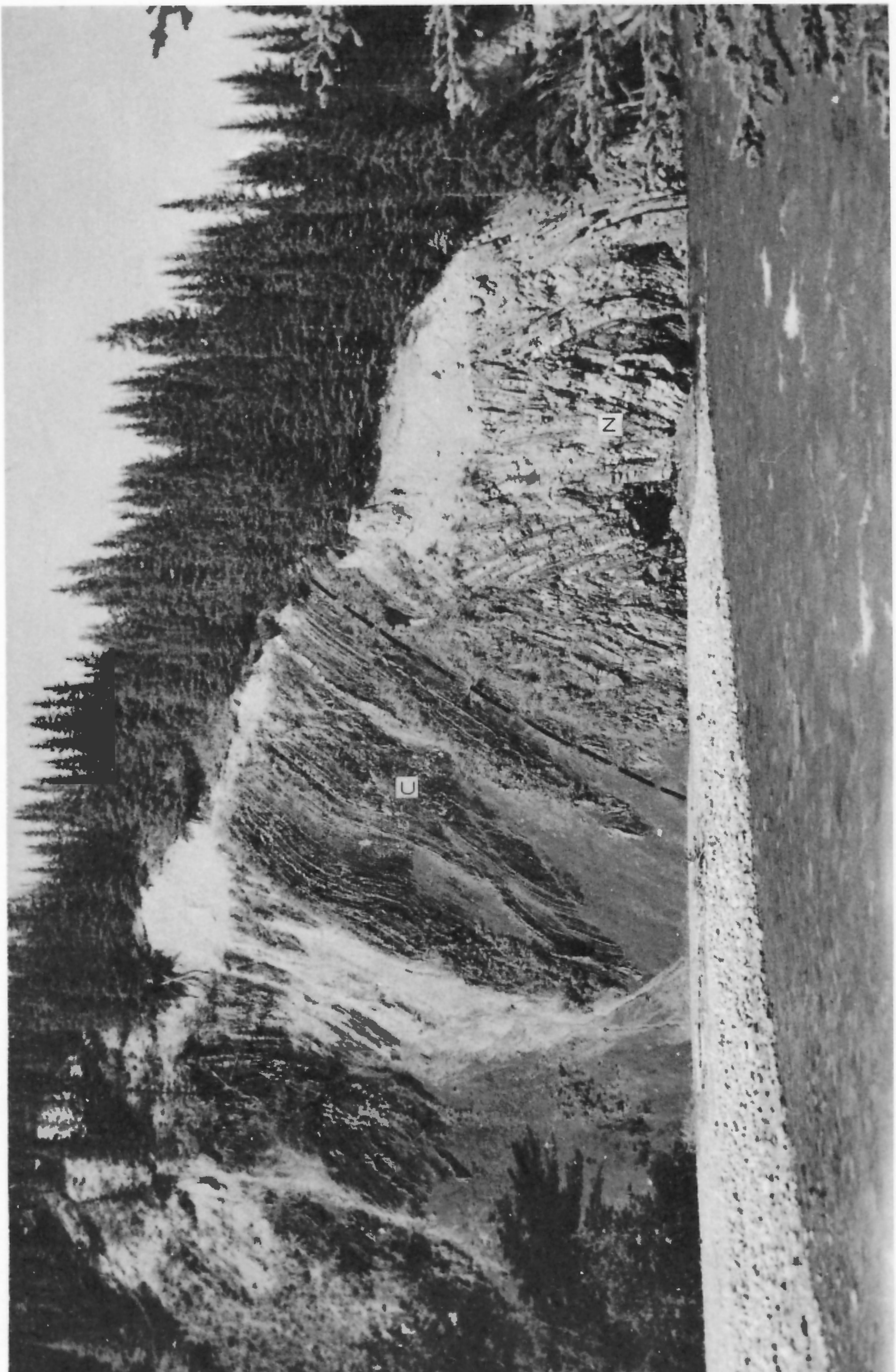

PLATE XII

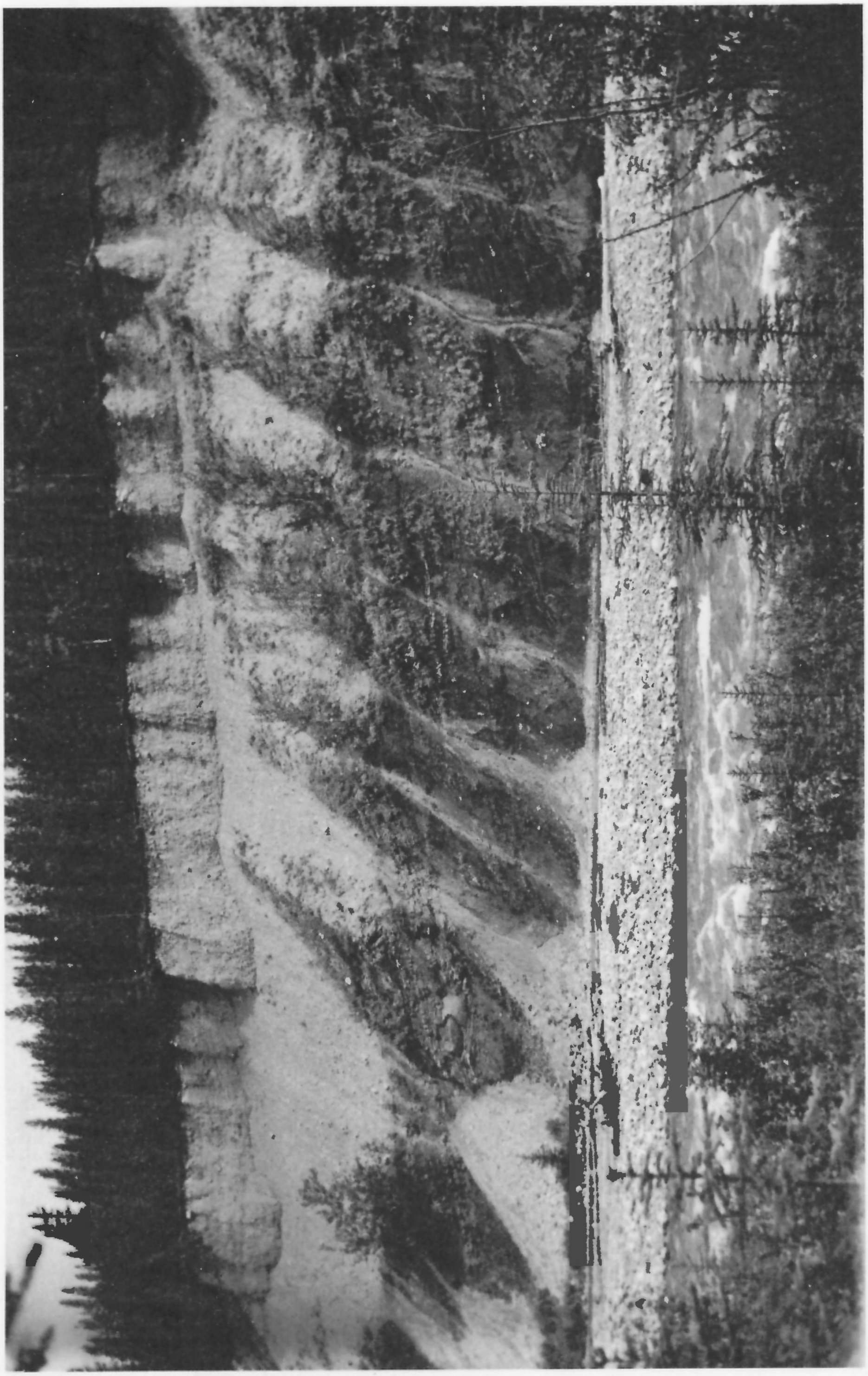

PLATE XII

Rocky River, Miette area, immediately downstream from Mountjoy's locality *F*. Dark shales with contorted thin, rusty weathering bands (unit *b*).