GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 81

PALÆONTOLOGY, STRATIGRAPHY, AND STRUCTURE OF THE JURASSIC ROCKS IN SALMO MAP-AREA, BRITISH COLUMBIA

Hans Frebold and H. W. Little

Price, $1.00

1962

PALÆONTOLOGY, STRATIGRAPHY, AND STRUCTURE OF THE JURASSIC ROCKS IN SALMO MAP-AREA, BRITISH COLUMBIA

2,500-1961-1898

GEOLOGICAL SURVEY
OF CANADA

BULLETIN 81

PALÆONTOLOGY, STRATIGRAPHY, AND STRUCTURE OF THE JURASSIC ROCKS IN SALMO MAP-AREA, BRITISH COLUMBIA

By

Hans Frebold and H. W. Little

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1962

Price $1.00 Cat. No. M42-81

PREFACE

Fossils collected in recent years from southern British Columbia indicate that a sea existed in this region during a considerable part of Jurassic time. Some of these fossils have already been described in Geological Survey of Canada Bulletin 49. The present report gives a full account of the stratigraphy and structure of the region and presents further palæontological data necessary for the correlation of this great thickness of Jurassic sediments.

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

OTTAWA, November 24, 1960

CONTENTS

Illustrations

PALÆONTOLOGY, STRATIGRAPHY, AND STRUCTURE OF THE JURASSIC ROCKS IN SALMO MAP-AREA, BRITISH COLUMBIA

Abstract

Additional ammonite horizons have been found recently in the Jurassic fossiliferous beds previously described in Salmo and Nelson areas, British Columbia (Frebold, 1959). The lowest fossiliferous Jurassic rocks occur in the Archibald formation. They contain possibly Hettangian with *Gyrophioceras*? and lower Sinemurian with *Arniotites kwakiutlanus*. Another lower Sinemurian horizon occurs, locally at least, in the lowest member of the mainly volcanic Elise formation. Lower Toarcian beds, containing *Harpoceras* cf. *H. exaratum* and *Dactylioceras*, occur in the upper Elise and lower Hall formations. The sedimentary Hall formation contains also middle Bajocian, identified by *Sonninia*? and younger beds with *Perisphinctes*? It is apparently succeeded by a considerable thickness of volcanic and sedimentary rocks of the upper Rossland group.

Some of the ammonites are widespread in either Western or Arctic Canada.

During part of the Early and Middle Jurassic the area belonged to an eugeosyncline. The end of the marine Jurassic transgressions in this part of southern British Columbia is still unknown. The main volcanic activity during which the rocks of the Elise formation were formed took place between the early Sinemurian and early Toarcian.

Early deformation, which resulted in folding and thrust faulting that dip gently east and southeast, was followed by granitic intrusion. Little is known of the sequence and origin of east-west and north-south faults, but northwest- and northeast-striking faults are believed to be latest and seem to be a consequence of north-south compression.

Résumé

On a récemment mis à jour, dans les régions de Salmo et de Nelson en Colombie-Britannique, de nouveaux horizons rocheux à ammonites au sein de couches jurassiques fossilifères (Frebold, 1959). Les roches jurassiques fossilifères les plus anciennes se trouvent dans la formation Archibald. Il se peut qu'elles soient formées de Hettangien à *Gyrophioceras*? et de Sinémurien inférieur à *Arniotites kwakiutlanus*. Un autre horizon du Sinémurien inférieur se trouve, en certains endroits tout au moins, au sein du niveau inférieur de la formation Elise, laquelle est surtout d'origine volcanique. Des couches du Toarcien inférieur, renfermant des *Harpoceras* cf. *H. exaratum* et des Dactylioceras, peuvent être aperçues dans la partie supérieure de la formation Elise et dans la partie inférieure de la formation Hall. La formation sédimentaire Hall renferme aussi du Bajocien moyen, déterminé grâce aux *Sonninia*?, et des couches plus récentes à *Peris-*

phinctes? Cette formation est recouverte apparemment d'une forte puissance de roches volcaniques et sédimentaires de la partie supérieure du groupe Rossland.

Quelques unes de ces ammonites sont très répandues dans l'Ouest ou dans l'Arctique canadien.

Durant une partie du Jurassique inférieur et du Jurassique moyen, cette région faisait partie d'une aire eugéosynclinal. La fin des transgressions marines du Jurassique dans cette région du sud de la Colombie-Britannique n'a pas encore été précisée. L'activité volcanique intense qui a amené la mise en place des roches de la formation Elise se situe entre le Sinémurien inférieur et le Toarcien inférieur.

Les déformations initiales, qui ont engendré la formation de plis et de surfaces de charriage à pendage est et sud-est peu accentué, ont été suivies par une intrusion granitique. On connaît très peu de choses sur la succession et l'origine des failles à direction est-ouest et nord-sud, mais on est généralement d'avis que les failles à direction nord-ouest et nord-est sont plus récentes et semblent résulter des forces de compression à direction nord-sud.

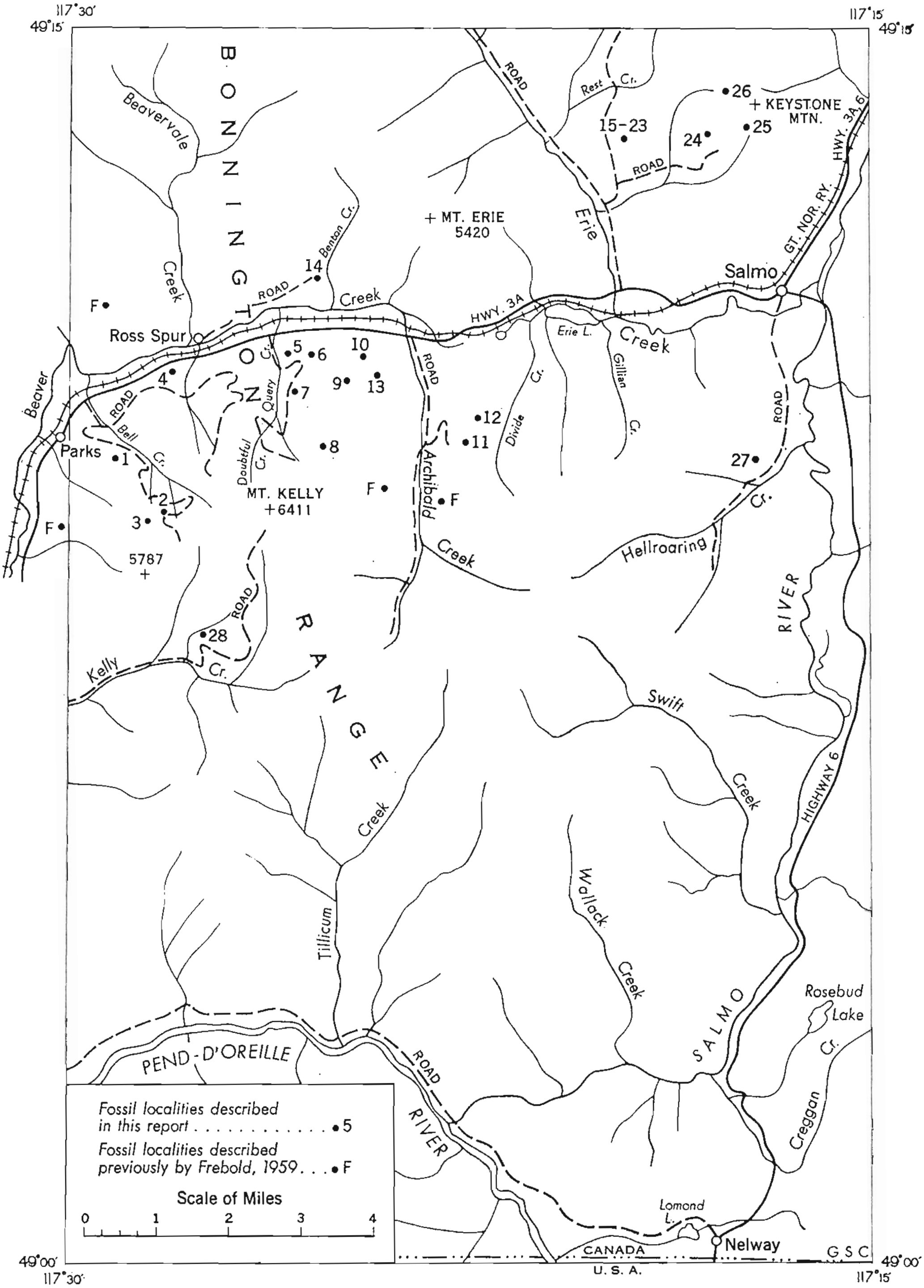


Figure 1. *Map showing Jurassic fossil localities of Salmo map-area.*

82 G/7

INTRODUCTION

Since the first fossils were discovered in the Jurassic rocks of the Nelson and Salmo areas, southern British Columbia, in 1948 and 1949 many new discoveries have been made. The marine Jurassic fossils found prior to 1958 are described in Bulletin 49 (Frebold, 1959). The fossils dealt with in this report were collected by Frebold in 1958 and by Little and Frebold in 1959. They comprise better preserved ammonites belonging to the same species as those previously described together with a number of species not hitherto found in this region. Among these are species that indicate the presence of zones hitherto unknown in this part of British Columbia. In addition some indeterminable ammonites were found. They are described despite their poor preservation because they also suggest the presence of zones new for this area.

The fossils have been invaluable in elucidating the stratigraphy and structure of the Jurassic rocks of Salmo area and the Jurassic palæogeography of the region.

STRATIGRAPHY AND STRUCTURE

(H. W. Little)

Description of Formations

See Table I

During the initial mapping of the Bonnington and Salmo map-areas (Little, 1949, 1950; Mulligan, 1951, 1952) it appeared that the Rossland volcanic group was divisible into three units which were named, in stratigraphic succession, the Elise, Hall, and Beaver Mountain formations. Tentative determinations of fossils collected in 1948 and 1949 (Frebold, *in* Little, 1950, pp. 26-28) appeared to confirm this relationship, for the age of the fossils collected from the Hall formation in Bonnington map-area was indicated as on the boundary between Lower and Middle Jurassic, and those from the supposed Hall (now Archibald) formation of Salmo map-area were believed to be possibly Upper Lias. Subsequent examination of the fossils, combined with material collected by Frebold from some of these and other new localities, showed (Frebold, 1959) that the fossils from the Hall formation are much younger (middle Bajocian) than those of the supposed Hall formation (Sinemurian), and that the upper part, at least, of the Elise formation is of intermediate age (Toarcian). Furthermore, it was shown by Frebold that the Beaver Mountain and Elise formations were, in part at least, equivalent to each other, so it was decided that, as no volcanic rocks younger than the Hall formation were known, only a single unit of volcanic rocks existed and this was called the Rossland formation (Little, 1960, pp. 62-64).

Further mapping and fossil collecting by the authors in Salmo map-area in 1959 have however shown that not only are volcanic rocks in that area equivalent in age to sedimentary rocks of the Hall formation in Bonnington area, but that

	STAGE	FOSSIL BED	HALL-BARRETT CREEKS AREA (Bonnington-Ymir map-areas)	ARLINGTON & KEYSTONE MINES	RIDGE NORTH OF PARKS	BELL-QUERY CREEKS AREA	ARCHIBALD-KELLY CREEKS AREA
MIDDLE AND (?) UPPER JURASSIC	?						UPPER ROSSLAND GROUP
MIDDLE AND (?) UPPER JURASSIC	Younger than middle Bajocian	*Perisphinctes* (?) sensu lato	Hall Formation				Hall Formation •
MIDDLE AND (?) UPPER JURASSIC	Early middle Bajocian	*Sonninia* (?) sp. indet.	Hall Formation •	Hall Formation			
MIDDLE AND (?) UPPER JURASSIC / LOWER JURASSIC	Toarcian or lower Bajocian	*Hildoceraceae* indet.	Hall Formation	Hall Formation •			
LOWER JURASSIC	Lower Toarcian	*Dactylioceras* spp. indet	Elise Formation	Hall Formation •	Elise Formation	Elise Formation	Elise Formation
LOWER JURASSIC	Lower Toarcian	*Harpoceras* cf. *exaratum*	Elise Formation •	Hall Formation •	Elise Formation	Elise Formation	Elise Formation
LOWER JURASSIC	Lowermost Toarcian Pliensbachian Upper Sinemurian		Elise Formation	Elise Formation	Elise Formation	Elise Formation	Elise Formation
			?	?			
LOWER JURASSIC	Lower Sinemurian	*Arnioceras* sp. indet., corals, pelecypods, gastropods	YMIR GROUP	Archibald Formation	Elise Formation •	Archibald Formation	Archibald Formation
LOWER JURASSIC	Lower Sinemurian	*Arniotites kwakiutlanus*	YMIR GROUP	Archibald Formation	Archibald Formation	Archibald Formation •	Archibald Formation •
LOWER JURASSIC	Hettangian (?)	*Gyrophioceras* (?) Amm. gen. et sp. indet., Nos. 1 & 2	YMIR GROUP	Archibald Formation	Archibald Formation	Archibald Formation • •	Archibald Formation •
			?	?	?	?	?
TRIASSIC (?) AND (?) OLDER							

Fossils present: . . . . •

GSC

Table 1. **Correlation of Jurassic rocks in Salmo, Bonnington, and Ymir map-areas.**

the Hall formation in Salmo area is overlain by a considerable thickness of volcanic and intercalated sedimentary rocks. It is therefore proposed that the Rossland formation be reinstated as a group comprising the Elise and Hall formations (which are in part equivalent in age though lithologically different), as well as the rocks that overlie the Hall which are for the present referred to the upper Rossland group. It is undesirable to apply the name Beaver Mountain formation to the upper Rossland group as was done previously (Little, 1950; Mulligan, 1952) because the rocks occupying this stratigraphic position do not outcrop on Beaver Mountain (now Mount Kelly), but some distance west. For the earlier history of the Rossland and Beaver Mountain groups, and Hall formation the reader is referred to Little (1960, pp. 62-64).

Archibald Formation

This formation is defined by the authors as the rock-unit composed predominantly of sedimentary rocks of early Lower Jurassic age and possibly older that lie immediately below the Elise formation, which comprises mainly volcanic rocks.

Probably the most complete section is exposed on the west side of Archibald Creek valley, which is its type locality. It is possible, however, that lower beds of the formation are exposed between Divide and Gilliam Creeks, but outcrops there are few. Elsewhere the formation has been identified in the valleys of Query and Bell Creeks, and on the north side of Beaver Creek from Beavervale Creek to Erie Creek, thence northward in the valley of Erie Creek to the Second Relief mine. At no locality has the base of the formation been identified, and no complete section is exposed.

The Archibald formation south of the Great Northern Railway consists mainly of hard, dark grey to black, light grey weathering, laminated siltstones which have yielded ammonites and ammonite fragments in many localities. The siltstones commonly exhibit graded bedding and crossbedding is rare and of small amplitude so that sedimentation apparently occurred under quiescent conditions. Thin sections of the rock show its composition to be plagioclase, calcite, quartz, potash feldspar, altered ferromagnesian minerals, and hematite(?), in decreasing order of abundance, in a fine-grained matrix of small rock fragments and unidentifiable minerals. In general, the siltstones appear to be tuffaceous and in some places are definitely so.

Argillite, argillaceous quartzite, greywacke, and water-lain tuffs are less abundant than siltstone, and a few sills or flows of andesite or latite are present. In a few places outcrops of agglomerate or flow breccia were observed.

In the valleys of Beavervale and Benton Creeks the Archibald formation closely resembles that in Archibald Creek valley, but argillaceous quartzite is more abundant although hard, black, laminated siltstone is predominant. In the valley of lower Erie Creek north of Erie Lake, coarse clastic rocks are common. There a considerable thickness of pebbly sandstone, dipping gently north and little metamorphosed, has been indicated by Mulligan (1951, p. 79, and plate).

Only one section of the Archibald formation, in Query Creek where it is comparatively well exposed along the road, has been measured. No reliable top determinations were made and the probable succession has been established by fossil determinations by Frebold. The measured section is as follows:

	Thickness (feet)
Agglomerate (Elise formation?)	
Argillaceous quartzite	2
Gap	12
Argillaceous quartzite, hard, massive	7
Arenaceous argillite, fine-grained, black, thinly laminated	7
Argillaceous siltstone, hard, laminated	2.5
Quartzite, hard, light grey	2
Gap	5.5
Argillite, fine-grained, black	2
Argillaceous siltstone, hard, dark grey, laminated	5
Gap	2.5
Argillaceous siltstone, hard, dark grey, laminated	2
Gap	5
Arenaceous argillite, black, finely laminated (*Arniotites kwakiutlanus* GSC locs. 38934, 38953)	7
Gap	4
Argillite, black, shaly	2
Gap	3
Argillite, black, shaly in lower part	2
Argillaceous quartzites, hard, black, laminated	26
Gap (may contain a fault)	40
Argillaceous siltstone, hard, black, laminated	16
Gap	6
Argillaceous siltstone, hard, black, laminated	20.5
Gap	22.5
Argillaceous siltstone, hard, black, laminated (poorly exposed)	22
Gap	17
Siltstone, hard, black, laminated	2
Gap	28
Siltstone, hard, black, laminated	8.5
Gap	26
Argillaceous siltstone, hard, black	2
Gap	29
Siltstone, hard, black, laminated	2
Gap	10
Argillaceous quartzite, hard, laminated	23
Gap	3
Siltstone, hard, black, laminated	2
Gap	50
Arenaceous argillite, black (*Gyrophioceras*? sp. indet. GSC loc. 39281)	2
Gap	41
Argillaceous quartzite	11
Gap	34
Quartzite, coarse-grained, massive, tuffaceous	10
Siltstone, black, laminated	9
Gap	18
Argillaceous siltstone, black, laminated (Amm. gen. et sp. indet. No. 2, GSC loc. 38927)	21
Indicated thickness	574
Base not exposed	

On the west side of Archibald Creek, the rock is not so well exposed but several top determinations, mainly by means of graded bedding, all indicated that the beds, which dip 30° to 75°W, are not overturned. The approximate thickness there appears to be at least 4,000 feet. The stratigraphic range of *Arniotites kwakiutlanus* appears to exceed 1,000 feet, and if the base of the Elise formation can be regarded as a reliable horizon marker for a distance of somewhat more than a mile, the range may be at least 2,000 feet. Similarly, on the east side of Archibald Creek, the stratigraphic range of *Arniotites,* almost directly across the strike, appears to be about 1,600 feet.

This apparently large stratigraphic range of *Arniotites kwakiutlanus* indicates that deposition of the Archibald formation was either very rapid or that on both sides of Archibald Creek strata have been repeated by undetected faults or tight folds. Although the fine-grained nature of the sediments appears to preclude their rapid accumulation, it may nonetheless have happened owing to the high proportion of volcanic ash.

Ymir Group

Within Salmo area the Ymir group underlies only a small area north of the granite stock in Hidden Creek valley. Rocks of the Ymir group there have been largely altered to hornfels as a result of contact metamorphism.

In Ymir map-area, which adjoins the north edge of the east half of Salmo map-area, the Ymir group conformably underlies the Elise formation. As it bears the same stratigraphic relationship to the Elise formation as does the Archibald formation, it follows that the Ymir group is, in part at least, equivalent to the Archibald formation. Careful search of the Ymir group for fossils by McAllister, Frebold, and the writer has, however, so far been unsuccessful. The authors of this paper therefore have not referred the fossiliferous Archibald formation to the Ymir group, which has been regarded as largely equivalent to the Slocan group (Little, 1960, p. 59). The lower part of the Slocan contains fossils of probably Triassic age.

Lithologically the Ymir group closely resembles the Archibald formation. Andesitic sills or flows are however known only in the uppermost part of the Ymir group (McAllister, 1951, p. 27). At some lower horizons many of the beds are distinctly tuffaceous, as in the Archibald formation. In general the clastic beds of the Ymir group are coarser grained and, according to McAllister (p. 26), comprise "slates, argillites, shales, argillaceous quartzites, quartzites, . . . and minor amounts of mica and mica-chlorite schists." Limestones, which are present in the group in the northern part of Ymir map-area, are rare or missing in the southern part. Nevertheless, as in the Archibald formation, some of the clastic beds are slightly calcareous.

Elise Formation

The Elise formation was originally defined by the writer (Little, 1950, p. 25) to include the volcanic and minor sedimentary rocks lying between the predominantly sedimentary rocks of the Ymir group and the Hall formation. The only change in this definition is that the Elise formation rests directly upon the Archibald formation as well as directly upon the Ymir group. Consequently, as shown by Frebold (1959), most of the rocks mapped previously by the writer (Little, 1950) as Beaver Mountain formation are in reality Elise formation.[1]

Defined thus as a lithological unit, the upper and lower boundaries of the Elise formation show temporal transgression (*see* Tables I and II). North of Parks, it has yielded fossils of Sinemurian age, so that the basal member of the Elise formation is older there than elsewhere where it rests upon Sinemurian beds of the Archibald formation. Where the Elise formation rests upon the Ymir group, the age of the basal part cannot be established.

Similarly the uppermost part of the Elise formation between Hall and Barrett Creeks in Ymir map-area has yielded fossils of Toarcian age, but at Arlington and Keystone mines the basal beds of the Hall formation are Toarcian. In Kelly Creek, however, the basal beds of the Hall formation contain fossils of post-Middle Bajocian age, so that the upper part of the Elise formation there is much younger than has been established elsewhere, and is even younger than the Hall formation on the ridge between Porto Rico and Barrett Creeks in Bonnington map-area, where a *Sonninia*? was collected (Frebold, 1959, p. 4).

The Elise formation consists of lava flows, ranging in composition mainly from andesite to basalt, flow breccia, augite porphyry that appears to be mainly intrusive, agglomerate, and minor tuff, siltstone, and argillaceous quartzite. Some of the flows are porphyritic, augite, feldspar, and hornblende comprising the phenocrysts. Thin sections of the lavas show that most are considerably altered, possibly largely through deuteric action.

Intercalated water-lain tuffs and sedimentary rocks up to 200 feet thick have been observed in various places. The thickest and most persistent laterally can be traced at intervals for perhaps 4 miles near the top of the ridge west of Archibald Creek, but may not represent the same stratigraphic horizon everywhere.

In Ymir map-area east of Salmo River, and in Salmo map-area west of Archibald Creek and along the south side of Beaver Creek from Query Creek to Bell Creek, the base of the Elise formation, where exposures are good, is quite accurately defined where predominantly sedimentary rocks are overlain by lava flows and flow breccias. Elsewhere, however, particularly in Erie Creek valley as far north as the Second Relief mine in Bonnington map-area, in the area between the heads of Gilliam and Archibald Creeks, and on the ridge north of Parks, the basal members of the Elise formation are mainly pyroclastic rocks with interbedded marine sediments. In these localities it is difficult to decide where the contact between the Archibald and the Elise formations should be placed.

[1] 'Beaver Mountain' has from 1904 been regarded as younger than the Rossland group. To avoid confusion, and because the name 'Elise' has become established in the literature, it is now retained to indicate the lowest formation in the Rossland group.

The top of the Elise formation is, so far as is known, more easily determined. The overlying dominantly sedimentary Hall formation, however, becomes thinner southward, and appears to be missing south of Kelly Creek and also south of Hellroaring Creek. If this be so, then the upper Rossland group is indistinguishable from the Elise formation, and the upper boundary of the latter cannot be determined.

The thickness of the Elise formation can only be estimated, as attitudes of flows are difficult to obtain and interbedded sediments are not common. Furthermore, top determinations are rare. In Ymir and Bonnington map-areas the maximum thicknesses are estimated to be 9,000 and 8,500 feet respectively. In Salmo map-area, between Archibald and Kelly Creeks, where the formation appears to have the greatest range in age between base and top, the thickness is estimated to be slightly more than 10,000 feet. This section is characterized by an unusual abundance of pyroclastic rocks, many water-lain, although flows and flow breccias predominate. North of Rest Creek the Elise formation has a maximum outcrop width of about 8,000 feet, and as the two attitudes obtained indicate moderate to steep east dips the thickness should be close to this figure. Uncertainty as to the structure and the possibility of faulting indicate that this figure for the thickness may be inaccurate.

Hall Formation

The Hall formation overlies the Elise formation. Along Hall Creek in Bonnington map-area where the formation was named, it comprises argillite, siltstone, phyllite, greywacke, and pebble-conglomerate. This was regarded by Mulligan (1952) as a homoclinal succession of rocks with the younger beds to the west. The writer (Little, 1960, pp. 69, 70), after Frebold (1959) had, through fossil evidence, shown that the Beaver Mountain and Elise formations are equivalent, proposed that the structure of the Hall formation there is synclinal rather than homoclinal. Confirmation of this structure was obtained by the writer and his assistants in 1959, by careful determinations of tops, mainly by graded bedding and crossbedding.

Farther south, from the valley of Barrett Creek southward, conglomerate is comparatively rare, but coarse greywacke is abundant (Mulligan, 1951, p. 74). On Keystone Mountain in Salmo map-area, hard, black, argillaceous siltstone and hornfels form a capping that appears to be the youngest part of the formation and rests upon thin-bedded, black shale, argillite, and grey phyllite. This hard, carbonaceous, fine-grained rock does not exhibit bedding in outcrops or in hand specimens, but in thin sections thin laminae can be seen. Except for the absence of laminae in outcrops, the rock resembles much of the Archibald formation. It consists of small angular fragments of feldspar (mainly saussuritized plagioclase), and quartz shards, in a groundmass of bladed tremolite, carbonaceous matter, and finely divided, unidentified interstitial material. The basal part of the formation, exposed near the Clubine Comstock, Keystone, and Arlington mines, comprises mainly thin-bedded, black or dark grey shales that have yielded abundant ammonites at the last two localities.

On the ridge between Salmo and Hellroaring Creek, the Hall formation contains an abundance of volcanic material — flows, agglomerate, and tuff — but interbedded sedimentary rocks appear to predominate. In Hellroaring Creek the Hall formation is much thinner, and consists of slaty, arenaceous argillite and grey phyllite. Its correlation is to a degree confirmed by a *Dactylioceras*? collected there. The formation is very thin, and is difficult to trace southwest of this locality, largely owing to paucity of outcrops.

Southwest of Mount Kelly and north of Kelly Creek, the Hall formation is well exposed in road-cuts. There it consists mainly of massive, black argillite, with some light green tuffs and grey phyllite, the latter in places containing abundant small plant fragments. These beds are underlain by massive lavas and flow breccia, with increasing amounts of pyroclastic material stratigraphically downward. They are overlain by volcanic rocks and intercalated sedimentary rocks and tuff, of the upper Rossland group. The Hall formation there is terminated to the northwest against a fault, and to the south, just beyond Kelly Creek, it appears to pinch out.

On the assumption that the rocks in Hall Creek are homoclinal, Mulligan (1951, p. 74) estimated the thickness of the Hall formation there to be about 3,500 feet. As the structure is now known to be a syncline, with apparently a complex subsidiary fold south of Hall Creek, the thickness exposed is not more than approximately 1,750 feet. A rough estimate of the section can be obtained from Mulligan's detailed map of the area (Mulligan, 1951, p. 75; Little, 1960, p. 69) as follows:

Top not exposed	*Thickness (feet)*
Siltstone, argillite, and phyllite	300+
Pebble-conglomerate and greywacke	200 to 300
Siltstone, argillite, and phyllite	200 to 400
Pebble-conglomerate and greywacke	300 to 600
Siltstone, argillite, and phyllite	150 to 1,100

The total thickness of roughly 1,750 feet north of Hall includes only the lowest two members and part of the middle member. South of Hall Creek it represents the total thickness of all members, but it is probable that these are thinned by compression, as shown by elongation of the pebbles in the conglomerates there.

In the area from Barrett Creek to Stewart Creek the apparent thickness of the Hall formation is much greater than in Hall Creek. In a 1959 study of the rocks in the valley of Barrett Creek, no reliable top determinations could be made to determine the structure, but south of Barrett Creek a subsidiary anticline, the core of which comprises lavas of the Elise formation, is shown by Mulligan

(1951, 1952). It is therefore probable that the thickness of the formation in Barrett Creek is not as great as indicated by the outcrop width, but the top of the formation is not exposed.

Between the Clubine Comstock and Arlington mines in Salmo map-area, the indicated thickness of the lower part of the formation, consisting mainly of black shale and argillite, is 2,000 to 3,000 feet. The upper part, comprising carbonaceous siltstone and hornfels, appears to be a few hundred feet thick, and the top is not exposed.

On the ridge between Salmo and lower Hellroaring Creek, where volcanic rocks are unusually abundant in the Hall formation, the structure is complex so that no accurate thickness can be established. It appears to be a few thousand feet thick at that locality. In Hellroaring Creek, however, few volcanic rocks are present in the formation, and the sedimentary rocks there are probably less than 1,000 feet thick, thinning rapidly to the southwest.

In the valley of Kelly Creek, the thickness to the north of the creek is about 400 feet, but pinches out or is faulted a short distance south of the creek.

Upper Rossland Group

Overlying the Hall formation in the valley of Kelly Creek is a succession of volcanic and sedimentary rocks that dip gently southwest. In approximate order of abundance, these rocks comprise lava flows and flow breccia, agglomerate, siltstone and argillite containing abundant small plant fragments, and tuff. The total thickness of these rocks exposed within Salmo map-area north of Kelly Creek is approximately 3,800 feet, but farther west, beyond the boundary of the map-area, it is probable that a greater thickness still is exposed.

Rossland Group, Undivided

South of Kelly and Hellroaring Creeks and the height of land between them, much of the map-area does not contain abundant outcrops, and large areas are underlain by granitic rocks. For these reasons, or possibly because it is thin or missing entirely, the Hall formation could not be identified. The Jurassic rocks in this part of the map-area consist of volcanic rocks, mainly lavas, and minor sedimentary rocks. As the upper Rossland group may be present there as well as the Elise formation, the rocks are mapped as undivided Rossland group.

Structure of the Jurassic Rocks

Earlier mapping (Little, 1960, p. 106) seemed to indicate that the structure of the Jurassic rocks of Salmo map-area consists mainly of open folds, and no faults of consequence were discovered. During more detailed mapping by the writer in August 1959, several major faults were discovered and the structure was found to be more complex than previously realized. Much new information was obtained from new logging road-cuts in parts of the area where outcrops were scarce, particularly in those underlain by sedimentary rock. Determinations of fossils collected by both authors from many localities confirmed the structural interpretations.

Fyles and Hewlett (1959, p. 14 and fig. 2) have divided the rocks of the Salmo lead-zinc area into four structural units. These are successively, from southeast to northwest, the Eastern, Black Argillite, and Mine Belts, and the Mesozoic volcanic area. They are bounded by generally low-angle thrust faults that dip southeasterly and each belt has been thrust upon the adjacent one to the northwest. This paper is not concerned with the three belts of Fyles and Hewlett, but only with the structure of their Mesozoic volcanic area, which along the periphery where they examined it south and southwest of Salmo, comprises mainly volcanic rocks, but elsewhere contains abundant sedimentary rocks. The Jurassic rocks together with the Nelson batholith and some satellites form the southern part of a block bounded on the east and south by the early Palæozoic and late Proterozoic rocks of the Kootenay arc.

Folds

In Salmo map-area two major folds were noted previously (Little, 1950, p. 35; 1960, p. 106). One of these is the syncline on Mount Kelly that plunges gently southwest. The northwest limb dips gently southward and is terminated against a major northeast-trending fault. The southeast limb dips gently west but steepens in the valley of Archibald Creek where it is terminated against a north-south fault, which also was previously undetected. East of this fault is an anticline that was formerly thought to share a common limb with the syncline mentioned above. The discovery in 1959 of Elise lava overlying the Archibald formation east of lower Archibald Creek indicates the presence of a fault, and also shows that the anticlinal axis strikes more easterly than was thought previously. The axis of the anticline strikes northeast from the forks of Archibald Creek, but its exact position cannot be determined owing to scarcity of outcrops and few top determinations, nor is it known if subsidiary folds are present on its limbs. This anticline cannot be traced north of the valley of Erie Creek between Erie Lake and Salmo, where the structure is complex. There appears to be an asymmetrical anticlinal fold there, with the southeast limb overturned, extending northeast from a probable fault near Erie nearly to Keystone Mountain. This fold appears to be a warp in the western limb of a syncline that can be traced from Keystone Mountain north to Hall Creek (Little, 1960, p. 106), and was probably formed later than the syncline, for its axis diverges greatly in direction from that of the syncline.

In Erie Creek valley from Burnt Creek north to the granitic stock near the Second Relief mine, the Archibald formation forms the core of an anticline that plunges south. There may be subsidiary folds near Burnt Creek, but it is equally possible that the repetition of strata may be due to an undetected fault, possibly the extension of that just east of Erie.

Between Benton and Beavervale Creeks the structure appears to be undulating, and the area south of the granitic stock is underlain by beds of the Archibald formation except for the crest of the ridge which is capped by amphibolite and meta-gabbro believed to be the metamorphic equivalents of lavas of the Elise formation. From Beavervale Creek west to the crest of the adjacent ridge, massive lava of the Elise formation presumably dips west.

Owing to paucity of outcrops and the few attitudes obtainable, the structure of the undivided Rossland group south of Kelly and Hellroaring Creeks is not known.

All the folds described above, except that southwest of Keystone Mountain, appear to be primary in that they are probably earlier than the Nelson granitic rocks. These folds are therefore related to the deformation that produced the "overturned and isoclinal folds" of Fyles and Hewlett (1959, pp. 47, 48) in the adjacent belts of Palæozoic rocks. The folds in the Jurassic rocks are however neither overturned nor isoclinal. The apparently asymmetrical fold southwest of Keystone Mountain, though later than the primary folds, cannot be termed secondary in the sense used by Fyles and Hewlett as it appears to be unrelated to the early period of deformation. The age relationship of this fold to granitic intrusion is not known.

Faults

The major faults in Salmo map-area are, according to Fyles and Hewlett (1959, pp. 47, 48, 55), thrust faults that dip east to southeast and are earlier than the granitic satellites of the Nelson batholith. These faults originated during the period of early deformation. The undulating thrust fault that forms the boundary between the Rossland group and the lower(?) Palæozoic rocks was named the "Waneta fault" by Fyles and Hewlett (1959, pp. 55, 56) and the "Pend-d'Oreille fault" by the writer (1960, p. 104), whose memoir was already in press when the bulletin by Fyles and Hewlett appeared. The name "Waneta" has priority and will be used henceforth by the writer.

Thrust faults in the Jurassic rocks are not common; only two such faults have so far been discovered. Though not observed the larger of these, which occurs in upper Bell Creek valley must have considerable displacement, for many hundred feet of the Archibald-Elise succession is repeated. This fault, which strikes east-west and dips south, is terminated on the east against the Doubtful Creek fault and may persist some distance west, but has not been traced because of the scarcity of outcrops. Another fault lower in Bell Creek valley may be a thrust fault, but is presumed not to be because it truncates beds of the Archibald formation at right angles. Other than this, little data are known of this fault.

The other thrust fault known is of relatively small magnitude and is well exposed in a large open-cut on the Lucky Boy property, about half a mile west of Salmo and north of highway 3A. Imbricate structure, the sole of which dips 5° to 10°E, is evident in Hall argillites, for a distance of 100 feet or more, beyond which it is obscured by overburden.

The remaining faults in Salmo map-area so far as is known dip steeply, and are believed to be all later than the Nelson granitic bodies. However, in only a few cases — those faults striking northwest near Erie Lake — could this later age be proven.

The fault with the greatest apparent displacement is the Doubtful Creek fault. It enters Salmo map-area from the east about 1½ miles north of Kelly Creek, strikes northeasterly across the north side of the 5,787-foot mountain west of Mount Kelly, thence to Doubtful Creek which it follows on the east side to Query Creek. Beyond this point its position is uncertain but it may split, one branch heading towards Benton Creek and the other towards Meadows. At the southwest end the Archibald formation is in fault contact with upper Rossland group, but the apparent displacement decreases to the northeast and the fault was not detected north of Beaver Creek. It appears to dip nearly vertically throughout its length.

East-west faults were not detected but one of uncertain magnitude is suspected on the ridge due west of Halfway Creek. The discrepancy in the geology across the broad valley occupied by the railway and highway 3A west of Salmo leads one to suspect the presence of an east-west fault of great magnitude. If so, then it must be earlier than the northwest-striking faults near Erie Lake.

The only north-south fault detected is that in Archibald Creek along the lower part of which lavas of the Elise formation are faulted against sediments of the Archibald formation, indicating a displacement of several thousand feet. To the south the fault seems to feather out into several branch faults, some of which may be seen on the divide between Archibald and Tillicum Creeks. South of this ridge outcrops are so scarce that the fault cannot be traced.

Near Erie Lake two vertical, northwest-striking faults that cut granitic and older rocks can be traced for many miles. The apparent horizontal displacement of these faults is up to several thousand feet, and in both cases is right hand. These faults are the most readily detected on air photographs of any in the map-area. A third, parallel to and west of the others, also indicated on the air photographs, cuts only granite and is shown on the map as an assumed fault.

Just east of lower Erie Creek and subparallel with the creek, is a fault the exact position of which is uncertain. It probably strikes about N30°W and dips steeply, and its displacement near Erie Creek is large, for sediments of the Archibald formation are brought nearly in fault contact with those of the Hall formation about a mile east of Erie Lake. The minimum vertical displacement is therefore several thousand feet. The fault cannot be traced south of highway 3A or north along Erie Creek, but may persist for some distance in both directions.

On the ridge north of Parks pyroclastic rocks, lavas, and sediments of the Sinemurian lower Elise formation are in fault contact with massive lavas to the west. This fault is exposed on the southwest side of the ridge where the strata are truncated by it. It strikes northwest and dips northeast moderately. The lower Elise formation there is assumed to be bounded on the east also by a fault because, although the structure is not clearly understood, the lower Elise formation would otherwise apparently be resting upon a great thickness of volcanic rocks of the Elise formation. This however is not in keeping with its Sinemurian age, and though the position of the Sinemurian rocks could be explained by complex folding rather than faulting, the presence of a fault seems more probable.

The sequence and pattern of faulting in Salmo map-area have not yet been completely worked out, and much detailed study would be required to do so, for in many parts of the area outcrops are sparse.

The low-angle thrust faults including the Waneta fault are of pre-Nelson granite age. South of highway 3A, overthrusting was from the southeast as shown by the northeasterly strikes of the thrust faults and of the major fold axes. To the north, however, the fold axes strike north, indicating east-west compression.

As the direction of dips of the north-south and east-west faults and their sequence relative to other faults are not known, no conclusions as to their origin can be drawn.

The apparent right-hand displacement of the northeast- and southeast-trending faults, which are believed to be the latest faults, suggests that they are a consequence of north-south compression. Possibly the presumed overturned fold southwest of Keystone Mountain was formed during this deformation.

Pending publication of a final map of Salmo map-area, which is now in press, the reader is referred to earlier maps from publications in the list of References.

PALÆONTOLOGY AND CORRELATION

(H. Frebold)

Description of Fossils

Ammonite gen. et sp. indet. 1

Plate I, figure 11

Material. One incompletely preserved specimen (GSC 15267), found in the Archibald beds west of Archibald Creek (GSC loc. 39283).

Description and remarks. The specimen is a fairly involute ammonite with high, moderately convex whorl which has forwardly inclined, moderately strong, narrowly but irregularly spaced ribs that are strongest in the outer half of the whorl. The strength of the ribs varies. In the posterior part of the whorl the ribs have an almost sigmoid shape and the space between them is much larger than it is in the anterior whorl-part. Shapes of venter, inner whorls, and suture line are not observable. The specimen is indeterminable. It was found as float in an area underlain by Archibald beds, the lithology resembles that of an adjoining outcrop. As the beds concerned belong to a level that is stratigraphically below the Sinemurian *Arniotites* bed, an older, possibly Hettangian, age may be considered.

Ammonite gen. et sp. indet. 2

Plate I, figure 13

Material. One poorly preserved specimen (GSC 15268) found in the Archibald beds in outcrop on Query Creek road, 0.7 mile south of highway 3A (GSC loc. 38927).

Description and remarks. The secondarily compressed specimen is more involute and has higher whorls than *Gyrophioceras*? sp. indet. and *Arniotites kwakiutlanus* Crickmay found in the same section along the Query Creek road, but at different stratigraphic levels. The ribs are fairly widely spaced, straight and of moderate strength, they are apparently thickest in the middle part of the whorl. No keel could be seen and the suture line is not preserved. This specimen is indeterminable. As its stratigraphic level is slightly below the probable Hettangian bed with *Gyrophioceras*, a Hettangian age may be considered.

Family PSILOCERATIDAE Hyatt, 1867
Subfamily ALSATITINAE Spath, 1924

Gyrophioceras? sp. indet.

Plate I, figure 12

Material. One fragmentary specimen (GSC 15269) collected in road-cut of Query Creek road, 0.8 mile from highway 3A (GSC loc. 39281).

Description. The specimen is very evolute and wide-umbilicate, the whorls slowly increase in height and are only slightly convex. The ribs are fairly strong, almost straight, regularly spaced and undivided. A fairly low keel is present, no furrows. No suture line is visible.

Remarks. The incomplete state of preservation of the specimen does not warrant detailed determination. It can be clearly distinguished from *Arniotites kwakiutlanus* Crickmay, which occurs in the same section at a higher stratigraphic level, by its greater evolution and wider umbilicus. In its general outline the specimen resembles some representatives of the subfamily Psiloceratinae Hyatt, as for instance *Caloceras* and *Laqueoceras*, but both these genera are distinguished by the absence of a keel. Among the subfamily Alsatitinae Spath, *Alsatites* is similar but has more numerous ribs, whereas *Paracaloceras* has similar ribbing but a carinate-bisulcate venter. However, the genus *Gyrophioceras* Spath has a general outline, venter, and ribs similar to those of the Query Creek specimen and it is possible that the Query Creek specimen belongs to that genus. As, however, the suture line and cross-section could not be seen, the determination remains doubtful until better preserved material is found.

Occurrence. The genus *Gyrophioceras* occurs in the Hettangian of Europe. If it could be proved that the Query Creek specimen belongs to this genus, the presence of Hettangian beds in the Query Creek area would be established with certainty.

Family ARIETITIDAE Hyatt, 1874

Subfamily ARNIOCERATINAE Spath, 1924

Genus ***Arniotites*** Whiteaves, 1889

Arniotites kwakiutlanus Crickmay

Plate I, figures 1-10

Arniotites kwakiutlanus Crickmay, 1928, p. 61, Pl. 1; Pl. 2, figs. a-e.
Arniotites begbiei Crickmay, 1928, p. 61, Pl. 2, figs. f, g.
Melanhippites harbledownensis Crickmay, 1928, p. 61, Pl. 3; Pl. 4, figs. a-d.
Arnioceras (Melanhippites) sp. indet., Frebold, 1959, p. 6, Pl. 1, figs. 1, 2.

Material. Many specimens, mostly preserved as fragments or imprints from the Archibald beds in Bell Creek (GSC locs. 38947, 38960), Query Creek (GSC locs. 38934, 38953, 28929), east and west of Archibald Creek (GSC locs. 38944, 38945, 38952, 38956, 29283), and between Archibald and Divide Creeks (GSC locs. 38930, 38931, 38949). Previously described material (Frebold, 1959) came from a locality west of Archibald Creek. All these localities are in the area south of highway 3A between Erie and Parks.

Description. The ammonites previously described from the Archibald Creek area (loc. cit.) are not so well preserved as some of the recently collected specimens. None of them shows the keel, and the innermost whorls are also poorly visible. The new material includes specimens with keel and innermost whorls preserved.

Both the previously described and the recently collected specimens are considered to belong to one and the same species. This evolute, wide-umbilicate ammonite has whorls that very slowly increase in height and are very slightly convex. The margin between flanks and venter is marked by a ridge (*see* specimen GSC 15270, Pl. I, fig. 1), the keel is fairly low and there is no sculpture on the venter. Some specimens have smooth inner whorls, others are ribbed and there are specimens without the inner whorls preserved. In the subsequent stages of growth up to a diameter of about 45 mm there are fairly high and sharp, straight, undivided ribs. In some specimens small tubercle-like elevations are preserved near the ventro-lateral border. The spaces between the ribs are larger than the ribs themselves. At diameters of more than about 45 mm the ribs are still sharp but are slightly curved. The forward arching of the ribs is somewhat increased in more adult specimens, and in such stages of growth the ribs are more rounded (*see* Frebold, 1959, Pl. 1, figs. 1, 2).

Only one smaller specimen (GSC 15271, *see* Pl. 1, fig. 2) collected in Query Creek shows part of the suture line which is very slightly incised and resembles that of *Arnioceras.*

Remarks. The specimens described agree very well with the figures and description of *Arniotites kwakiutlanus* Crickmay and *A. begbiei* Crickmay (Crickmay, 1928, p. 61, Pl. 1; Pl. 2, figs. a-e and Pl. 2, figs. f, g respectively), two 'species' that, according to Crickmay, differ from each other in that *A. begbiei* has a longer smooth stage (as much as 16 mm), less stiff and less pronounced ornament and more closely spaced ribs than *A. kwakiutlanus.* In the writer's opinion these differences may occur within the variation of one and the same species. Also Crickmay's *A. kwakiutlanus* has small tubercles at the ventral termination of each rib and indication of tricarination as is so in certain stages of growth of the Salmo area material. Very similar also are Crickmay's specimens of *Melanhippites harbledownensis* (loc. cit.). Crickmay's genus *Melanhippites* comprises forms without prolonged smooth stage, but in all other aspects it agrees with *Arniotites.* The writer now believes that both *Arniotites* and *Melanhippites* belong to one and the same genus, i.e. *Arniotites* Hyatt. Also, Arkell (1957, p. L240) has questioned the status of *Melanhippites* as an independent genus. Even within the genus *Arniotites* Hyatt the prolongation of the smooth stage differs, as stated by Crickmay (loc. cit.), and the difference in comparison with forms described as *Melanhippites* is only a slight and gradual one. In many cases the inner whorls are not preserved as is illustrated by specimens figured by Crickmay (loc. cit.). Thus, most of the specimens of *Arniotites kwakiutlanus, A. begbiei,* and *Melanhippites harbledownensis* figured by Crickmay (op. cit., Pl. 2, figs. a, b, c, d, f; Pl. 3; Pl. 4, figs. b, c respectively) do not have the innermost whorls preserved and consequently their assignment to *Arniotites* or *Melanhippites* would be doubtful. The writer considers that both of Crickmay's *Arniotites* species and his single *Melanhippites* species belong to one and the same species, as is indicated in the synonymy, and has chosen to include all three under *A. kwakiutlanus,* which is the first species described by Crickmay.

It is to Crickmay's credit to have recognized that his *Arniotites* and *Melanhippites* are related to *Arnioceras* and are not connected with *Balatonites.*

The very close relationship of the Canadian species to species of the *Arnioceras semicostatum* group is, indeed, striking.

Occurrence. As already stated by Crickmay (op. cit., p. 60), *Arniotites* belongs to the Sinemurian. He thought that the forms described by him as *Melanhippites* were somewhat younger than his *Arniotites* but as here suggested, all these forms belong to one and the same species. The exact position of the specimens described in this report within the Sinemurian may be debatable, but their close relationship with forms of the group of *Arnioceras semicostatum* suggests to the writer an assignment to that zone.

Family HILDOCERATIDAE Hyatt, 1867
Subfamily HARPOCERATINAE Neumayr, 1875
Genus ***Harpoceras*** Waagen, 1869
Harpoceras cf. *H. exaratum* Young and Bird

Plate II, figures 1-9; Plate III, figure 5

Ammonites exaratus Young and Bird, 1828, p. 266.
Ammonites subplanatus Dumortier, 1874, p. 51. Pl. 10; Pl. 11, figs. 1, 2, 8.
Ammonites exaratus Tate and Blake, 1876, p. 305, Pl. 11, fig. 5.
Harpoceras exaratum Wright, 1878-86, pp. 441-443, Pl. 62, figs. 1, 2, 3.
Harpoceras cf. *H. exaratum* Donovan, 1954, pp. 20, 46.
Harpoceras cf. *H. exaratum* Imlay, 1955, p. 88, Pl. 11, figs. 12, 13, 15.
Harpoceras cf. *H. exaratum* Frebold, 1957, p. 47, Pl. 17, fig. 1; Pl. 18, figs. 2, 3.
Harpoceras aff. *H. exaratum* Frebold, 1959, p. 7, Pl. 3, fig. 1.

Material. Numerous and fairly well preserved specimens collected from the lower part of the Hall formation in the surroundings of Arlington mine (GSC locs. 38912, 38914, 38915, 38916, 38918, 38924, 38932). At Keystone mine (GSC locs. 38909, 38921, 38923) and Second Chance mine (GSC loc. 39282), Salmo area, and on highway between Hall and Porto Rico other but poorly preserved specimens were collected. Specimens from the last locality were described by the author (Frebold, 1959, p. 7, Pl. 3, fig. 1).

Description. Specimen GSC 15291 from GSC loc. 38932 near Arlington mine is one of the best preserved imprints, the rubber cast of which is illustrated in Plate II, figure 1. The maximum diameter is about 79 mm, the height of the last whorl at its end is about 40 mm, and the width of the umbilicus about 18 mm. As the specimen is secondarily laterally compressed, all measurements are approximate. There is a high keel which does not seem to be separated from the flanks. On the last whorl all ribs are strongly sickle-shaped and undivided, but their number and strength change in the course of the ontogenetic development; they are stronger and more widely spaced at the beginning of the last whorl than near and at its end. Continuation of the ribs on the keel can be seen near the end of the whorl. The umbilical wall seems to have been steep.

A number of large whorl fragments illustrate that the species attained about twice the size of the specimen described above. Smaller specimens are also abundantly associated, they have the same type of ribbing down to diameters of about 40 to 70 mm; in still smaller ones, however, the ribs are not sickle-shaped, but only sigmoid and eventually almost straight. In these young stages of growth bifurcation of the ribs is fairly frequent. The change of ribbing begins at different diameters in different individuals and in some specimens the first sickle-shaped ribs are comparatively coarse whereas in others they are fine.

Associated with *Harpoceras* cf. *H. exaratum* several aptychi of the type *Laevicornaptychus* were found (*see* specimens GSC 15294, 15299, 15300, Pl. II, figs. 6-8). They resemble aptychi described by Quenstedt (1883-85, p. 352, Pl. 43, fig. 9). As there are no ammonites other than *Harpoceras* cf. *H. exaratum* in the beds concerned, it is supposed that the aptychi belong to this species.

Remarks. Some of the better preserved specimens from the Arlington mine area are very similar to *H.* cf. *H. exaratum* figured by Wright and to *H. subplanatum* Dumortier. The specimens described from the Fernie group in Alberta (Frebold, loc. cit.) and the poorly preserved specimens from the highway between Hall and Porto Rico belong to the same species.

The poorly preserved specimens from Keystone mine do not warrant exact determination but belong at least to a very similar species.

There are a great number of young specimens with bifurcated and more or less sigmoid ribs that are too small to show the change to the stage with sickle-shaped ribs. It is probable that all these small forms, which are very similar to those small individuals that could be proved to belong to *exaratum,* belong to the same species.

Occurrence. Lower part of Hall and upper part of Elise formations. At Keystone mine associated with *Dactylioceras.* In England, *H.* cf. *H. exaratum* is the index fossil of the subzone of *H. exaratum,* which forms the lowermost subzone of the *Hildaites serpentinus* zone of the lower Toarcian.

Indeterminable Hildoceraceae

Plate III, figures 1-4

Material and description. On several dumps of the Arlington mine (GSC locs. 38910, 38911) very poorly preserved ammonites were collected from a fairly hard rock belonging to the lower part of the Hall formation. Some of these are Dactylioceratids, described on page 19, but others are Hildoceraceae. The two groups have never been found in the same piece of rock and it is therefore possible that they came from different beds. Furthermore, these Hildoceraceae have never been found in the very fossiliferous beds with *Harpoceras* cf. *H. exaratum.* These ammonites are mentioned and figured here because they belong to one or more hitherto unknown beds.

Among these Hildoceraceae are impressions of young specimens with widely spaced and more or less straight ribs (*see* specimen GSC 15301, Pl. III, fig. 4) which cannot be determined. One larger specimen (GSC 15302, Pl. III, fig. 1) has a fairly narrow umbilicus, high whorls and a keel. Slightly bent ribs are recognizable in the outer part of the whorl. The specimen is indeterminable but has some very superficial similarities to certain species of *Pseudolioceras.* The specimen GSC 15303 (*see* Pl. III, fig. 2) is entirely different. It has a comparatively wide umbilicus, fairly strong undivided, widely spaced sinuous ribs and a fairly high keel. It resembles faintly representatives of *Pseudogrammoceras* and *Grammoceras* but is also indeterminable, both specifically and generically. This applies also to the keeled whorl fragment (GSC 15304) with irregular ribs, figured in Plate III, figure 3.

Occurrence. The mine tunnels from where the dump material came are in the lower part of the Hall formation. It is probable that the beds concerned are younger than the *Harpoceras* cf. *H. exaratum* bed.

Family DACTYLIOCERATIDAE Hyatt, 1867

Genus ***Dactylioceras*** Hyatt, 1867

Dactylioceras sp. indet.

Plate III, figures 6, 7; Plate IV, figures 6-9

Material. Several fragmentary specimens collected in the lower part of Hall formation on road-cut at Keystone mine, Salmo area (GSC locs. 38909, 38919, 38920), and loose on mine dumps at Arlington mine, Salmo area (GSC locs. 38910, 38917).

Description and remarks. All specimens are fragmentary, stretched and distorted. In general, only the flanks are preserved, but a few longitudinally stretched venters were found at Arlington mine. The specimens from Arlington mine show only rarely the bifurcation of the ribs because the outer part of the whorl is broken off or concealed. The specimen GSC 15285, however, collected at Keystone mine and illustrated on Plate III, figure 6, has primaries that bifurcate somewhat above the half height of the flanks; other undivided ribs are intercalated. Among the specimens from Keystone mine are such with very narrowly spaced ribs (*see* specimen GSC 15286, Pl. III, fig. 7), and others with more widely spaced ribs (*see* specimen GSC 15285, Pl. IV, fig. 7), but the preservation of all specimens is too unsatisfactory to warrant assignment to known species. The specimens with more widely spaced ribs resemble *D. commune* Sowerby.

Occurrence. At both localities *Dactylioceras* occurs in beds that belong to the lower part of the Hall formation. At Keystone mine they are associated with *Harpoceras* cf. *H. exaratum,* but at Arlington mine they have not been found in the beds with typical *Harpoceras.* At this locality they were found only in mine dumps in a fairly hard rock that contains Harpoceratids different from the true *Harpoceras.* It is however, probable that beds containing both *Dactylioceras* and the true *Harpoceras* are concealed at this locality. The beds with *Dactylioceras* are of Toarcian age.

Family PERISPHINCTIDAE Steinmann, 1890

Perisphinctes? sensu lato sp. indet.

Plate IV, figures 1-5

Material. Numerous mostly poorly preserved specimens, collected in the upper Rossland group on Kelly Creek road (Fruitvale area), 50 feet north of switchback, 3.6 miles above old mill, elevation 4,350 feet, GSC loc. 38942.

Description. The specimens are preserved as imprints or are secondarily compressed, venter and suture lines are not visible. Most of the specimens belong to young forms of an average diameter of 17 to 20 mm, the best preserved specimen (GSC 15281) reaches about 43 mm and the largest one (GSC 15283) about 53 mm. It is evident that the small forms belong to the same species as the large ones.

The general shape is fairly evolute and wide-umbilicate, the flanks were apparently very slightly convex with gradual transition to the venter, which is not preserved. No constrictions were seen. The primary ribs are straight and fairly widely spaced. No subdivision into secondaries could be observed up to a diameter of about 17 mm, but this may have been caused by unsatisfactory preservation. In the immediately following stage of growth the primaries bifurcate close to the ventral margin, but at a diameter of about 37 mm the point of division is at about half the height of the flanks and the number of secondaries has increased to three or four. Small tubercles seem to have been present at the point of division.

Discussion and occurrence. The specimens are indeterminable as the shape of the venter, cross-section and suture line are unknown. The observable parts show, however, similarities to certain Perisphinctaceae, but until better material is found any further comparison would be pure speculation. It can, however, be stated that the specimens are younger than any known Lower or lower Middle Jurassic species. This fossil bed is the youngest one hitherto found in the Nelson and Salmo areas. In the shales below and above this bed plant remains occur frequently.

Age and Regional Correlation

See Table II, p. 21

The Marine Fossil Beds

In the area between Salmo and Fruitvale about seven different ammonite beds can be recognized. A few miles to the north of Salmo, i.e. 2.7 miles southwest of Porto Rico station the presence of a further bed is indicated. Three of these eight beds were found earlier and described (Frebold, 1959). Some of these beds are only poorly indicated and as the ammonites concerned are indeterminable their accurate age remains doubtful.

The succession of ammonite beds from the top to the bottom is as follows:

8. *Bed with* PERISPHINCTES? *sensu lato sp. indet.* The beds containing this ammonite (*see* description on p. 19) occur on the Kelly Creek road, Fruitvale area (loc. 28, Fig. 1), and consist of shales that lie on volcanic rocks believed to be Elise formation. The age of the ammonite-bearing beds, which are placed in the Hall formation, is indeterminable, because the ammonites are too fragmentary to warrant definite identification. It is, however, obvious that they are

GROUPS	FORMATIONS	FOSSIL BEDS	STAGES	MAIN CANADIAN EQUIVALENTS	
UPPER ROSSLAND GROUP	**Undivided volcanic rocks and sediments**	?	?	?	
LOWER ROSSLAND GROUP	**Hall Formation**	8. *Perisphinctes* (?) sensu lato	Younger than middle Bajocian		
		7. *Sonninia* (?) sp. indet.	Early middle Bajocian	Hudson Bay Mountain, B. C. Lower part of Rock Creek Member, Fernie Group, Alberta	
		6. *Hildoceraceae* indet.	Toarcian or lower Bajocian		
		5. *Dactylioceras* spp. indet 4. *Harpoceras* cf. *exaratum*	Lower Toarcian	Paper shale of Fernie Group, Alberta and B. C.; Canadian Arctic, Maude Fm. Queen Charlotte Is.	BONANZA GROUP, WESTERN VANCOUVER ISLAND
	Elise Formation	Mainly volcanic rocks	Lowermost Toarcian	?	
			Pliensbachian	Marine deposits in southern Yukon Terr., N. W. British Columbia, and Canadian Arctic coast region	
			Upper Sinemurian	Canadian Arctic	
	Upper Archibald Formation	3b. *Arnioceras* sp. indet. Pelecypods, Gastropods, Corals 3a. *Arniotites kwakiutlanus*	Lower Sinemurian	Queen Charlotte Islands, Vancouver Island, other parts of British Columbia; Nordegg Member of Fernie Group in Alberta and British Columbia, Canadian Arctic	
	Lower Archibald Formation	2. *Gyrophioceras* (?) 1a, 1b. Amm. gen. et sp. indet.	Hettangian (?)	?	

Table II. Age and regional correlation of the Jurassic rocks in Salmo area, southern British Columbia (numbers of fossil beds correspond to numbers in text, pp. 20-24).

younger than middle Bajocian; they could belong to younger stages of the Middle Jurassic (Callovian included). This interesting fauna, which was discovered in 1959, proves the presence in this area of marine Jurassic sediments that are younger than those hitherto known. As there are considerable thicknesses of volcanic rocks and sediments on top of this bed, still younger stages are probably present.

As the age of this ammonite bed is unknown, no correlation with other parts of Canada can be made.

7. *Bed with* SONNINIA? *sp. indet.* This bed was found 2.7 miles southwest of Porto Rico station, Bonnington map-area, and belongs to the Hall formation. Its probable age is early Middle Jurassic (Frebold, 1959, pp. 8, 12, 13), more exactly early middle Bajocian. Representatives of Sonninids are known to be present in the Hudson Bay Mountain and Smithers area, British Columbia (McLearn, 1926), and in the lower part of the Rock Creek member of the Fernie group in the Rocky Mountains (Frebold, 1957, pp. 14, 15, 47-49).

6. *Bed with indeterminable Hildoceraceae.* The age of the indeterminable Hildoceraceae found loose on mine dumps of the Arlington mine, Salmo area (locs. 22 and 23, Fig. 1), and described on page 18 of this report, is not accurately determinable because of their very poor preservation. As their stratigraphic relationship to bed 4 with *Harpoceras* cf. *H. exaratum* cannot be stated with certainty, a slightly younger or older age may be considered. On one of the mine dumps they were associated with Dactylioceratids but the two groups were never found in the same piece of rock. They may therefore be younger or older than the Dactylioceratids and the various forms of Hildoceraceae found and may even belong to different horizons. The beds concerned belong to the lower part of the Hall formation, their age is Toarcian or possibly Bajocian.

5. *Beds with* DACTYLIOCERAS *sp. indet.* *Dactylioceras* was found loose on mine dumps of the Arlington mine (loc. 22, Fig. 1) and in situ in a road-cut at Keystone mine (loc. 23, Fig. 1). At the latter locality both fine and more coarsely ribbed Dactylioceratids are associated with *Harpoceras* cf. *H. exaratum* but at Arlington mine such an association has not yet been observed. At this locality indeterminable Hildoceraceae occur loose in the same type of rock but the two groups have never been found in the same piece of rock. In the in situ sections at Arlington mine in which *Harpoceras* cf. *H. exaratum* occurs abundantly, no *Dactylioceras* was found. Comparison with the Keystone mine section seems to suggest that the bed containing both *Harpoceras* cf. *H. exaratum* and *Dactylioceras* is probably concealed at Arlington mine. One questionable *Dactylioceras* was found in Hellroaring Creek (loc. 27, Fig. 1).

The beds containing *Dactylioceras* belong to the lower Toarcian and are placed in the lower part of the Hall formation.

The genus *Dactylioceras* is widely distributed in the Toarcian of Western Canada, i.e. in the Paper Shales of the Fernie group where it is associated with

Harpoceras cf. *H. exaratum* (Frebold, 1957), in the Canadian Arctic islands (Frebold, 1957, 1958, 1960), and in the lower part of the Maude formation on Queen Charlotte Islands (McLearn, 1932, 1949).

4. *Beds with* HARPOCERAS *cf.* H. EXARATUM *Young and Bird.* These beds were found in two sections at Arlington mine (locs. 15-21, Fig. 1), where abundant and fairly well preserved specimens of this ammonite occur associated with a few poorly preserved pelecypods. No other ammonites were found at Arlington mine where a thickness of about 40 feet was exposed. At Keystone mine (loc. 24, Fig. 1) *Harpoceras* cf. *H. exaratum* is associated with *Dactylioceras* (*see* description of bed 5); at Second Chance mine (loc. 25, Fig. 1) one fragment was found loose. Poorly preserved specimens of *Harpoceras* cf. *H. exaratum* were found on the highway between Hall and Porto Rico, Ymir map-area (*see* Frebold, 1959).

In England *Harpoceras* cf. *H. exaratum* is the index fossil of the lowermost subzone of the *Hildaites serpentinus* zone and belongs to the lower Toarcian. The association of *H.* cf. *H. exaratum* with *Dactylioceras* at Keystone mine suggests that the age difference of beds 4 and 5 at Arlington mine is very slight.

H. cf. *H. exaratum* is widely distributed also in other parts of Western Canada, i.e. in the Paper Shales of the Fernie group (Frebold, 1957), where it is associated with *Dactylioceras,* in northwestern British Columbia, and in the Canadian Arctic (Imlay, 1955; Frebold, 1960).

The beds with *H.* cf. *H. exaratum* at Arlington, Keystone and Second Chance mines are placed in the lower Hall formation. On the highway between Hall and Porto Rico they belong to the upper part of the Elise formation (*see* section "Description of Formations").

3a. *Beds with* ARNIOTITES KWAKIUTLANUS *Crickmay.* Beds with this index ammonite are widely distributed in the Salmo area, particularly south of highway 3A between Salmo and Fruitvale (locs. 1, 2, 7, and 9-12, Fig. 1). As the species is similar to *Arnioceras semicostatum* it is placed in the west European zone characterized by that ammonite. Its age is early Sinemurian.

The genera *Arniotites* and *Arnioceras* are widely distributed in other parts of Western Canada, i.e. in the lower part of the Fernie group (Frebold, 1957), in various parts of British Columbia (Crickmay, 1928), and in the Canadian Arctic (Frebold, 1960). The beds in the Salmo area containing *A. kwakiutlanus* form the upper part of the Archibald formation.

3b. *Coquina bed with* ARNIOCERAS *sp. indet., numerous pelecypods and corals.* The type locality of this coquina bed is on the west slope of a ridge about 7,200 feet northeast of Parks station. The fauna, except for the corals and gastropods, is described in Bulletin 49 (Frebold, 1959). The pelecypods include *Cardinia, Trigonia, Goniomya, Lima,* and Pectinids. As the Arnioceratids of this coquina bed are too poorly preserved to warrant identification with the Arnioceratids of the Archibald formation, i.e. *Arniotites kwakiutlanus,* a direct correlation with the *Arniotites* beds of the Archibald formation is not certain. The two compared beds may be of slightly different age. The coquina bed, which is of early Sinemurian age, belongs to the lower part of the Elise formation (*see* section "Description of Formations"). This member seems also to be present northeast of Kelly Mountain.

2. *Bed with* GYROPHIOCERAS? *sp. indet.* In Query Creek (loc. 6, Fig. 1) an ammonite described in this report as *Gyrophioceras*? sp. indet. was found in the lower part of the Archibald formation, i.e. 370 feet below bed 3a with *Arniotites kwakiutlanus*. According to Little (*see* section on fossil localities, p. 27) there may be an intervening fault between the two beds, so the actual stratigraphic position of the bed with *Gyrophioceras*? is not certain. If this ammonite is a true *Gyrophioceras,* it would prove the presence of part of the Hettangian stage.

1a. *Bed with Ammonites gen. et sp. indet. 2.* In the Query Creek road section, about 130 feet below the bed 2 with *Gyrophioceras*? an indeterminable ammonite, described on p. 14 of this report was found (loc. 5, Fig. 1). The beds concerned belong to the lower part of the Archibald formation for which a Hettangian age is tentatively suggested.

1b. *Bed with Ammonite gen. et sp. indet. 1.* This indeterminable ammonite, described on p. 13 was found loose but the rock is the same as that of a nearby outcrop (loc. 13, Fig. 1). The beds concerned are, according to Little, about 1,500 feet stratigraphically below the bed with *Arniotites kwakiutlanus* and belong to the lower part of the Archibald formation. It is possible that this bed, which is the lowest one so far known in the Archibald formation, is also of Hettangian age, but better material must be found before a definite statement can be made.

The Age of the Elise Formation

The volcanic rocks of the Elise formation are in the Hall-Porto Rico area, north of Salmo, underlain by the Ymir group and overlain by the Hall formation. The marine beds with *Harpoceras* cf. *H. exaratum* in this area, which are immediately on top of the volcanic rocks, are placed in the upper Elise formation. As the *Harpoceras* beds belong to the lower Toarcian, the upper boundary of the Elise formation in this area is early Toarcian in age. As the underlying Ymir group has not yielded any index fossils, the age of the lower boundary of the Elise formation cannot be determined with absolute confidence in the Hall-Porto Rico area. In the Salmo area on the other hand the age of both the overlying and underlying rocks is known at several localities. The rocks of the Elise formation in this area, which had previously been described mainly as Beaver Mountain formation (*see* section "Description of Formations"), lie at some localities between the lower Sinemurian upper part of the Archibald formation and the lower part of the Hall formation which is of early Toarcian age. At one locality, i.e. on the ridge northeast of Parks station, a marine lower Sinemurian coquina bed (*see* fossil bed 3b) is present in the lower part of the Elise formation. The lower boundary of the Elise formation lies therefore locally within the lower Sinemurian, but it may be slightly younger at other localities. The age of the bulk of the Elise volcanic rocks is accordingly Sinemurian, Pliensbachian, or earliest Toarcian. In which of these times the main volcanic activity took place cannot be stated. Locally, for instance in Kelly Creek, the upper boundary of the Elise formation is younger than Toarcian as the overlying shales contain ammonites probably younger than middle Bajocian.

Some of the Canadian equivalents of the Elise formation are parts of the Bonanza group and other volcanic and sedimentary rocks on the west coast of Vancouver Island described by Jeletzky (1954, p. 1270), and marine deposits in various parts of Western and Arctic Canada (*see* Table II).

Conclusions

The increase in number of marine fossil beds found since the publication of previous studies (Frebold, 1959) indicates that the marine Jurassic rocks of the Salmo area may contain still more fossiliferous horizons than those known so far. There is hope that the presence of Hettangian beds can be fully proved in the future when better preserved fossils are available. Fossils of late Sinemurian, Pliensbachian, and earliest Toarcian age can hardly be expected to be found in this area, as during these times major volcanic activity took place. The possibility of finding more Toarcian and Bajocian zone fossils is strongly indicated. One major problem is the age of the end of the marine Jurassic deposition. *Perisphinctes*? sensu lato sp. indet. (fossil bed 8) and the thick volcanic rocks and sediments above this bed indicate that horizons younger than middle Bajocian are present. The accurate age determination of the marine beds of the upper Rossland group would be of great importance.

Notes on the Jurassic History of the Salmo Area

The Jurassic history of the area was outlined in a recent report (Frebold, 1959, pp. 15-17) to which the reader is referred. The area was then characterized as an eugeosynclinal zone covered by the sea in various Jurassic times. The present report indicates that the sea cover was more continuous than could be proved earlier. In addition to the transgressions in the early Sinemurian, early Toarcian, and part of the Bajocian, inundations are now also indicated in Hettangian, other Toarcian and Bajocian times. The youngest marine bed known to date is that containing *Perisphinctes*? sensu lato, which was deposited in an indeterminate post-middle Bajocian time. It is still not known when the marine Jurassic sedimentation reached its end but it is obvious that during much of the Jurassic the area was not part of a land mass as had been thought in the past.

During part of the Early Jurassic strong volcanic activity took place and the rocks of the Elise formation were formed. From the correlation tables it can be seen that it began somewhat earlier and ceased somewhat later in some parts of the Salmo-Hall area than in others. The main volcanic activity took place in a time between the early Sinemurian and the early Toarcian. At present it is impossible to say whether the volcanic activity was continuous throughout the whole time involved or was limited to certain times, as for instance the Pliensbachian. It is an interesting fact that considerable volcanic activity took place at about the same time in other parts of British Columbia, as for instance in Vancouver Island (*see* Jeletzky, 1954, p. 1270) and apparently also in the Harrison Lake area (unpublished observations by the author).

FOSSIL LOCALITIES

(Description of lithology by Little;
fossil and age determinations by Frebold.
Fossils with an asterisk are not described in this report.)

See Figure 1, p. X

1. Bell Creek road, 1.5 miles from highway 3A, elev. 3,000 feet. Archibald formation.
   GSC loc. 38947. *Arniotites* cf. *A. kwakiutlanus* Crickmay, Sinemurian.

   Lithology: Hard, black, laminated siltstone, somewhat contorted but in general dipping steeply southeast. This rock is exposed almost continuously for about 200 feet along the road northwest of the fossil locality. To the southeast of the locality about 100 feet of the siltstone is exposed, followed successively by 30 to 50 feet of arenaceous argillite separated from the siltstone by a gap of about 50 feet. Another 50 feet of arenaceous argillite is exposed 40 feet farther southeast, succeeded by 50 to 60 feet of faintly laminated siltstone in fault contact with massive andesitic lava and agglomerate that contain fragments of crystalline limestone.

2. Upper Bell Creek road, 0.10 mile before last switchback, elev. 4,650 feet. Archibald formation.
   GSC loc. 38960. *Arniotites* cf. *A. kwakiutlanus* Crickmay, Sinemurian.

   Lithology: Hard, black, laminated siltstone, dipping about 60°S, is exposed almost continuously, roughly along the strike, for 200 feet easterly and more than 500 feet westerly to locality 3. From this point the beds are exposed several hundred feet southward across the strike, and there they have a flatter dip. The beds are therefore several hundred feet thick and are overlain near the head of Bell Creek successively by agglomerate and massive flows of the Elise formation. A few dykes, sills, or thin flows are poorly exposed below the contact with the Elise.

3. Bell Creek road, highest switchback, elev. 4,750 feet. Archibald formation.
   GSC loc. 38955. *Belemnites sp. indet., Sinemurian.

   Lithology: See description of locality 2.

4. Road-cut in highway, 0.6 mile west of Query Creek culvert.
   GSC loc. 38946. Indeterminable pelecypods. Age unknown.

   Lithology: Thin-bedded, black, shaly argillite, dipping 70°W at the fossil locality, decreasing to 55°W 300 feet east where it rests on massive, fine-grained andesitic flow breccia. About 300 feet of these beds are exposed almost continuously.

5. Query Creek road, 0.7 mile from highway 3A. Archibald formation.

   GSC loc. 39281. *Gyrophioceras*? sp. indet., Hettangian?

   Lithology: Rusty weathering, black, slaty argillite, 30 to 40 feet thick, succeeded to the west by 6 or 7 feet of coarser, tuffaceous quartzite.

6. Query Creek road, 0.8 mile from highway 3A. Archibald formation.

   GSC loc. 38927. Ammonites gen. et sp. indet. 2, Hettangian?

   Lithology: Thin-bedded, hard, black, siltstone about 40 feet thick and dipping vertically is exposed across the strike. From this point the road turns south nearly parallel with the strike and for 400 feet outcrops of arenaceous argillite and argillaceous quartzite, locally well bedded, are exposed intermittently.

7. Query Creek road, 0.9 mile from highway 3A. Archibald formation.

   GSC locs. 38934, 38953. *Arniotites kwakiutlanus* Crickmay, Sinemurian.

   Lithology: A gap that could conceal perhaps 40 feet of beds, or a fault, separates the rocks at this locality from those described above. The fossils occur in black, thin-bedded, arenaceous shale. Northward, the rocks are exposed along the road for several hundred feet, but as the road nearly parallels the strike of the beds, only roughly 40 feet of beds are represented. These become more argillaceous southward. To the north, more than 50 feet of argillaceous quartzite and argillite are exposed intermittently, succeeded by about 20 feet of agglomerate that may represent the basal part of the Elise formation.

8. Top of ridge west of Archibald Creek. 0.6 mile southwest of northeast end of ridge, elev. 5,300 feet. Lower part of Elise formation.

   GSC loc. 38945. *Pelecypods indet., Sinemurian?

   Lithology: Fine-grained, argillaceous quartzite, dipping 35°SW, intercalated with lava and some pyroclastic rocks and a few thin beds of greywacke, is poorly exposed, but is estimated to be roughly 200 feet thick. This appears to be at or near the horizon of the coquina north of Parks (*see* Frebold, 1959, p. 4).

9. 0.1 mile east of northeast end of ridge west of Archibald Creek, elev. 4,750 feet. Float from Archibald formation.

   GSC loc. 38944. *Arniotites kwakiutlanus* Crickmay, Sinemurian.

   Lithology: Black, thin-bedded, slaty quartzite, about 50 feet thick, lies directly below basal massive lava of the Elise formation. Below these beds is fine-grained andesite, probably a sill at least 50 feet thick, that rests upon a thick assemblage of black, grey weathering laminated siltstone. The ammonite is in float that appears to be nearly in place.

10. Ridge, approx. 0.8 mile due west of Archibald Creek and 0.8 mile from highway 3A, elevs. 3,850-3,775 feet. Archibald formation.

    GSC loc. 38952. *Arniotites kwakiutlanus* Crickmay, Sinemurian.

    Lithology: Laminated, massive siltstone, dipping 60°W, and nearby is interbedded porphyritic hornblende andesite. Some of the beds are tuffaceous. The contact with the Elise formation is probably a short distance west.

11. West slope on ridge 3,000 feet due east of Archibald Creek and 1.7 miles due south of highway 3A, elevs. 4,350-4,650 feet. Archibald formation.

    GSC locs. 38933, 38956. *Arniotites kwakiutlanus* Crickmay, Sinemurian.

    Lithology: Hard, black, grey weathering, laminated siltstone exposed across several hundred feet, becoming rusty weathering to the east. Near the contact with the Elise formation to the west a band of coarse agglomerate is intercalated.

12. On top of ridge between Archibald and Divide Creeks. Between elevs. 4,825 and 4,775 feet, approximately 4,000 feet east of Archibald Creek and 1.5 miles due south of highway 3A. Archibald formation.

    GSC locs. 38930, 38931, 38949. *Arniotites kwakiutlanus* Crickmay, Sinemurian.

    Lithology: Black, laminated, slaty argillite and siltstone, locally rusty weathering, with some interbedded, fine-grained, tuff and andesite lava.

13. 0.7 mile east of northeast end of ridge west of Archibald Creek, elev. 3,700 feet. Archibald formation, float.
    GSC loc. 39283. Ammonites gen. et sp. indet. 1, Hettangian?

    Lithology: Dark grey, light grey weathering, laminated, locally tuffaceous, siltstone, well exposed across a thickness of several hundred feet.

14. Benton Creek road, 1 mile north of highway 3A, elev. 3,000 feet.

    GSC loc. 38948. *Ammonite fragment, indet. Sinemurian.

    Lithology: Mainly black, laminated, hard siltstone with some interbedded quartzite and arenaceous slate. An estimated thickness of 200 feet of beds is exposed along the road.

15. Arlington mine. Road-cut on old mine road above administration building. Lower part of Hall formation.

    GSC loc. 38918. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology of Nos. 15-23: The rocks exposed in the vicinity of Arlington mine comprise mainly thin-bedded, soft, black shales with some interbedded massive, black argillite and argillaceous quartzites, all these rocks being poorly exposed. A thin bed of black limestone was also noted. The beds in general dip gently eastward but locally dip steeply.
    Rock exposed on dumps of the lower and upper adits is for the most part hard, black, thinly laminated, arenaceous or feldspathic argillite. It contains numerous small fractures that are nearly at right angles to the bedding and are filled with pyrite. In the rock on the upper dump some of the laminae as well as the cross-fractures are pyritized.

16. Same locality, but 10 feet above GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38914. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology: See No. 15.

17. Same locality, but 15 feet above GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38915. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology: See No. 15.

18. Same locality, but 20 feet above GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38924. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology: See No. 15.

19. Same locality, but 6 to 10 feet below GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38916. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology: See No. 15.

20. Same locality, but 10 to 14 feet below GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38912. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology: See No. 15.

21. Arlington mine, old mine road, a few hundred yards northwest of GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38932. *Harpoceras* cf. *H. exaratum* Young and Bird, lower Toarcian.

    Lithology: See No. 15.

22. Arlington mine, lower dump, immediately above GSC loc. 38918. Lower part of Hall formation.

    GSC loc. 38910. *Dactylioceras* sp. indet., lower Toarcian; indeterminable Hildoceraceae, Toarcian or Bajocian.

    Lithology: See No. 15.

23. Arlington mine, upper dump, immediately above GSC loc. 38910. Lower part of Hall formation.

    GSC loc. 38911. Indeterminable Hildoceraceae, Toarcian or Bajocian.

    Lithology: See No. 15.

24. At junction of road from north with Keystone road, 0.1 mile from Keystone buildings, elev. 4,525 feet. Lower part of Hall formation.

    GSC locs. 38909, 38921, 38923. *Harpoceras* cf. *H. exaratum* Young and Bird, *Dactylioceras* sp., lower Toarcian.

    Lithology: Twenty feet of soft, black shale and grey phyllite dipping 45°SW, are poorly exposed in the road-cut. About 10 feet above the fossiliferous bed is 5 feet of fractured grey phyllite. About 20 feet higher is 18 inches of hard, coarse-grained tuff.

    To the northwest of the fossiliferous bed widely spaced outcrops of, successively, massive argillite, thin-bedded black shale, and grey phyllite are exposed.

25. Second Chance mine, loose on mine dump. Lower part of Hall formation.

    GSC loc. 39282. *Harpoceras* sp. indet., lower Toarcian.

    Lithology: The rocks at the Second Chance property comprise soft, black shales with minor argillite and phyllite. Overlying these beds is a flow breccia 15 to 20 feet thick which is similar to that exposed above the Arlington workings.

26. Northwest slope of Keystone Mountain, 0.5 mile west-northwest of summit, elev. 5,150 feet. Hall formation. *Ammonite fragment, indet. Discarded.

    Lithology: A few small outcrops of faintly laminated, hard, feldspathic argillite and rusty weathering hornfels that dip 45°E. To the northwest no outcrops occur but slate and phyllite float is abundant. About 100 feet southeast of the locality large outcrops of unlaminated black siltstone and hornfels that cap Keystone Mountain are exposed.

27. Hellroaring Creek road, 0.1 mile before crossing first tributary from west, elev. 2,900 feet. Lower part of Hall formation.

    GSC loc. 38941. Ammonites (*Dactylioceras*?) sp. indet., Toarcian?

    Lithology: Hard, black, slaty argillite that splits into large slabs, dipping 80°SE. Immediately northeast is a small gully that probably contains a fault, beyond which is a big outcrop of black shale and phyllite that is somewhat contorted. To the southwest intermittent outcrops of argillite and light grey phyllite are exposed for 500 or 600 feet along the road to a bridge on a tributary of Hellroaring Creek.

28. Fifty feet north of switchback on Kelly Creek road. 3.6 miles above old mill, elev. 4,350 feet. Hall formation.

GSC loc. 38942. *Perisphinctes*? sensu lato, younger than middle Bajocian.

Lithology: Massive, black argillite and some shale, dipping 15°SW, are exposed across a thickness of about 30 feet. Along the road to the southeast intermittent outcrops of similar argillite are exposed for some distance. To the southwest, along the lower road, for some hundreds of feet from the fossil locality outcrops of fine-grained, greenish grey tuff are exposed, succeeded by 20 or 30 feet of grey, micaceous phyllite and hard, black argillite containing numerous small plant fragments. Two unidentifiable ammonite fragments were found in the phyllite.

REFERENCES

Arkell, J. W.

1957: Treatise on Invertebrate Paleontology, Part L, Mollusca 4, Cephalopoda, Ammonoidea; *Geol. Soc. Amer.* and *Univ. Kansas Press.*

Crickmay, C. H.

1928: Stratigraphy of Parson Bay, British Columbia; *Univ. Calif. Publ., Bull. Dept. Geol. Sci.*, vol. 18, pp. 51-70.

Donovan, D. T.

1954: Synoptic Supplement to T. Wright's "Monograph on the Lias Ammonites of the British Islands" (1878-86); *Palaeont. Soc., London.*

Dumortier, E.

1864-1874: Études paléontologiques sur les Dépots Jurassiques du Bassin du Rhone; Paris.

Frebold, H.

1957: The Jurassic Fernie Group in the Canadian Rocky Mountains and Foothills; *Geol. Surv., Canada,* Mem. 287.

1958: Fauna, Age and Correlation of the Jurassic Rocks of Prince Patrick Island; *Geol. Surv., Canada,* Bull. 41.

1959: Marine Jurassic Rocks in Nelson and Salmo Areas, Southern British Columbia; *Geol. Surv., Canada,* Bull. 49.

1960: The Jurassic Faunas of the Canadian Arctic. Lower Jurassic and Lowermost Middle Jurassic Ammonites; *Geol. Surv., Canada,* Bull. 59.

Fyles, J. T., and Hewlett, C. G.

1959: Stratigraphy and Structure of the Salmo Lead-Zinc Area; *B.C. Dept. Mines,* Bull. 41.

Imlay, R. W.

1955: Characteristic Jurassic Mollusks from Northern Alaska; *U.S. Geol. Surv.,* Prof. Paper 274-D.

Jeletzky, J. A.

1954: Geological History of West Coast of Vancouver Island and Quatsino Sound; *Geol. Soc. Amer.,* vol. 65, No. 12 (2), pp. 1269-1270.

Little, H. W.

1949: Preliminary map, Nelson (West Half), British Columbia; *Geol. Surv., Canada,* Paper 49-22.

1950: Salmo Map-area, British Columbia; *Geol. Surv., Canada,* Paper 50-19.

1956: Nelson (West Half) Kootenay and Similkameen Districts, British Columbia; *Geol. Surv., Canada,* Map 3-1956.

1960: Nelson Map-area (West Half), British Columbia; *Geol. Surv., Canada,* Mem. 308.

McAllister, A. L.

1951: Ymir Map-area, British Columbia; *Geol. Surv., Canada,* Paper 51-4.

McLearn, F. H.

1926: New Species from the Hazelton Group of British Columbia; *Geol. Surv., Canada,* Bull. 44.

1932: Contributions to the Stratigraphy and Palaeontology of Skidegate Inlet, Queen Charlotte Islands, B.C.; *Trans. Roy. Soc. Can.,* ser. 3, vol. 26, sec. 4.

1949: Jurassic Formations of Maude Island and Alliford Bay, Skidegate Inlet, Queen Charlotte Islands, British Columbia; *Geol. Surv., Canada,* Bull. 12.

Mulligan, R.

1951: The Geology of the Nelson (Bonnington) and adjoining part of Salmo Map-areas, British Columbia; McGill University, Ph.D. thesis (unpub. ms.).

1952: Bonnington Map-area, British Columbia; *Geol. Surv., Canada,* Paper 52-13.

Quenstedt, F. A.

1883-1885: Die Ammoniten des Schwäbischen Jura, Vol. 1 Der schwarze Jura (Lias); Stuttgart.

Tate R., and Blake, J. F.

1876: The Yorkshire Lias; London.

Wright, T.

1878-1886: Monograph on the Lias Ammonites of the British Islands; *Palaeont. Soc., London.*

Young, G., and Bird, J.

1882: A Geological Survey of the Yorkshire Coast; Whitby.

PLATES I to V

Types in collections of the Geological Survey of Canada.

All figures natural size.

PLATE I

Arniotites kwakiutlanus Crickmay (Page 15)

Figure 1. Lateral view and part of venter. GSC 15270. GSC loc. 28929.
Figure 2. Lateral view and suture line. GSC 15271. GSC loc. 39934.
Figure 3. Lateral view. GSC 15273. GSC loc. 38953.
Figure 4. Lateral view. GSC 15278. GSC loc. 38934.
Figure 5. Lateral view. GSC 15277. GSC loc. 38934.
Figure 6. Lateral view. GSC 15275. GSC loc. 38924.
Figure 7. Lateral view and keel. GSC 14271. GSC loc. 38934.
Figure 8. Lateral view. GSC 15272. GSC loc. 38949.
Figure 9. Lateral view. GSC 15276. GSC loc. 38953.
Figure 10. Lateral view. GSC 15279. GSC loc. 38953.

Ammonite gen. et sp. indet. 1 (Page 13)

Figure 11. Lateral view. GSC 15267. GSC loc. 39283.

Gyrophioceras? sp. indet. (Page 14)

Figure 12. Lateral view. GSC 15269. GSC loc. 39281.

Ammonite gen. et sp. indet. 2 (Page 14)

Figure 13. Lateral view. GSC 15268. GSC loc. 38927.

Plate I

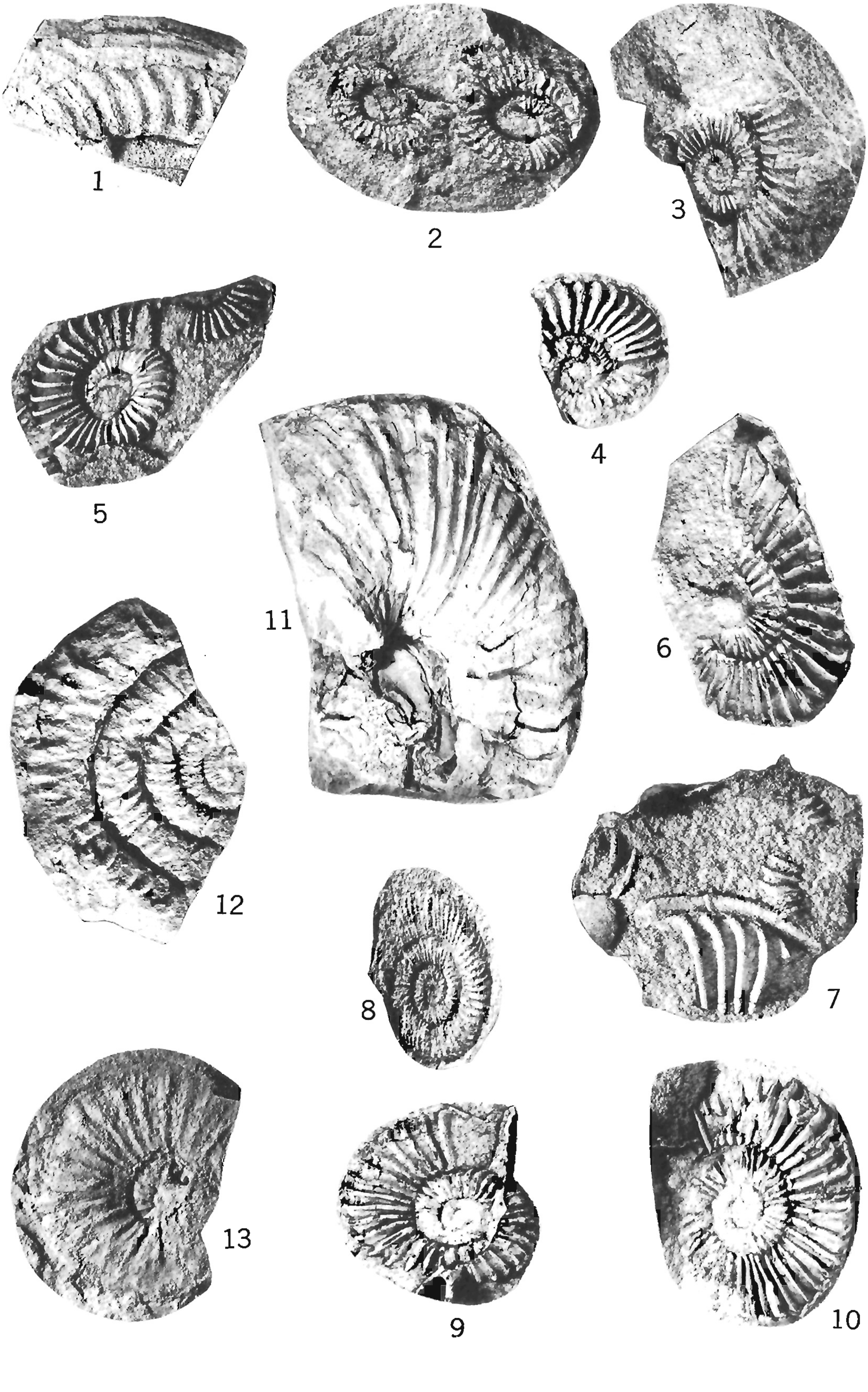


Plate II

Harpoceras cf. *H. exaratum* Young and Bird (Page 17)

Figure 1. Lateral view. GSC 15291. GSC loc. 38932.

Figure 2. Lateral views of young specimens. GSC 15297. GSC loc. 38918.

Figure 3. Lateral view. GSC 15292. GSC loc. 36219

Figure 4. Rubber cast. Lateral view. GSC 15296. GSC loc. 38932.

Figure 5. Rubber cast. Lateral view. GSC 15295. GSC loc. 38932.

With part of aptychus

Figure 6. Rubber cast. Lateral view. GSC 15294. GSC loc. 38918.

Aptychus, associated with *Harpoceras* cf. *H. exaratum*

Figure 7. GSC 15299. GSC loc. 38918.

Figure 8. GSC 15300. GSC loc. 36219.

Figure 9. Lateral view. GSC 15298. GSC loc. 38918.

Plate II

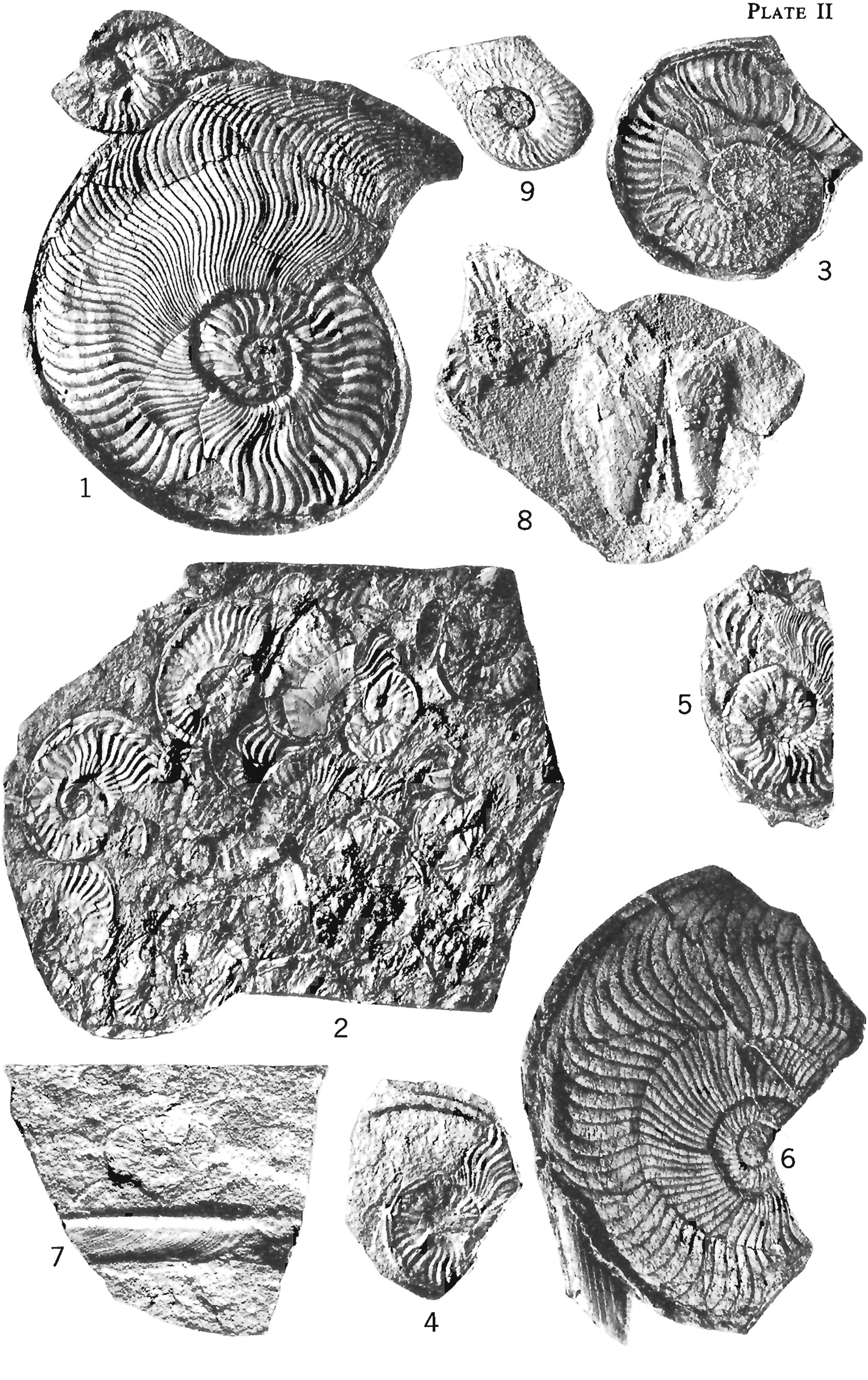


Plate III

Hildoceraceae gen. et sp. indet. (Page 18)

Figure 1. Lateral view. GSC 15302. GSC loc. 38917.

Figure 2. Lateral view. GSC 15303. GSC loc. 38910.

Figure 3. Lateral view. GSC 15304. GSC loc. 36255.

Figure 4. Lateral view. GSC 15301. GSC loc. 38917.

Harpoceras cf. *H. exaratum* Young and Bird (Page 17)

Figure 5. Lateral view of large specimen. GSC 15293. GSC loc. 38918.

Dactylioceras sp. indet. (Page 19)

Figure 6. Lateral view. GSC 15285. GSC loc. 38920.

Figure 7. Lateral view. GSC 15286. GSC loc. 38919.

PLATE III

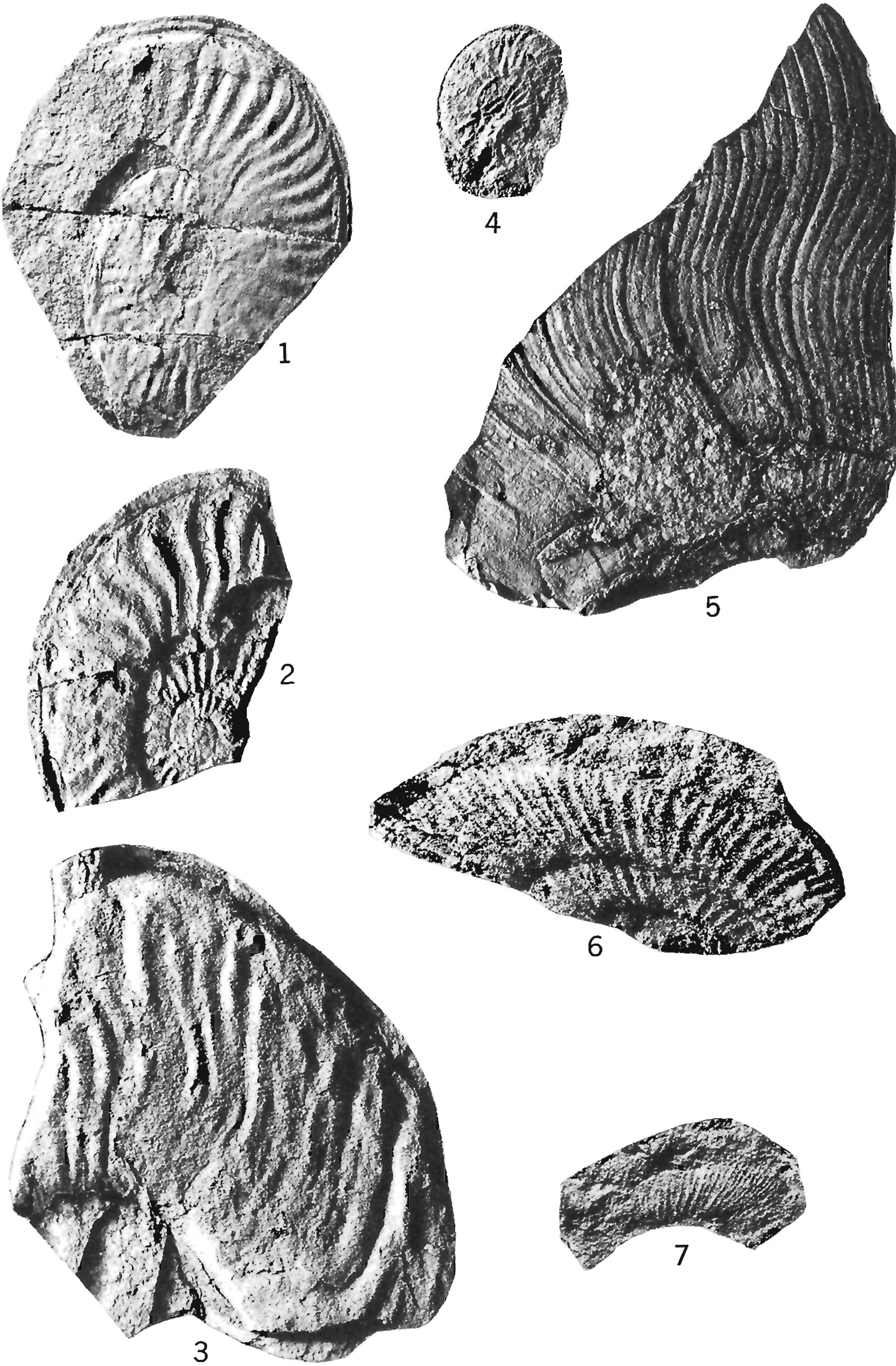


PLATE IV

Perisphinctes (?) sensu lato sp. indet. (Page 19)

Figure 1. Rubber cast. Lateral view. GSC 15281. GSC loc. 38942.

Figure 2. Lateral view. GSC 15283. GSC loc. 38937.

Figure 3. Lateral view. GSC 15281. GSC loc. 38942.

Figure 4. Lateral view. Same specimen as figure 1. GSC 15284. GSC loc. 38942.

Figure 5. Lateral view. GSC 15282. GSC loc. 38913.

Dactylioceras sp. indet. (Page 19)

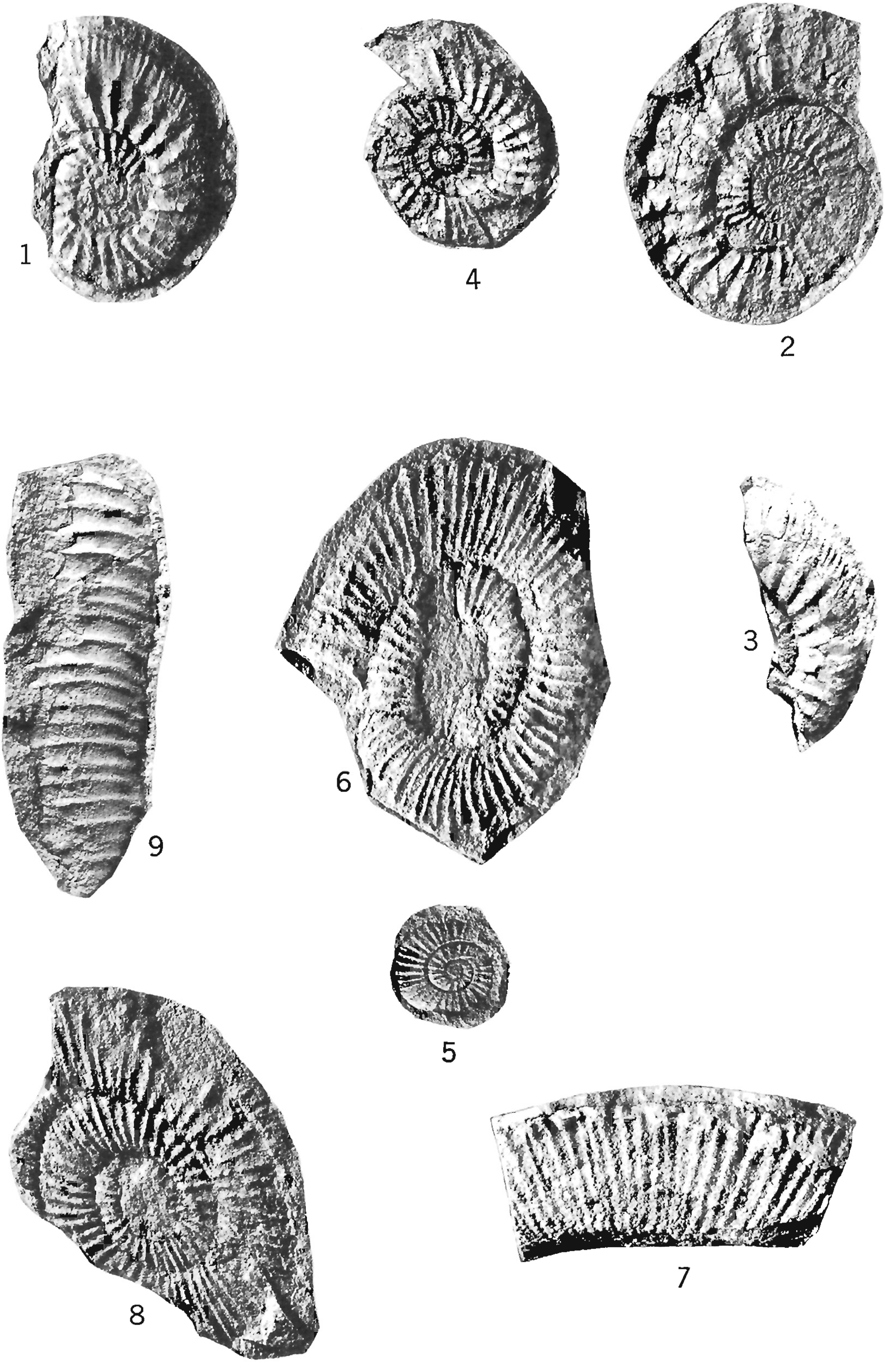
Figure 6. Lateral view. GSC 15288. GSC loc. 38910.

Figure 7. Lateral view. GSC 15287. GSC loc. 38910.

Figure 8. Lateral view. GSC 15289. GSC loc. 38910.

Figure 9. Ventral view. GSC 15290. GSC loc. 38910.

PLATE IV



Little, 1959-1-3

A. View south across Erie Lake towards Divide Creek. The mountains in the foreground consist of Archibald beds.

Plate V

B. Fossil locality on Kelly Creek road.

Frebold, 1959-1-2