

TRILOBITE ZONES IN THE MURRAY RANGE,
PINE PASS MAP-AREA,
BRITISH COLUMBIA

by

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ABSTRACT

Trilobites and other fossils from three measured sections in the Murray Range, Pine Pass map-area, British Columbia, are described and their zonal significance is discussed.

Zones represented by fossil assemblages are the Upper Olenellus subzone (uppermost Lower Cambrian), the Ogygopsis klotzi and Tonkinella stephensis subzones of the Bathyriscus-Elrathina zone (upper Middle Cambrian), the upper Conaspis zone and Ptychaspis subzone of the Ptychaspis-Prosaukia zone (Upper Cambrian, Franconian Stage), the Lower or Middle Saukia zone (Trempealeauan Stage), and Zones A, B and D of the Lower Ordovician (Canadian Series). The lower Middle Cambrian, Dresbachian and lower Franconian zones, and the Lower Ordovician Zone C, appear to be missing.

Early Cambrian assemblages show some affinities with faunas of the southern hemisphere (the archaeocyathid genera Sigmocyathus, Syringocnema and Monocyathus) and eastern Canada and the United States (species of Bonnia, Kootenia, Paedeumias and Eoptychoparia). However, these affinities become weaker in Middle Cambrian and later assemblages, and all the present collections are predominantly Cordilleran in character. They are considered representative of the intermediate extracratonic biofacies realm as defined by Lochman-Balk and Wilson (1958).

The sections provide a further example of the transition, well-known in other parts of the Canadian Cordillera, from Lower Cambrian argillaceous and arenaceous clastic rocks to more or less argillaceous limestone and dolomite of the Middle Cambrian and later Series. Throughout Cambrian and early Ordovician time the original area represented by the present sections was covered by miogeosynclinal seas which progressively encroached upon the craton. This marine transgression was interrupted at times, and the comparatively local uplift of the Peace River Arch was responsible for extreme reduction in thickness of the Middle and Upper Cambrian portions of the early Palaeozoic section.

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The Department of Geology, University of British Columbia, has been most generous with its space and facilities; the writer would particularly like to thank Dr. V.J. Okulitch, now Dean of the Faculty of Science, for his guidance in the study of Archaeocyatha, and Dr. R.V. Best for his constant accessibility, constructively critical supervision of the work, and long-suffering tolerance of the intruder upon his office-space.

Dr. Ellis Yochelson and Dr. A.R. Palmer of the United

States Geological Survey, Washington, D.C., confirmed the identification of Salterella and suggested the generic assignment of Lower Ordovician gastropods. Dr. Norford also identified two Upper Ordovician corals from dolomite overlying the measured section on Mount Hunter.

INTRODUCTION

This thesis presents the results of field work undertaken in 1961 while the writer was working in the McLeod Lake and Pine Pass map-areas, B.C., as Senior Assistant to Dr. J.E. Muller of the Geological Survey of Canada.

The purpose of the work was to obtain biostratigraphic information on Palaeozoic rocks that are exposed in several thrust plates in the Pine Pass area. Interest was centred on the Cambrian section, but a considerable thickness of Precambrian strata was measured in addition, partly because the lower limit of the Cambrian section was not precisely known. On Mount Hunter, also, many hundreds of feet of Ordovician beds were measured under the initial impression that they might have been of Cambrian age.

The writer's original intention was to examine Cambrian and Ordovician rocks at several localities, but lack of time, and adverse weather and flying conditions, confined his attention to the three sections discussed herein. Under the circumstances, a more ambitious study of regional biostratigraphy could not be attempted, and the broader topics of facies variations and changing depositional environments are only very briefly discussed here.

Although the fossil collections at first appeared to be meagre, there proved to be far more material for description

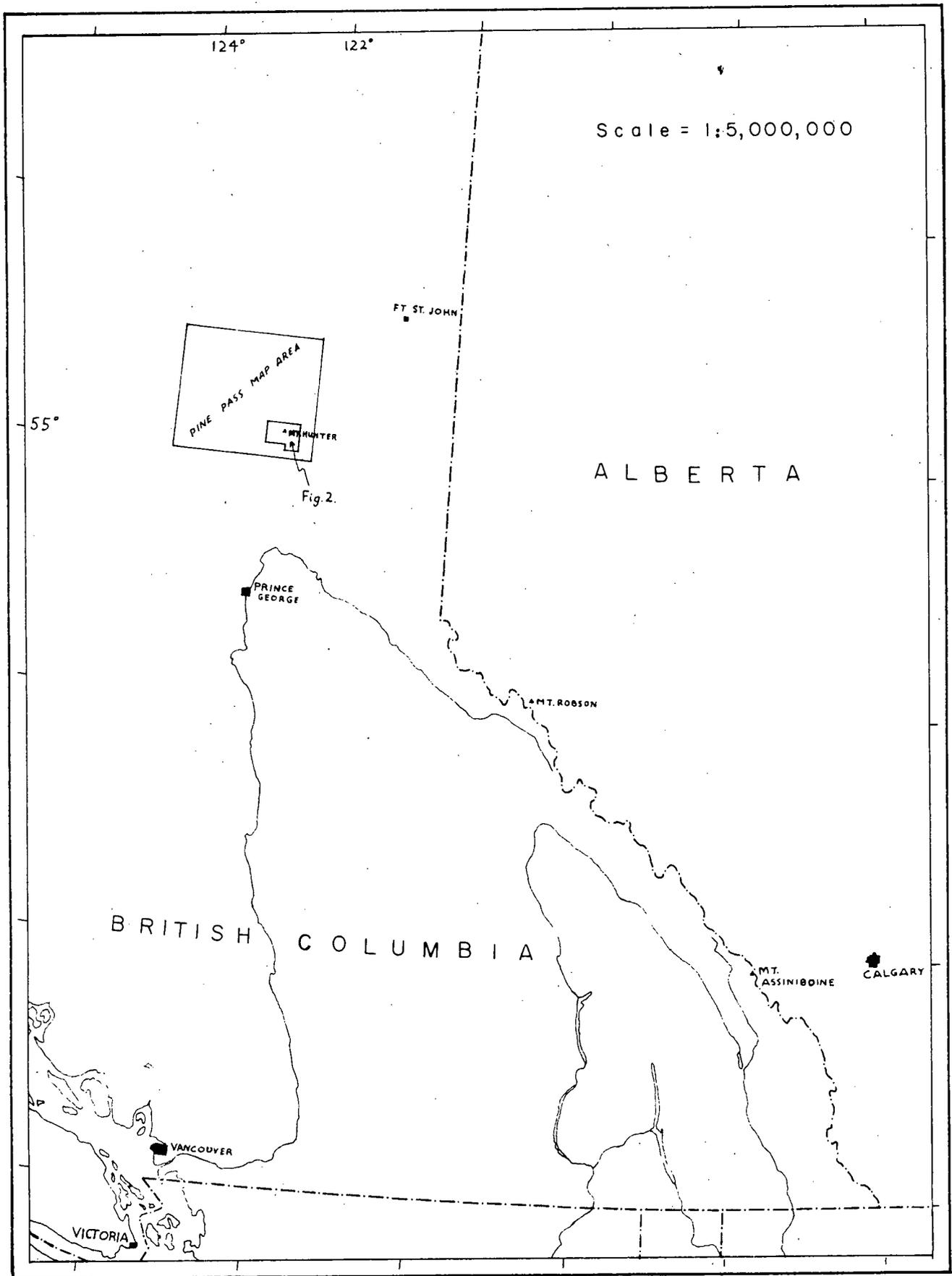


Fig. I. LOCATION OF MT. HUNTER AREA

than expected; description of fossils and discussion of their zonal significance are therefore considered to be the principal concern of the thesis. It proved similarly impractical, and beyond the writer's competence, to devote equal attention to all the phyla represented in the collections. Trilobites have received the most attention by reason of their value as zonal indicators, and Archaeocyatha have been described at some length because of their unusual interest. On the other hand, brachiopods and gastropods are generally too poorly preserved to warrant corresponding attention, and their study calls for the experience of a specialist.

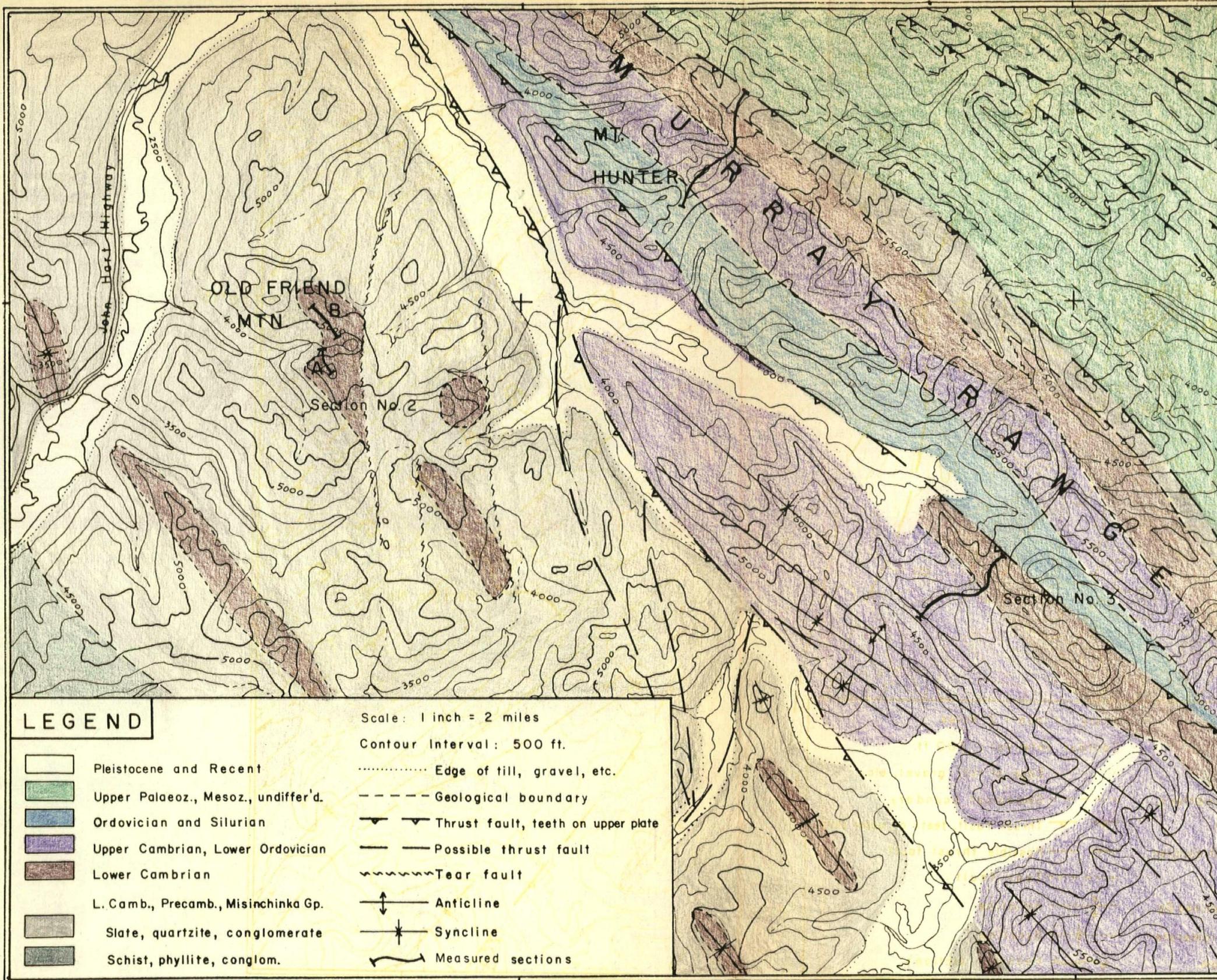
LOCATION AND ACCESS

The Pine Pass map-area lies between lat. 55° and 56° North, and long. 122° and 124° West; its centre is about 425 miles north of Vancouver. The Murray Range includes some of the highest peaks in the southeast corner of the map-area (Fig. 1), and flanks the headwaters of the Misinchinka River and the Pine River; the first big bend of the Pine River truncates the range abruptly to the northwest.

The John Hart Highway from Prince George to Dawson Creek is now paved, and passes within 4 miles of Old Friend Mountain (Section 2), 9 miles of Mount Hunter and 16 miles of Section 3 (Fig. 2). However, it is impractical to cross the Misinchinka

30'

122°15'



55°15'

Geology by J.E. Muller (unpublished revision of GSC Map II-1961)

Fig. 2. LOCATION OF SECTIONS; GEOLOGY

River on foot unless a detour of several miles is made to a Pacific Great Eastern railroad bridge; moreover, the lower valley slopes are thickly forested with white spruce, alpine fir, lodgepole pine and alder, and river and creek valleys are generally deeply incised. Horse travel is virtually impossible without extensive trail-cutting, and even the very hardy will find that walking is hampered by luxuriant growths of Oplopanax horridus, especially on northeast-facing slopes. The helicopter is the only recommended means of access from the highway, and clear landing-places are easy to find above the tree-line.

PREVIOUS WORK

The earliest geological expedition into any part of the Pine Pass map-area was led by Selwyn, who made an exploratory traverse along the Peace River to Finlay Forks in 1875; he was followed by Dawson who travelled from the Pacific coast to Edmonton in 1879 and 1880, observing en route the pale silvery mica schists that he named the Misinchinka schists (1881). Dolmage (1928) reported similar rocks on both sides of the Finlay River valley.

Selwyn had described massive quartzites, overlain by pink calcareous shales, on the prominent peak named after him by his companion, the botanist Macoun; Williams and Bockock (1932, p. 200) named this unit the Mount Selwyn Formation, and considered it

comparable with Cambrian quartzites in the southern Rocky Mountains. They observed similar quartzites in the Murray Range at the summit of Pine Pass.

McLearn and Kindle's (1950) compilation of the geology of northeastern British Columbia cites the work mentioned above, but follows Williams and Bocoock in attributing Devonian age to limestones that crop out on the west slopes of the Murray Range at Pine Pass. The present work demonstrates that these beds are of Late Cambrian and Early Ordovician age; they can easily be traced along strike to corresponding beds in the Mount Hunter section. The specimen of "Athyris" found by Dawson, upon which the suggested Devonian age is based, is very likely to have been an Ordovician clarkellid brachiopod similar to those collected by the writer (GSC localities 46416 and 46418).

In 1959 and 1960 Muller (1961) mapped the Pine Pass map-area, returning in 1961 for additional structural and stratigraphic information. He recognizes three units below the massive Lower Cambrian quartzites, the lowest of which is the mica schists observed by Selwyn and others, and suggests that they be jointly designated the Misinchinka Group. During the 1961 season Norford, in cooperation with Muller, measured Ordovician sections in several places in the map-area including the western ridge of Mount Hunter (in McCrossan and Glaister, 1964, p. 46, fig. 4-12), discovering in the course of this work unsuspected repetition of the upper part of the Ordovician section.

Irish (1963) mapped the adjacent Halfway River map-area, and (1964, p. 810 ff.) discusses the age of the rocks assigned to Williams and Bocoock's Mount Selwyn Formation. He concludes that they should be mapped as part of the Misinchinka Group, the upper parts of which may be of earliest Cambrian age.

At least two oil companies have mapped in the Peace River and Pine Pass areas, and Shell Oil Company has measured the Mount Hunter section (Muller, personal communication). Unfortunately their results are not available for discussion.

GENERAL GEOLOGY

The Rocky Mountains, exclusive of the foothills, are almost at their narrowest in the Pine Pass map-area; they are less than 20 miles wide at the Peace River, and about 24 miles wide at Mount Hunter, if their eastern limit be regarded as coinciding approximately with the most easterly high peaks formed by Palaeozoic rocks, or the most westerly peaks of similar elevation in Mesozoic rocks. The narrowest belt of Palaeozoic rocks in the map-area, about 22 miles northwest of Pine Pass itself, is only 13 miles wide. By contrast, in the Columbia Icefields area between Banff and Jasper the total width of the Western, Main and Front Ranges is at least 65 miles, and the Rockies are wider still, although less spectacular, near the headwaters of the Muskwa and Toad Rivers 150 miles north of the Peace River.

In the present area the distinction between Main and Front Ranges becomes somewhat blurred, although Muller (1961) distinguishes between the Rocky Mountains sensu stricto, and the Front Range in Upper Palaeozoic and Lower Mesozoic rocks immediately east of Callazon Creek. North (in McCrossan and Glaister, 1964, p. 31) defines the boundaries of the Main Range as the Rocky Mountain Trench on the west, and the traces of the Chetamon, Pyramid and Castle Mountain thrusts on the east. By this definition the Main Range extends no farther north than the Morkill Pass, at latitude 54° North; and in the Pine Pass area "structures more nearly of Front Range type begin at the Trench . . . (as) a consequence of the great reduction in thickness of the early Palaeozoic part of the section . . . "

The structural trend is northwest-southeast. The mountain belt is sharply delimited on the southwest side by the alluvium- and till-covered Rocky Mountain Trench, but gives way gradually to foothills and plains topography towards the northeast. For a fuller account of structures and rock-units within the map-area the reader is referred to GSC Map 11-1961 (Muller, 1961).

In the main ranges a series of west-dipping imbricate thrust faults has produced extreme crustal shortening in rocks of Precambrian to Silurian age (Middle Devonian rocks being involved only in the northern part of the map-area); the lower units of the Misinchinka Group have been particularly strongly deformed, and consist mainly of schist, phyllite and schistose grit, where-

as Upper Cambrian to Silurian rocks, although generally steeply-dipping, have undergone only mild shearing. Deformation varies with competence; in rocks of probable Precambrian age east of Mount Hunter, quartzose sandstone and quartzite members are interbedded with highly fissile slate.

A short distance east of Mount Murray and Mount Hunter, the Murray Range thrust brings Palaeozoic and Precambrian rocks over Middle Triassic shales (of Anisian age), which in turn overlies shales considered to be equivalent to the Upper Devonian and Mississippian Besa River Formation (Muller, personal communication). The latter name was proposed by Kidd (1962, p. 97) for rocks in the Muskwa River area near Fort Nelson, B.C., and is extended to the Pine Pass area on the evidence of Devonian plant fossils, the discovery of which has entailed revision of GSC Map 11-1961.

The pattern of imbricate thrust faulting persists for a short distance east of the Murray Range, and has been interpreted by Muller as a series of secondary thrusts in a major overthrust sheet of moderately folded Mesozoic rocks. Folding becomes progressively gentler and more open further east, and tends to die out in the virtually flat-lying rocks of the Mesa Hills and the Interior Plains of the Peace River block.

DISCUSSION OF FAUNAL ZONES

Lower Cambrian

Lower Cambrian fossils were collected from three localities within a stratigraphic interval of 125' in Section 3, and from two localities approximately 900' apart in Section 2A-2B. The two sections have no faunal assemblages in common, and correlation is possible only within rather broad limits.

The lowermost locality in Section 3 (GSC 46427) yields only Salterella pulchella; the genus is not uncommon in western North America, but this species has previously been found only in the Quebec conglomerates at Lévis, in the Parker slate of Vermont, and in New York State. Handfield (1965, pp. 18, 19) reports Salterella rugosa in two sections in the Mackenzie Mountains. In one, they occur stratigraphically below Bonnia sp. and two species of antagminid trilobites and above three species of Olenellidae, and in the other, below Olenellidae and Bonnia sp. and above rocks containing six species of Archaeocyatha. The Wulff River Formation of northwest Greenland contains S. expansa (Poulsen, 1958, p. 10) associated with species of Wanneria, Holmia, Paedeumias and Olenellus. According to Poulsen, the Wulff River Formation is "a probable stratigraphic equivalent of the Ella Formation" (uppermost Lower Cambrian) of East Greenland (ibid, p. 7). Specific differences in Salterella do not appear to have much stratigraphic significance.

The second locality, GSC 46428, is approximately 75' higher in Section 3. Eoptychoparia sp., and two species of Bonnia thought to be identical with eastern forms, place the locality in the Bonnia-Olenellus zone, but do not help to define its position more closely. Paterina sp. is similarly of little value for zonal refinement; it is found in some of the earliest Lower Cambrian localities (for example, the Addy Quartzite of north-eastern Washington; Okulitch, 1951, p. 405) and ranges into the Middle Cambrian (e.g. the Mount Whyte Formation; Rasetti, 1951, p. 110). Ogygopsis aff. O. batis and Zacanthopsis contractus are associated with species of Bonnia, Wanneria, Paedeumias, Olenoides and Syspacephalus in the Saline Valley Formation of southwest Nevada; although they are found well below beds containing other olenellids (Bristolia), they cannot be said to indicate a particularly old part of the Bonnia-Olenellus zone. Piaziella (Piaziella pia) is known as a member of the Bonnia fieldensis faunule in the Peyto Limestone member of the Mount Whyte Formation, but its range extends into the lower Middle Cambrian; although this is the youngest Early Cambrian fauna occurring in the Field, B.C., area, its precise zonal position is not definitely established (Rasetti, 1951, p. 83). Olenellus gilberti, first described from the Pioche Shale of Nevada, is one of the latest Olenellidae, and occurs in great abundance in the Peyto Limestone (Best, oral communication). Acrotreta sp. is found more commonly in Middle or Upper Cambrian than in Lower Cambrian rocks. Wenkchemnia sulcata occurs in three of the four faunules of Rasetti's Wenkchemnia-Stephenaspis zone on Mount

Whyte and Mount Stephen; its presence in a Lower Cambrian assemblage therefore tends to confirm the relatively late Early Cambrian age suggested by the previous three species mentioned.

Evidence of the later Early Cambrian age of the assemblage at GSC 46429 is supplied by Paedeumias transitans, Wanneria sp., and two species of Kootenia that are indistinguishable from forms occurring in the Lower Parker Slate of Vermont and the Middle Cambrian Rutledge Formation of Alabama. As in GSC 46428, Wenkchemnia sulcata suggests a later Early Cambrian age. The assemblage also contains species of Bonnia similar to those found in conglomerates in Quebec, and Obolella sp., but none of these is of much value for refined zonation. Ogygopsis aff. O. batis and Eoptychoparia sp. are common to GSC 46428 and 46429.

It is evident that the assemblages at GSC localities 46428 and 46429 are part of a Bonnia-Olenellus zone fauna, but it is impossible to make any meaningful distinction between the ages of the two collections other than the obvious conclusions from the fact of superposition (they are barely 20' apart in the section). The presence of opisthoparian trilobites clearly puts both assemblages in the Upper Olenellus subzone as understood by Lochman-Balk and Wilson (1958) and Lochman (1956b), and the Antagmus-Onchocephalus zone as defined by Lochman (1947) and enlarged in subsequent published accounts (cf. Shaw, 1954, p. 1045 on Lochman's proposal of the term). The term "Syspacephalus zone", proposed by Howell et al. (the Cambrian Subcommittee) to designate a zone with opisthoparian trilobites but without olenellids,

and the equivalent Kochiella zone of Resser and Howell (1938), are now in disuse; Lochman's Antagmus-Onchocephalus zone was never intended to be their equivalent, and in the Canadian Cordillera Rasetti (1951, p. 81) does not recognize a post-Olenellus Lower Cambrian zone. However, the upper faunule of the Elliptocephala asaphoides fauna in New York State is considered to be somewhat older than the youngest Lower Cambrian fauna in Europe, that of the Protolenus zone (Lochman, 1956b). Kootenia marcoui, found in GSC 46429, and Acrotreta sp., in GSC 46428 and 46429, occur in the upper faunule of the E. asaphoides fauna; Salterella pulchella is definitely part of the lower faunule, but only questionably in the upper faunule.

Thus GSC locality⁴⁶⁴²⁷ may reasonably be assigned to the lower part of the Upper Olenellus subzone, but the other two localities belong without much doubt to the upper part of that subzone. The term "Bonnia-Olenellus zone" was first used by Deiss (1939b, p. 999) with reference to the lowest 26' of the Mount Whyte Formation on Ptarmigan Peak, a limestone member containing Bonnia, Olenellus, Antagmus, Onchocephalus and Syspacephalus, which appears to be the unit designated by Rasetti (1951, p. 55) as the Peyto Limestone member of the St. Piran Formation. In most places the Peyto member is lithologically distinct from the St. Piran Formation, and is more logically associated with the overlying carbonate rocks, from which it can generally be distinguished only on faunal grounds. As North remarks (in McCrossan and Glais-ter, 1964, p. 31) ". . . for gross mapping purposes it is still

part of the Mount Whyte Formation (the rest of which is Middle Cambrian) and not part of the Gog Group". Rasetti warns that the term "Bonnia-Olenellus zone" may not be recognized as generally applicable even within the Cordilleran province, but he uses it on the grounds that Bonnia and Olenellidae are the most common fossils in the Peyto Limestone.

The age of the Archaeocyatha collected at two localities in Section 2A-2B is discussed in more detail immediately following their systematic description.

Archaeocyatha at the lower horizon are regarded as younger than the Colville archaeocyathid fauna; although this, in turn, is thought to be the oldest such fauna in western North America, there is no evidence that it is older than the Upper Olenellus subzone. Both archaeocyathid horizons, therefore, can probably be assigned to the Upper Olenellus subzone; the upper collection may be of roughly the same age as the Early Cambrian trilobite faunas of Section 3, but the lower collection may be younger than the Salterella pulchella at GSC locality 46427. However, this is mere speculation, as there is no proof that S. pulchella is particularly characteristic of any restricted portion of the Upper Olenellus subzone.

Middle Cambrian

Almost 400' of section separates the late Lower Cambrian

GSC 46431

Alokistocarids, indet.
?Bathyriscus sp.
Chancia evax
Dictyonina pannula
Kootenia burgessensis
Pachyaspis isabella
P. typica
Pagetia cf. P. bootes
P. cf. P. ellsi
Wenkchemnia sp.

Alokistocarella fieldensis
faunule

Alokistocarella fieldensis
Bathyriscus rotundatus
Iphidella cf. I. fieldensis
Kootenia burgessensis
Pagetia bootes

Pagetia bootes faunule

Chancia palliseri
Iphidella pulchra
Kootenia burgessensis
Pagetia bootes

Tonkinella stephensis faunule

Alokistocare sinuatus
Bathyriscus adaeus
Chancia odarayensis
Pachyaspis attenuata
Pagetia cf. P. bootes
Zacanthoides spp.

GSC 46430

Chancia evax
?Elrathiella sp.
?Elrathina sp.
Kootenia exilaxata
Ogygopsis, 2 new spp.
Olenoides maladensis
O. serratus

Ogygopsis klotzi faunule

Chancia palliseri
Elrathina cordillerae
Kootenia dawsoni
Ogygopsis klotzi
Olenoides serratus

Pagetia bootes faunule

Chancia palliseri
Elrathina cordillerae
Kootenia burgessensis
Olenoides serratus

FIG. 3 - FOSSILS OF THE BATHYRISCUS-ELRATHINA ZONE IN SECTION 3, COMPARED WITH FAUNULES CONTAINING SIMILAR FORMS.

assemblage at GSC locality 46429 from the oldest Middle Cambrian fossils at GSC 46430, which is the lower of two Middle Cambrian faunal horizons that have 87' of non-fossiliferous strata between them. Both of the latter can be assigned to the Bathyriscus-Elrathina zone.

Rasetti (1951, pp. 99-108) has described eight faunules of the Bathyriscus-Elrathina zone; they are designated, in ascending order, by the following species: Ogygopsis klotzi; Olenoides serratus and Alokistocarella fieldensis (probably contemporaneous); Pagetia bootes; Ehmaniella burgessensis; Bathyriscus adaeus; Tonkinella stephensis and Parkaspis endecamera (also probably contemporaneous). The assemblage at GSC 46430 compares most closely with that of the O. klotzi faunule, and that at GSC 46431 may correspond to the Alokistocarella fieldensis or Pagetia bootes faunules, or even, because of the presence of two species of Pachyaspis, to the Tonkinella stephensis faunule. For easy comparison, the present assemblages are listed in Figure 3 beside selected relevant species of each of the above faunules.

The lower assemblage has affinities with faunules as high as that of Pagetia bootes, above which Olenoides serratus does not occur; but the genus Ogygopsis, which first appears in the Wenkchemnia-Stephenaspis zone, occurs no higher than in the O. klotzi faunule. The genera Chancia and Kootenia are long-ranging; but the upper collection contains K. burgessensis, which occurs in two of the three higher faunules mentioned. Similarly, the higher assemblage has four genera, including Pagetia and

Bathyriscus, in common with the O. klotzi faunule, but Pachyaspis occurs no lower than the Tonkinella stephensis horizon, and Kootenia is the only genus of the lower subzones that is not also seen in the T. stephensis faunule.

It is concluded that GSC locality 46430 can definitely be assigned to the O. klotzi subzone, but that the collection from GSC 46431 appears to be transitional in character. It occupies a position fairly high in the Bathyriscus-Elrathina zone, probably in the Tonkinella stephensis subzone, but possibly a little lower.

Upper Cambrian

The Dresbachian Stage and most zones of the Franconian Stage are not represented faunally in the Mount Hunter section; only a very few uppermost Franconian and Trempealeauan trilobites have been found. Collecting was confined to the sharp ridge of Mount Hunter, but in any case the section appeared to be very sparsely fossiliferous.

The three localities GSC 46408, 46409 and 46420 span a stratigraphic interval of 150', but all fall into one rather narrow range of subzones in the Upper Franconian. The most restricted range is suggested by Saratogia, which is characteristic of the lowest teilzone (Idahoia wyomingensis) of the Ptychaspis subzone in Montana and northern Wyoming; on Mount Hunter, Saratogia was collected at the top of this 150' interval.

Pseudagnostus, on the other hand, is long-ranging in Nevada, where it occurs throughout the Franconian and Trempealeauan Stages; in Texas it is confined to the Taenicephalus and Ptychaspis subzones, and in Montana and northern Wyoming, to the Ptychaspis subzone alone. In Vermont and the Gaspé, however, it is known only in the Saukia zone.

Wilbernia characterizes most of the Ptychaspis subzone in St. Croix area, Texas and the Cordillera, but also ranges throughout the Conaspis zone in Montana, and the upper half of it, the Taenicephalus subzone, in Wisconsin. The ranges of Wilbernia spp. are discussed in more detail in the descriptive systematics portion of this work.

Loganellus and Lauzonella are known hitherto only from Quebec, where they are part of the Hungaia magnifica fauna, and range from the Prosaukia, or upper Prosaukia, subzone into the lowest part of the Saukia zone. But on Mount Hunter they are found almost 150' stratigraphically below Saratogia; it is tempting to speculate that these genera may have migrated from west to east in late Franconian time.

In conclusion, it seems reasonable to assign these three localities to the uppermost Conaspis zone and the Ptychaspis subzone of the Upper Franconian Stage.

An isolated collection (GSC 46419) was made approximately

350-400' above GSC 46408, and its position fixed to within about 50' by computation based on elevation readings taken from a helicopter altimeter. It yielded only Westonia linguloides and Micragnostus sp. cf. Geragnostus (Micragnostus) bisectus var. typica.

The eastern variety of Geragnostus bisectus with which the present specimen most closely compares occurs in the Morses Line Slate of Vermont. Shaw (1951) concludes that this is probably correlative with the Upper Trempealeauan Gorge Formation. Westonia linguloides ranges from Middle Cambrian to Lower Ordovician.

Two factors suggest that the present locality should perhaps be assigned to the lower or middle, rather than the upper, part of the Saukia zone. Shaw traces a progressive change in the age of several members of the Morses Line fauna, not of Geragnostus alone, as distance from the Vermont locality increases. Significantly, in the Cordilleran region they are found in rocks older than those in Vermont, whereas in the Maritime provinces, Greenland and South America they are of early Ordovician age. Minor exceptions contradict but do not invalidate the general trend, and the occurrence of Saratogia in the Murray Range in rocks of the Taenicephalus and Ptychaspis subzones offers additional evidence in support of it.

Secondly, Lochman-Balk (1960, p. 40) reports a distinct faunal break in the Williston Basin, Montana, where a "middle Trempealeauan fauna is immediately overlain by the early Tremadocian

assemblage" in a lithologic succession that is otherwise undifferentiated. The Williston Basin is a long way from the Pine Pass area, and there may be many reasons for the absence of a fauna; however, Greggs also (1962, p. 10) finds a "major faunal break" between his Upper Cambrian Mistaya Formation and Lower Ordovician Howse River Formation in the Rocky Mountains of the Banff-Jasper area, Alberta.

Consequently, but without claiming that either of these lines of reasoning is conclusive, the writer is inclined to place GSC locality 46419 no higher than the middle of the Saukia zone.

The uppermost locality in Section 3, GSC 46432, contains billingsellid and nisusiid brachiopods that could be of Middle or Late Cambrian age, and sparse trilobite fragments that suggest idahoiid or pterocephaliid affinities and Late Cambrian age. The collection is useless for faunal correlation.

Ordovician

The stratigraphic range of individual species is discussed in detail in the section dealing with systematic palaeontology. Here it is necessary only to summarize the zonal assignment of assemblages at each locality.

Since Ross published his monographic study (1951) of the trilobite faunas of the Garden City Formation, his system of zones,

designated A to M in ascending order, has been the standard of reference for all workers in North American Ordovician biostratigraphy. In 1952 Hintze added two more zones in the Chazyan Stage, but the biostratigraphic framework remains essentially as Ross established it. The age of Zones A to K corresponds to the Canadian Epoch, and that of Zones L and M to the Chazyan Age.

On Mount Hunter the zonal position of GSC localities 46407, 46417 and 46418 is not precisely defined, but their sparse assemblages are clearly Early Canadian in age. The lowermost collection, at GSC 46407, contains only Apheoorthis ocha, of "Ozarkian" age in Walcott's term, found in Zones B and C of the Deadwood Formation in the Williston Basin. At GSC 46418, about 350' higher in the section, the most useful indicator is a species of Hystriurus that strongly resembles H. genelatus and H. paragenalatus, which are found only in Zone B of the Garden City Formation. This is confirmed by Apheoorthis aff. A. vicina, known in Zone B of the Deadwood Formation, and by Schizambon ?discoidea, which ranges from the Upper Cambrian Saukia zone to Zones A and B of the same formation. Nanorthis hamburgensis is a Zone C species, but undetermined species of Nanorthis are found also in Zone A. The clarkellid brachiopods are of no value for zonation. GSC locality 46417 is 30' upsection from GSC 46418, and yields only Symphysurina aff. S. spicata. Symphysurina generally indicates earliest Ordovician age, but fragments referred to it are found on Mount Hunter more than 1100' upsection from GSC locality 46417.

The lowest of these three localities should thus be assigned to the lowermost part of Zone B, or even Zone A, and the two upper localities almost certainly to Zone B.

Almost 800' of section separates these Zone B beds from the next localities that yielded identifiable fossils (GSC 46416 and 46404). Organic fragments were found about 140' and 790' respectively above the uppermost Zone B assemblage, but these did not survive attempts to remove them from their matrix by etching (GSC 46406, 46405)..

The association of Kainella with Lloydia (Leiostegium) manitouensis in collections from GSC localities 46416 and 46404 immediately identifies them as characteristic of Zone D. Although Lloydia (Leiostegium) manitouensis itself may range as high as Zone G, in the Garden City Formation this association is known only in Zone D. The occurrence of Nanorthis aff. N. hamburgensis is unusual for Zone D, but its specific assignment is questionable. Pliomeroides and an unnamed species of Hystricurus in the upper collection add no useful information. The age of Raphistomina sinclairensis is known simply as "Ozarkian", and is consistent with Zone D assignment. There are no grounds for making any zonal distinction between these two assemblages.

About 280' higher in the section, beds containing abundant organic trash yielded no identifiable specimens, but three very small collections were made at two horizons respectively 20' and

30' higher still. The lower one has Ophileta (Ozarkispira) leo, known as "Ozarkian" in Walcott's Mons Formation, but ranging up to Zone F in Nevada and Utah. However, both collections contain Symphysurina sp., found only in Zones A and C in Utah; Nanorthis hamburgensis is rarely found above Zone C; and Kainella is generally very earliest Ordovician in age. Thus the two horizons are unlikely to^{be} referable to any zone higher than Zone D, and unless there is structural complexity in the section that escaped notice, they cannot be as low as Zone C. Although they are more than 300' upsection from the Zone D horizon already described, it is concluded that all four localities should be assigned to the same zone.

Of the three remaining localities on Mount Hunter, GSC 46401 proved to be non-fossiliferous, and GSC 46400 yielded only worm-casts in thin-bedded quartzose sandstone. Silicified corals, identified by Dr. B.S. Norford as Catenipora sp. and Palaeophyl-ium sp., were collected at GSC locality 46399, approximately 480' above the top of the measured section, and are "late Middle Ordovician to Middle Silurian, almost certainly late Ordovician" in age.

STRATIGRAPHIC CORRELATION

The Local Section

Figures refer to footage above base of sections.

The top of Section 2A-2B is an erosional surface, and the section has no defined base; it appears to be underlain by an undetermined but very great thickness of quartz-sandstone and slate, in intercalated beds of variable thickness.

On Mount Hunter and in Section 3, Precambrian rocks are thrust over Triassic and Ordovician rocks respectively; zero datum level in both sections is the thrust plane. On Mount Hunter, measurement was carried up to the top of a major quartzite unit, 1600' thick, overlain by dolomite containing Upper Ordovician corals 480' higher in the section. Norford (in McCrossan and Glaister, 1964, p. 46) refers to these as "early Middle Ordovician" fossils, but he has more recently identified corals collected by the writer at the same locality (GSC locality 46399) as "almost certainly late Ordovician" (Geol. Surv. of Canada, internal report). On Section 3, practical considerations halted measurement at the top of a non-fossiliferous dolomite unit 850' thick, overlain by silty limestone displaying strong cleavage oblique to bedding. Significance of the cleavage in this instance is not known, and the section cannot be said to have any obvious structural or faunal upper limit.

When the work was undertaken, it was hoped that faunal control would provide close chronologic correlation, and that lithologic variation would then reveal in some detail the depositional history of all three localities vis-a-vis one another. But because there is no well-established faunal overlap of the two principal sections, they can be correlated only in terms of gross lithology; moreover, there is simply not enough information to estimate the amount of crustal shortening involved, and some idea of the palinostatic distribution of the three sections is necessary before different lithofacies can be related in time and space.

The lower portions of both sections, more than half of Section 3 (0-3883') and about a third of the Mount Hunter section (0-3674'), consist of quartzite and quartz-sandstone with occasional shaly partings or slaty interbeds. In both sections, however, there is a fairly abrupt change from the lower part of these clastics, with a high shale and slate content, to the upper part which comprises comparatively pure quartzite and quartz-sandstone, some of it conspicuously cross-bedded. In the Mount Hunter section, the break comes at 1814' above base, and in Section 3, at 2536' above base. It seems reasonable to regard the respective upper and lower clastic units in the basal portions of these two sections as lithologically correlative.

Approximately half-way up the upper clastic unit in Section 3 is a limestone member, slightly over 100' thick, closely resembling another limestone member of similar thickness, containing

Lower Cambrian fossils, at the top of the same clastic unit (3894-3963'). The lower limestone yields no recognizable organic remains, but it is immediately overlain by 12' of highly calcareous, very coarsely-crystalline dolomite; this is brecciated, weathers a vivid orange- or reddish-brown, and can be traced for a great distance along strike. The two limestone members may be stratigraphically equivalent, and if they are, the brilliantly-weathering calcareous dolomite may be the trace of a thrust plane of minor importance. However, there is no faunal evidence to confirm the equivalence of the two limestone members.

In the Mount Hunter section the two clastic units are overlain by almost 400' of interbedded silty dolomite and slightly calcareous or dolomitic red and maroon shales, in which desiccation cracks suggest shallow-water deposition. The unit is resistant and highly distinctive, and appears to have no counterpart in Section 3, except in so far as it is the first unit with appreciable carbonate content overlying a great thickness of quartzose clastic rocks. It may therefore be an argillaceous facies equivalent to the Olenellus zone limestone of Section 3, and considerably thicker than the latter; but in the absence of faunal control such correlation is highly speculative.

In Section 3, limestones containing Lower Cambrian and upper Middle Cambrian fossils underlie and overlie respectively a 300' thickness of quartz-sandstone which in turn appears to have no obvious lithologic counterpart on Mount Hunter. The overlying

limestone (base at 4268') is thin-bedded, argillaceous and platy-weathering, and may indicate conditions of sedimentation similar to those represented on Mount Hunter by thinly-interbedded silty dolomite and shale (4443' and up-section). Similarity in bedding thickness is regarded in this instance as more significant than differences in dolomitization and argillaceous content.

Correlation is made more difficult by the presence on Mount Hunter, from 4115' to 4443', immediately below the unit just described, of silty dolomite that ranges from thin-bedded near the base to massive and thick-bedded near the top of the interval; it is separated from the red and maroon shales only by a covered recessive interval of 62'. Perhaps it is the 4115' not the 4443' level on Mount Hunter that corresponds to the 4268' level of Section 3; and perhaps the 300' of sandstones in the latter section have their counterpart in finer-grained, less resistant clastic rocks on Mount Hunter with a much shorter history of deposition. Again one must stress the dangers of speculating on the chronologic significance of unexpectedly thin portions of the rock record, especially when they are covered and cannot even be examined.

In this case the time lines are virtually impossible to draw. The quartz-sandstones between 3963' and 4268' of Section 3 were almost certainly laid down in earlier Middle Cambrian time, because they are underlain by rocks containing uppermost Olenellus zone assemblages, and the overlying limestone contains a

lower Bathyriscus-Elrathina zone assemblage. But any attempt to assign a corresponding Middle Cambrian age to the silty dolomites of the interval 4115-4443' on Mount Hunter would rely heavily on the suggested lithologic, not even chronologic, correlation of the overlying thin-bedded carbonates of both sections, and on the occurrence of Franconian fossils at 5015' on Mount Hunter.

Further correlation between the two sections is suggested by the rather tenuous evidence of poorly preserved fossil fragments at 4600' in Section 3, which have slight affinities with the sparse middle to upper Franconian assemblage at 5015-5020' on Mount Hunter. Moreover, in both sections the limestone containing these fossils is interbedded with black shale, and bedding thickness varies within the same range (from very thin up to 3'). The top of this unit in Section 3 and on Mount Hunter is at 4650' and 5165' respectively.

The remainder of Section 3, and all of the Mount Hunter section except the Middle (?) Ordovician quartz-sandstone unit consists of varieties of limestone and dolomite. There appears to be a fairly strong resemblance between a "nodular-weathering", thin- to medium-bedded silty and argillaceous limestone on Mount Hunter and a corresponding variety in Section 3; and this possible correlation seems to be confirmed by the appearance of several resistant ribs of massive and very thick-bedded limestone, some of it oolitic, at closely corresponding horizons. Specifically, the more or less "nodular" limestone units occupy the interval 4550'

to 5800' in Section 3, 5165' to 6711' on Mount Hunter. The base of the resistant ribs of massive limestone is at 5295' and 6084' respectively, but they are much more strongly and more rhythmically developed on Mount Hunter than in the other section.

Because the lower part of the "nodular" unit (as above) on Mount Hunter contains fossils of probably early to middle Trempealeauan age at 5516-5566', that age is suggested also for the interval 4800-5100', approximately, in Section 3; on similar grounds, the lowest resistant limestone ribs in the latter section, at 5295', are probably of earliest Ordovician age (Zone A or Zone B). If sedimentation continued at the same rate in both places, a confirmed Zone B age can be assigned to the approximate interval 5700-5800' in Section 3. On Mount Hunter this carbonate unit, quite strongly resistant at the top, gives way up-section to a recessive thin-bedded silty limestone, and in the other section it is followed by a conspicuously recessive covered interval 77' thick.

There appears to be little resemblance between the uppermost dolomite of Section 3, with its high percentage of quartz sand-grain content, and the silty limestone, alternately resistant and recessive in comparatively narrow bands, that forms the sharp, broken summit ridge along the highest part of Mount Hunter. However, the beds at the top of Section 3 may be roughly of Zone D (early Ordovician) age, but only on the doubtful assumption that sedimentation was maintained at a similar rate in both places.

Both of the archaeocyathid horizons of Section 2A-2B are assigned to the Upper Olenellus subzone of the Lower Cambrian. Barring structural complication, therefore, the time required there for the deposition of about 950' of assorted clastic and carbonate rocks is represented in Section 3 by not more than 200' of beds. However, one cannot assume that the entire Cambrian section was proportionately thicker on the original site of Section 2 than it is in the other two sections; at present there is insufficient evidence to explain this remarkable thickening of a restricted part of the Lower Cambrian section. If there is no faulting at 3236-3248' of Section 3, the lower limestone member, apparently non-fossiliferous, may correspond to the lower archaeocyathid beds of Section 2, and the upper Lower Cambrian limestone of Section 3 to the upper archaeocyathid beds.

Regional Correlation

Precambrian?

Discussion of local correlation has already touched on the contrast between the lower and upper portions of the very thick basal clastic succession on Mount Hunter and in Section 3. The more argillaceous lower part, consisting of interbedded shale, slate and quartzite, probably corresponds to the Miette Group as redefined by Mountjoy (1962) in the Mount Robson (south-east) map-area. The name was proposed by Walcott (1913, p. 340)

for massive grey sandstone with interbedded shale underlying Lower Cambrian quartz-sandstone near the Yellowhead Pass. Similar units in other parts of the Jasper area have been named the "Jasper series" (Allan, Warren and Rutherford, 1932) and the "Hector Formation" (Walcott, 1910b, p. 428). North (in McCrossan and Glaister, 1964, p. 30) regards all these rocks as equivalent to the Windermere Group in southeastern British Columbia, and, by extension, in the Main Range of the Rocky Mountains in Alberta.

Immediately overlying the thrust plane at the base of the Mount Hunter section are 476' of homogeneous grey slates, which may correspond to the Old Fort Formation (Charlesworth and Remington, 1960, p. 12); this is as much as 1300' thick eight miles west of Jasper, and although argillite predominates at the type locality, the unit is much less homogeneous than the comparable beds on Mount Hunter. It is not feasible in the Murray Range to distinguish between possible equivalents of the two upper units of the Miette Group, known to Charlesworth and Remington as the Miette and Jasper Formations.

The Misinchinka Group is discussed below.

Uppermost Precambrian to Lower Cambrian

The stratigraphic position of the Misinchinka Group is still not clearly defined. According to Muller (1961) it comprises three units of low-grade metamorphic rocks; the upper unit of

dark slates "grades without apparent unconformity into Lower (?) Cambrian orthoquartzite".

The Misinchinka Group rocks are overlain by quartzite, interbedded with minor shale and slate, overlain in turn by dolomite; near its base, the dolomite contains interbeds of red shale, siltstone and sandstone. This unit of quartzite and dolomite (Muller's map-unit 7) "probably contains the Lower Cambrian Archaeocyathids, collected by the provincial mines department on highway 97, 17.1 miles from Parsnip River".

Quoting the same source, Okulitch (1956, pp. 722-723) locates this discovery of Archaeocyatha "in the Misinchinka schists . . .", adding "This makes at least the upper part of the Misinchinka Lower Cambrian in age and, in all probability, correlative with the Atan Group of northern British Columbia and the Donald Formation of the Purcells". It is entirely possible that the stratigraphic position of this occurrence became better defined between 1956 and 1961.

One may reasonably expect that either the lower or the upper occurrence of Archaeocyatha on Old Friend Mountain is of the same age as that found on the highway not far away. If the highway locality is in Muller's map-unit 7, the Misinchinka Group may indeed grade upward into Lower Cambrian quartzites; but if it is in the Misinchinka Group itself, then the upper part of that Group does not everywhere grade into Lower Cambrian quartz-

ites but may well be a facies variant, correlative with part of those quartzites in age.

Discussion of the age of Archaeocyatha (under "Systematic Palaeontology") has led to the conclusion that most North American occurrences, especially in the northern Cordillera, should be assigned to the Upper Olenellus subzone, i.e. to the upper part of the Lower Cambrian. The writer has accordingly suggested that the age of the archaeocyathid beds in two places on Old Friend Mountain should fall within the time range represented in Section 3 by the comparatively narrow stratigraphic interval containing both Salterella and a Bonnia-Olenellus assemblage.

The stratigraphic significance of the beds in Section 2 thus depends on that of the highway archaeocyathid locality. The Misinchinka Group either includes the Old Friend Mountain archaeocyathid beds, and is therefore a time-correlative facies variant of the Lower Cambrian quartzites and carbonates of Section 3 and Mount Hunter; or its upper boundary falls short of the fossil localities in Section 2, and should probably be placed near the top of the very thick, uniform dark slates that constitute the lower portion of Old Friend Mountain. In any case, there is a marked change from a clean sand and limestone facies to a highly argillaceous facies between the Murray Range sensu stricto and the lesser ranges immediately to the west of it.

Lower Cambrian

Williams and Bocock (1932, p. 200) clearly intended that the name "Mount Selwyn Formation" should refer to rocks that strongly resemble "the Cambrian quartzites of the southern Rocky Mountains". Unfortunately they did not designate a type-section, and their suggested correlation was not supported by detailed comparison and discussion. However, they regarded the quartzites on Mount Selwyn as the same unit as those on the east slopes of the Murray Range, now known on faunal evidence to be not younger than later Early Cambrian.

Okulitch (1956, p. 722) remarks that "the Mount Selwyn Formation is correlated with the MacDougal Group of the Mackenzie Mountains, which would make it, at least in part, Middle Cambrian in age". However, if Williams and Bocock's correlation is correct, and if the unit is not significantly diachronous between the Murray Range and Mount Selwyn, then the Mount Selwyn Formation is unlikely to be fully time-correlative with the MacDougal Group. But it is generally unwise to assume that coarse quartz-sandstones are not time-transgressive, even over relatively short distances, so the question remains unanswered.

Use of the term "Gog" has been extended to the Jasper-Mount Robson area by Mountjoy (1962, p. 6) to designate the widespread Lower Cambrian quartz-sandstones that are variously known elsewhere in the Rocky Mountains under the names St. Piran, Fort

Mountain, Cavell, Jonas Creek, Mahto, Tah, McNaughton and Mural Formations. Mountjoy remarks "since all of these formations occupy the same stratigraphic position and are essentially part of the same sandstone sequence that can be traced from area to area, these units should be grouped together under one formation or group name", and he accordingly proposes the name Gog Group.

Deiss (1940, p. 771) apparently established the Gog Formation to accommodate rocks in the Mount Assiniboine section that were younger than the Lake Louise and Fort Mountain Formations to which Walcott had assigned them. It is not entirely clear why he could not regard them as equivalent to the St. Piran Formation; perhaps, as North (in McCrossan and Glaister, 1964, p. 310 suggests, there is not enough significant lithologic break in the thick Lower Cambrian clastic succession to warrant the use of three formational names, and it is best known by a single name, whether of formational or group rank. Deiss's name "Gog" has been generally adopted to meet the need (cf. Mountjoy, *op. cit.*).

At Deiss's type-locality the Gog Formation does not include a carbonate interval near the top comparable with the Peyto Limestone member of the Mount Whyte Formation in the central portion of the Main Ranges. Walcott's (1928, p. 298) report of olenellid fragments in the upper part of the Gog Formation near Mount Assiniboine could not be substantiated by Deiss.

However, Mountjoy reports "a distinct carbonate and argil-

laceous interval" occurring towards the top of his Gog Group in the area north of Jasper, commonly containing abundant Archaeocyatha; this unit is said to be equivalent to the Tah (Mural) Formation of the Mount Robson district, but the Tah-Mural-Mahto nomenclature of that area is hopelessly confused (Burling, 1955, p. 47 attempts to clarify it). The Tah-Mural carbonates are overlain by the Mahto quartz-sandstones which Walcott has variously described as carrying Olenellus (1913, p. 335), and, emphatically, as having no fossils (1928, p. 253, footnote) (fide Burling, 1955, p. 33). Perhaps Mountjoy's "distinct carbonate . . . interval" is the lithologic and faunal equivalent of the Peyto Limestone member further south in the Main Ranges, but he does not suggest that it is.

As already mentioned in the discussion of faunal zones (Lower Cambrian), the Peyto member is more naturally regarded as the basal part of the Mount Whyte Formation, which it resembles lithologically, rather than the uppermost part of the St. Piran Formation, with which Rasetti associates it on the basis of its Lower Cambrian faunal content. Hughes (1955, p. 80) also maps it as part of the Mount Whyte Formation in the Sunwapta area. The writer agrees that in the southern and central Main Ranges, the Peyto member could be assigned to the Gog Group only by doing violence to accepted definitions of rock-stratigraphic units.

In the Murray Range, the Lower Cambrian part of Section 3 contains two limestone members at or near the top of the very

thick quartz-sandstones. The enclosed fauna suggests that the upper one is equivalent to the Peyto Limestone member, and should not be considered part of the Gog Group. But it is overlain by a further 300' of quartz-sandstone; is it not reasonable therefore to include it in the Gog Group, just as Mountjoy includes archaeocyathid-bearing carbonates in that Group near Jasper? The problem is simpler in the Mount Hunter section, where the interbedded dolomite and red shale that may be correlative with the Lower Cambrian carbonates of Section 3 give way up-section to a recessive covered interval, overlain in turn by thick-bedded dolomite; at least the recessive interval presents no positive reason why the dolomite and shale unit should not be associated with the overlying carbonates.

One is forced to conclude that the effort to establish meaningful correlations inevitably bogs down in semantic and nomenclatural triviality unless there is adequate information, based on the measurement of numerous sections spaced sufficiently closely both along and across the structural trend. Quite arbitrarily, therefore, the top of the Gog Group is placed here at the top of the uppermost quartz-sandstone in Section 3, and at the top of the recessive interval on Mount Hunter (at 4268' and 4115' respectively). The Lower-Middle Cambrian time boundary may come anywhere within that upper sandstone unit, or, more probably, at the top of it where a major change of depositional environment is marked by the transition to limestone; it is unlikely to occur above 4268' because later Middle Cambrian fossils are found only

100' higher in the section.

Middle Cambrian

It is clear that no lithologic and faunal equivalent of the Mount Whyte and Cathedral Formations of the Main Range is present in the Murray Range sections, except for the possible Peyto Limestone equivalent. In Section 3, beds of the Bathyuriscus-Elrathina zone very rapidly succeed the Gog-type sandstones, the age of which is unknown but is probably latest Early Cambrian or earliest Middle Cambrian. They are tentatively correlated with the fairly thick-bedded dolomites (4115-4443') immediately overlying a recessive interval (4053-4115') on Mount Hunter. The recessive interval may be occupied by a facies variant roughly equivalent to the uppermost quartz-sandstone of Section 3 already mentioned.

The closest Main Range counterparts of these beds are the Stephen and Eldon Formations; the upper part of the Stephen contains the Bathyuriscus-Elrathina fauna, and the Mount Hunter section includes thick-bedded dolomite reminiscent of the Eldon. They probably correspond to Mountjoy's (1962) map-units 3 and 4, including the Titkana Formation north of Jasper, and to the upper part of the Sunwapta Peak Formation in the Sunwapta Pass area (Hughes, 1955).

It is impossible to relate these sections closely to the

succession described by Walcott and Burling for the Mount Robson area. The Hota-Adolphus and Chetang Formations are probably older than any Middle Cambrian rocks in the Pine Pass area, and Walcott himself (1928, p. 250) remarks of the Tatei Formation that it " . . . is probably a relatively local deposit and may not be recognized outside of the Robson district".

On Mount Hunter Middle Cambrian beds probably extend from 4115' to 4967', and in Section 3, from 4268' to 4579'. The upper limits are only tentatively suggested.

Upper Cambrian

The Middle to Upper Franconian and Trempealeauan Stages appear to be represented on Mount Hunter, but in Section 3 the presence of Upper Cambrian fossils is suggested only by fragmentary and not highly diagnostic remains. The interval 4967' to 5800' on Mount Hunter and 4579' to 5100' in Section 3, approximately, may be referred to this Series; however, the upper limits are even more arbitrary in this case than for the Middle Cambrian, as there is no faunal control in Section 3, and no perceptible change in lithology between beds containing the highest Cambrian and lowest Ordovician fossils on Mount Hunter.

There is no sign of any multicoloured, thick-bedded shale unit resembling the widespread Arctomys Formation that is regarded as marking the lowermost Upper Cambrian at Mount Robson. Greggs

(1962, p. 9) offers evidence that the *Arctomys* and its equivalents are actually of later Middle Cambrian age in some places. The Dresbachian and Lower Franconian Stages may or may not be represented in the section; there is little room for them in Section 3, and the correlation already suggested brings the top of the Middle Cambrian close beneath strata containing a Middle Franconian fauna on Mount Hunter.

It is unnecessary to discuss here the breakdown of the Upper Cambrian section as established and revised by Walcott (summarized 1928), Burling (1923, 1955), Greggs (1962, 1963), Hughes (1955), North (1953), North and Henderson (1954) and Rasetti (1956). All authors agree that the Upper Cambrian Series in the Jasper-Robson area is represented by the Lynx Formation, which consists of limestone, generally fairly thin-bedded, and argillaceous, silty and sandy in varying degree.

Burling (1955, p. 30 ff.) reviews Walcott's estimate of the thickness of the Lynx, and arrives at the figure of 3,756' in Iyatunga Mountain near Mount Robson, including up to 200' of grey, greenish and reddish shales at the base which are regarded as equivalent to the *Arctomys* Formation. By contrast, rocks in the Mount Hunter section believed to be Upper Cambrian are less than 1,000' thick, and, as already noted, there is no *Arctomys* equivalent.

If the Murray Range sections be compared with those at Wal-

cott's Glacier Lake locality, one may observe a tenuous parallelism between the more argillaceous limestones of the Sullivan Formation and beds in the interval 4967' to 5165' on Mount Hunter, and between the purer, more massive, occasionally cliff-forming Lyell Formation and the interval 5165' to about 5800' on Mount Hunter. But the comparison is challenged by the presence of Franconian, not Dresbachian, fossils in the Mount Hunter beds that are proposed as basal Upper Cambrian. If the similar beds at these two localities are correlative rock-units, then they appear to be time-transgressive, and to have been deposited much later in the Murray Range than in the Robson or Glacier Lake areas.

Greggs (1962) argues that the Lyell and Sullivan should be considered obsolete on the grounds that they are improperly and inadequately defined by Walcott, and that in any case they are too poorly exposed, especially the Lyell, to warrant redescription and redefinition even at the type locality. Walcott's type Sullivan Formation is also regarded as incorporating approximately 755' of excess thickness as a result of duplication in a composite section. Greggs also rejects the name Tangle Ridge Formation (Hughes, 1955) as unnecessary.

Although the Upper Cambrian lithology in the Murray Range, as above, cannot be regarded as equivalent to the Sullivan-Lyell succession, it can be compared with Greggs' Bison Creek and Mistaya Formations, of Franconian and Trempealeauan age respectively.

The Bison Creek is thinner-bedded, argillaceous near the top and comparatively recessive, and the Mistaya is a fairly resistant unit of purer dolomite and limestone. Both formations tend to thicken to the northwest. Faunal evidence suggests that the Murray Range beds (i.e. 4967' to approximately 5800' on Mount Hunter) are time-correlative with the Bison Creek and Mistaya Formations, but this two-fold lithologic division of the Upper Cambrian cannot be traced through the Jasper-Robson area.

At Ranger Canyon Brook Greggs observed signs of erosion and scour in Collenia beds at the top of the Mistaya, the depressions being filled by shales of the Lower Ordovician Howse River Formation. Similar features suggesting a disconformity were found at 5005' in Section 3, and that horizon is proposed as a likely place for the Upper Cambrian-Lower Ordovician boundary. However, no algal forms were seen in Section 3, although Middle Cambrian beds on Mount Hunter contain diffuse structures that might have been recognized as algae by a more experienced eye.

Lower Ordovician

The base of the Lower Ordovician in Section 3 was originally placed at approximately 5100' somewhat arbitrarily, on the grounds that resistant limestone members at 5295' are likely to be lithologically correlative with those at 6084' on Mount Hunter; the latter contain a Zone A or lower Zone B assemblage. The possible disconformity at 5005' is now preferred as the Cambrian-Ordovician

boundary for the reasons mentioned above. On Mount Hunter the boundary is still placed arbitrarily about midway between horizons yielding a Lower or Middle Saukia zone, and a Zone A or lower Zone B, assemblage respectively, i.e. at approximately 5800'.

Lower Ordovician rocks in Section 3 comprise a thick succession of carbonates with little differentiation other than the transition from limestone to dolomite at approximately 5730', and the resistant member already mentioned. Both limestone and dolomite are argillaceous and silty, laminated and commonly nodular-weathering, with interbedded siltstone and shale. The corresponding carbonates on Mount Hunter are almost entirely non-dolomitic, and consist mostly of nodular, silty and argillaceous limestones, generally fairly thin-bedded to platy-weathering. However, the rib-forming unit of alternating thick, massive limestone and thin-bedded nodular and laminated limestone is 552' thick and highly distinctive. Possible correlative beds in Section 3 are much less distinctive, and for this reason the writer considers that it would be unwise to propose a new formational name for the unit on Mount Hunter despite its appreciable thickness. Further field work may show to what extent, and for what distance, the unit persists along strike with comparable thickness.

There appears to be no reason why the Ordovician nomenclature in the Jasper-Robson area should not be extended to the Mur-

ray Range sections. The Lower Ordovician carbonates are accordingly designated here as equivalent to the Chushina Formation near Mount Robson.

Norford (in McCrossan and Glaister, 1964, p. 45) summarizes the lithology of the Chushina Formation thus:

"The lower part of the formation consists of recessive weathering interbedded greenish grey argillaceous limestones and limy shale, with minor intraformational limestone conglomerates. Similar rocks are present in the less recessive upper part of the formation, together with limestones and nodular limestones. The Chushina closely resembles the lower part of the Mons-Sarbach unit, both lithologically and faunally."

He adds that at Cecilia Lake, slightly southeast of Mount Sir Alexander,

"The lowest rocks whose age is demonstrated to be Ordovician are greenish grey limy shales, limestones, limy mudstones, and intraformational limestone conglomerates. Trilobites indicate very low Lower Ordovician. These rocks are at least 300 feet thick and correlate both lithologically and faunally with the lower part of the Chushina Formation of Jasper Park."

Grey dolomites, 2570' thick, with minor limestone near the base, overlie the lower Chushina equivalent at Cecilia Lake, and are overlain in turn by dolomitic quartz-sandstone and quartzite. Beds just below the quartzite yielded early Middle Ordovician fossils. Norford continues:

"The sandstone sequence and subjacent beds can be compared with rocks at Mount Hunter 130 miles to the northwest but the higher strata cannot be readily correlated. They probably represent a thick sequence of Middle Ordovician age, but could include Upper Ordovician, Silurian and Devonian horizons."

Thus at Cecilia Lake a total of at least 2870' of carbonates

lie between the base of the Ordovician and the quartz-sandstone unit; this compares with a suggested 2365' of carbonates in the Lower Ordovician on Mount Hunter. Two other important differences should be noted; the carbonates on Mount Hunter are limestone not dolomite, and Upper Zone D fossils (i.e. of Chazyan age) are found within 375' of the base of the major Ordovician quartzite unit. Unidentifiable organic remains were collected halfway between the Zone D horizon and the basal beds of the quartzite, and they may be of Middle Ordovician age; but the writer would not extend to the Mount Hunter area Norford's comment that "the sandstone sequence and subjacent beds . . . probably represent a thick sequence of Middle Ordovician age . . ." (present writer's underlining). A later limit to their age is set by the presence of Late Ordovician corals at 10,246' on Mount Hunter.

Middle (?) to Upper Ordovician

Quartzite and quartzose sandstone slightly exceeding 1600' in thickness overlie the Lower Ordovician limestone on Mount Hunter. Norford (op. cit., p. 46, fig. 4-11) appears to correlate them with a "sub-Skoki" quartzite in the eastern part of the southern Rocky Mountains; he regards the unit as late Early to early Middle Ordovician in age.

However, this opinion is probably based on the presence of "early Middle Ordovician" fossils 480' above the top of the

quartzite, and if these fossils are actually Late Ordovician in age, as Norford's later report suggests (GSC internal report), there is no reason why this very thick body of quartzite should not be correlated with the Middle to Upper Ordovician Mount Wilson Formation. Mountjoy (1962, p. 17) also mentions "quartz sandstones occurring between Lower Ordovician and Devonian strata" in the area north of Jasper, and remarks that ". . . some of these sandstones may also represent part of the Mount Wilson quartzite or may represent sandstones in the Ordovician succession recorded by Harker, Hutchinson and McLaren (1954, pp. 61-62) at Cecilia and Kakwa Lakes, some 50 miles northwest of the map-area".

Dolomite overlying the quartzite appears to be at least in part equivalent in age to the Beaverfoot Formation of the western Main Ranges of the southern Rocky Mountains. Norford (op. cit.) indicates the existence of three dolomite bodies, separated by disconformities, above the quartzites in the section he measured on Mount Hunter; the lower two are said to be of Middle Ordovician age, the upper one Late Ordovician to Early Silurian, although disconformities at the base and top of the latter are marked as questionable in Norford's correlation chart (op. cit., fig. 4-11). The present writer did not examine the dolomite carefully, and cannot confirm or question the presence of these depositional and erosional breaks.

TECTONIC INTERPRETATION OF THE SECTIONS

Many authors (from Willis, 1907; Walcott, 1908, 1927, 1928; to Deiss, 1941; North, 1953; North and Henderson, 1954; Okulitch, 1956; Rasetti, 1956; White, 1959; McCrossan and Glaister, 1964; and others) have discussed the tectonic history of the Canadian Cordillera, and there is little point in attempting to recapitulate it here. The important compilation of the geological history of Western Canada edited by McCrossan and Glaister (1964) gives comprehensive bibliographies.

In the Western Cordillera (i.e. west of the Rocky Mountain Trench) Lower Cambrian quartzite and quartzose sandstone conformably overlie rocks of the Windermere Group, but in the Western and Main Ranges of the Eastern Cordillera, Lower Cambrian rocks are separated by unconformity or disconformity from Precambrian rocks of both the Windermere and Purcell Groups. A progressive down-cutting by erosion of the Precambrian section can be traced from west to east. It would be surprising if such unconformity did not exist also between the Miette and Gog Group rocks in the Murray Range sections, although no such break is seen on the scale of the individual section or outcrop. Regional unconformity might be revealed if the Precambrian succession in this area were better exposed and better known. The difficulty of detecting such unconformity is aggravated by the low-grade metamorphism to which the Misinchinka Group in particular has been subjected.

Miette Group rocks of the Murray Range contain a higher proportion of shale and slate than those of the overlying Gog Group, and this may indicate that they were laid down farther from a source of coarse clastic material. However, "shoreline deposits of the Windermere sea" are described in the vicinity of Jasper (Burwash et al., in McCrossan and Glaister, 1964, p. 15), and have been tentatively traced from Watson Lake to Ross River and to the north towards the Mackenzie River delta. The Murray Range is approximately on line with the first two localities.

Miette Group rocks in this range are appreciably thicker in Section 3 than in the Mount Hunter section. Three factors may contribute to this, either alone or in combination: firstly, a post-Miette erosional surface may cut down-section from west to east; secondly, the original site of Section 3 may have been closer to a source of clastics, and sediments accumulated there at a greater rate, than at the site of the Mount Hunter section; and thirdly, the plane of the thrust fault at the base of these two sections may cut up-section from west to east.

In the Pine Pass area two facies of Precambrian rocks appear to be in close proximity as a result of thrust faulting. The Misinchinka Group is notably more argillaceous than the Precambrian rocks of Mount Hunter and Section 3, here correlated with the Miette Group, which contain abundant coarse clastics as well as shale and slate.

Great thicknesses of well-sorted fairly pure quartz-sandstone and quartzite in the Gog Group rocks suggest shallow-water deposition of material derived from the craton. Similar thicknesses of quartzose sedimentary rocks are known wherever Lower Cambrian rocks are exposed in the Main Ranges, Western Ranges and west of the Rocky Mountain Trench, with the exception of the Radium-Fairmont area of the Columbia River valley and the "Montania" area southeast of Cranbrook. They are seen at their greatest thickness, approximately 10,000', in the Hamill Quartzite of the Selkirk Mountains west of the Trench.

In general terms, the Murray Range sections display the same transition from Lower Cambrian clastic deposits to Middle and Upper Cambrian and Ordovician carbonates and argillaceous rocks as is seen elsewhere in the Cordillera. They also illustrate, in very compressed form, the familiar eastward migration of depositional environments through early Palaeozoic time. The Pine Pass area is distinguished from most other regions, however, by the great reduction of the Cambrian section over the so-called "Peace River Arch".

North's brief account (in McCrossan and Glaister, 1964, p. 32) of this feature does not distinguish clearly between the western and central ranges in the Pine Pass area; hence, understandably, he does not recognize the likelihood of a facies change between Misinchinka- and Miette-type rocks that are probably of closely-corresponding Proterozoic age, as no studies of immediate relevance

to the point have been published. The influence of the Peace River Arch could have been more precisely asserted if the presence and thickness of Middle Cambrian rocks had been reliably known (the faunal evidence for Irish's "Middle Cambrian" rocks in this area (Irish, 1963) later proved to be of Upper Cambrian origin; Muller, personal communication). Although the Lower and Upper Cambrian rocks in the Main Ranges to the southeast are very much thicker than in this area, nevertheless, 2250' of Lower Cambrian strata is by no means an insignificant thickness. Admittedly, Middle and Upper Cambrian rocks on Mount Hunter probably total no more than 1750', but the most striking reduction of section is seen in the Middle Cambrian of Section 3, where it is unlikely to be more than about 350' thick; the Upper Cambrian section, also, is probably only about 450' thick in Section 3. The great cliff-forming carbonates of the Middle and Upper Cambrian in the Main Ranges are entirely absent here.

Discussing this reduction of section over the Peace River Arch and "Montana Island", as Walcott called it, North remarks (op. cit., p. 32) "Whether this is due to the existence of these features from Precambrian time, or to their periodic elevation during the Palaeozoic, is not established". There seems to be no striking evidence, however, that sedimentation was proceeding more slowly, or less copiously, in the Pine Pass area than in other parts of the Windermere sea; unfortunately the Miette Group rocks terminate down-section by faulting, as already noted, making it impossible to determine their original thickness. But

by the end of Early Cambrian time, the pattern of sedimentation controlled by the Peace River Arch had certainly been initiated, and the influence of that Arch became most pronounced in Middle and Late Cambrian time.

Three questions are raised by the peculiarities of the Middle and Upper Cambrian section in the Murray Range. Firstly, what accounts for the absence of all Middle Cambrian zones older than the Bathyuriscus-Elrathina zone, and of all the Dresbachian and early Franconian zones? Secondly, why do both Series virtually double in thickness from west to east, rather than in the reverse direction? Thirdly, does the reduced Middle and Upper Cambrian section in the Murray Range represent single or multiple cycles of deposition and erosion, or more-or-less continuous deposition at a greatly reduced rate?

To all these questions only negative answers can be given. Thus, there is no evidence that earlier Middle Cambrian rocks were ever laid down here, as any erosional surface at 4268' in Section 3 can only be assigned a "pre-Bathyuriscus-Elrathina" age; nor is there any evidence pointing in one direction or the other in the Upper Cambrian "passage beds" on Mount Hunter. Similarly, as there is not yet enough evidence to attempt palinspastic restoration of the sections, it is impossible to correlate them with distance from an ancient shoreline; perhaps petrography of the carbonate rocks would provide information about depositional environment, but it is beyond the scope of this work. It is

possible that the original site of Section 3 was closer to land than that of the Mount Hunter section, but one can only speculate on the sinuosities of ancient coastal topography; one cannot expect it to follow the neat, smooth lines so popular with highly-skilled draftsmen. As for the third question, this writer does not intend to undertake a discussion of rates of sedimentation. To permit the building up of great thicknesses of carbonates, not only must there be depression of the basin commensurate with the thickness of rock deposited, but there must also be an ample supply of biogenic and chemical carbonate sediment. It is not clear which of these requirements was lacking in the area under discussion; perhaps the answer lies in petrography rather than biostratigraphy.

In the Lower Ordovician portions of the Murray Range sections, lithology is sufficiently similar at the two localities to permit tentative correlation, yet different enough to suggest that their original sites may have been at a considerable distance from each other. The very strongly cyclic deposition of alternate pure, massive carbonates and thinner-bedded argillaceous carbonates at 6084' to 6711' on Mount Hunter is in marked contrast to its much weaker expression in Section 3 (5295-5800'). Perhaps the interval on Mount Hunter represents the alternate depression and elevation of a comparatively restricted basin. In this instance also, petrography might usefully indicate depositional environment.

LONG-RANGE FAUNAL AFFINITIESLower Cambrian

Two collections of Archaeocyatha contain genera typical of widely-scattered localities, including Australia, Antarctica, Mexico, southern California, southeastern and central British Columbia, the Yukon Territory and Labrador. The lower collection (GSC 46424) shows some affinity with the faunas of the southern hemisphere and the southwestern United States, the upper collection (GSC 46421) being more representative of genera and species commonly found in British Columbia and the Yukon; the earlier fauna may be considered more cosmopolitan, whereas the later fauna displays a slightly more provincial, or regionally-restricted, character.

Lower Cambrian trilobites and brachiopods from GSC localities 46428 and 46429 in Section 3 consist mostly of forms known in Mexico, Nevada, Utah, Idaho and the Canadian Cordillera; however, the same localities yield several species of Bonnia, two of Kootenia, Paedeumias transitans and Eoptychoparia sp., which were originally described from eastern Canada and the United States. The evidence of this mixed faunal assemblage supports the hypothesis of unbroken marine connections between the western and eastern margins of the craton in later Early Cambrian time. According to the classification of North American Cambrian biofacies proposed by Lochman-Balk and Wilson (1958), the assemblages at

both these localities are characteristic of the cratonic and intermediate realm in the Cordilleran region. In the west, Kootenia is more commonly found in the Middle than in the Lower Cambrian (op. cit., text-figs. 1-3).

Middle Cambrian

Trilobites of the present collections assigned to the Bathyriscus-Elrathina zone are exclusively western in character, except for a species of Pagetia that is compared with P. ellsii Rasetti in the Levis conglomerates of Quebec. Forms collected at GSC localities 46430 and 46431 are known in the Main Range of the Canadian Rocky Mountains, in Montana, Idaho, Utah, Nevada, Arizona and Mexico. They are rather too few for exclusive assignment to the cratonic or intermediate realm of the Cordillera, but appear to be more characteristic of the latter. A collection at the upper locality (46431) contains a doubtful specimen of Wenkchemnia sp., which is not known at all in the Cordilleran cratonic realm. The assemblage is definitely more typical of the cratonic and intermediate realms in eastern North America than of the marginal-intermediate or extracratonic realms. Eastern affinities are much weaker in the Middle Cambrian than in the Lower Cambrian collections from these three sections.

Upper Cambrian

Although they have proved useful for zonal determination,

the Franconian and Trempealeauan assemblages on Mount Hunter are much too sparse to permit much speculation about faunal affinities. The Franconian genera are divided almost equally between forms from the Canadian Cordillera, Texas, the Mississippi Valley (Wisconsin and Minnesota) and Quebec, and the only Trempealeauan fossils are an agnostid trilobite of extremely wide geographic range in both hemispheres, and an inarticulate brachiopod previously described from the Yukon-Alaska border.

Wilbernia, Saratogia and Pseudagnostus are said to be characteristic of the cratonic realm in the Croixian area, the Llano uplift of Texas, and in Montana and Wyoming. They are not part of the intermediate realm biofacies in Nevada. The eastern forms Lauzonella and Loganellus belong to the intermediate realm in Vermont and the Gaspé, and have not hitherto been reported from Western North America; however, the subjective element in fossil identification may be partly responsible for this.

Lower Ordovician

In so far as the scanty number of species permits comparison, there is a strong correspondence of the Mount Hunter Ordovician assemblages with those described by Kobayashi (1955) from the McKay Group of southeastern British Columbia. The Zone B assemblage at GSC localities 46407, 46417 and 46418 is probably equivalent to Kobayashi's Symphysurina fauna, and the Zone D assemblages at GSC localities 46416, 46404, 46415, 46414 and

46402 (in ascending order) correspond to his Kainella-Evansaspis fauna, which contains not only Kainella, Leiostegium, Symphysurina and Hystricurus but also the gastropods Raphistomina sinclairensis and Ophileta (Ozarkispira) leo, all represented in the present collections.

Kobayashi classifies his Canadian trilobites in the McKay Group as cosmopolitan, interprovincial, provincial or local in their geographic range (op. cit., p. 399). He describes Symphysurina and Leiostegium as interprovincial genera, finding the former also in the "Arctic province" and the latter in the "Andean province" of South America.

Lochman-Balk and Wilson (1958, p. 344) refer to the assemblages listed by Kobayashi as ". . . of mixed composition from the intermediate realm," but remark that they ". . . show a steady increase higher in the section of genera having extracratonic euxinic affinities". This tendency is consistent with movement towards the interior of ". . . the mobile belts encircling the Laurentian craton . . . (which) . . . culminated in the Canadian with a cratonward thrust or pulse", the broadening of miogeosynclinal areas and the intermediate biofacies realm, and the restriction of ". . . the cratonic belt and shallow shelf biofacies . . . to relatively narrow bands around the continent . . ."

"Mixed" assemblages of early Canadian age (Zones A to D) are known also in the Williston Basin of Montana, in Utah, Colo-

rado, Nevada, New Mexico and Texas, and from Newfoundland to southern Vermont and adjoining eastern New York State. In the Williston Basin, Zone D "mixed" assemblages are succeeded immediately upsection by faunas of predominantly extracratonic character, constituting a graptolitic biofacies.

Summary

Although one must be careful not to place too much weight on slender evidence, the vertical change in character of the Murray Range fossil assemblages is consistent with what is already known about early Palaeozoic sea-ways and tectonic history.

Faunal affinities suggest that throughout Cambrian and early Ordovician time no real barriers existed to prevent migration of trilobite stocks between the Canadian Cordilleran region and the faunal provinces to the north and south (in present-day geographic terms), including the southern hemisphere. Whatever the effect of "Montania" on patterns of sedimentation during Early and Middle Cambrian time, it does not appear to have impeded the spread of animal populations. However, faunal migration between western and eastern North America seems to have been easier in the Early Cambrian than at any later time.

Lower Cambrian faunas in the Murray Range already display characteristics of the intermediate extracratonic rather than the purely cratonic biofacies realm. Middle Cambrian assemblages

confirm a trend away from the cratonic realm, which is not seriously challenged by the presence of three Upper Cambrian genera said to be typically cratonic in the mid-West and western United States. Such slight evidence could not be used to suggest marine regression in the Late Cambrian in the face of abundant stratigraphic evidence of the spread of miogeosynclinal areas during that time. The presence of Lauzonella and Loganellus, if correctly identified, point to the possibility that a marine connection existed between western and eastern North America at this time; but the effects of evolutionary convergence may simulate those of faunal migration.

Lower Ordovician assemblages support the suggestion that the intermediate biofacies realm progressively gave way to the extracratonic realm in this region. The assemblages themselves do not actually contain a high proportion of extracratonic genera, but they have characteristics in common with faunas of the McKay Group of southeastern British Columbia and the Deadwood Formation of the Williston Basin where the same trend is known to be supported by faunal evidence.

SUMMARY AND CONCLUSIONS

Lithology

Sedimentary rocks of Precambrian to Late Ordovician age

are exposed in a series of thrust fault blocks in the Murray Range and lesser ranges adjacent to it. In the more easterly thrust sheet the Precambrian section consists of interbedded argillaceous rock (shale, slate) and coarse quartz-sandstone and quartzite; they probably correspond to the Miette Group of the Jasper-Mount Robson area. The westernmost thrust sheet on Old Friend Mountain comprises Precambrian to Lower Cambrian rocks that are appreciably more argillaceous than those further east, and appear to correlate with the Misinchinka Group exposed elsewhere in the same map-area. A lithofacies change is indicated by these contrasting rock groups of roughly corresponding age.

Lower Cambrian rocks consist chiefly of clean, well-sorted quartz-sandstone and quartzite, but include at least one, probably two, carbonate members. The Lower Cambrian succession is regarded as equivalent to the Gog Group of the Mount Robson area, and the carbonate members, which are fossiliferous in Sections 2 and 3, are reminiscent of the Peyto Limestone member of the Mount Whyte Formation of the Main Ranges.

Predominantly clastic Lower Cambrian rocks are overlain by a thick succession of limestone and dolomite, in places more or less silty and argillaceous; systemic and series boundaries are difficult to place on purely lithologic grounds, although it is thought that a disconformity marks the base of the Ordovician system in Section 3. Lithologic equivalents of the Middle Cambrian Stephen and Eldon Formations of the Main Ranges, and of the Upper

Cambrian Lynx Formation and Lower Ordovician Chushina Formation of the Jasper area, are recognized here. A thick succession of quartz-sandstone and quartzite, Middle (?) Ordovician in age, may be equivalent to the Mount Wilson Quartzite of the Main Ranges. Dolomite at the top of the Mount Hunter section is of Late Ordovician age, and compares with the lower part of the Beaverfoot-Brisco Formation of southeast British Columbia.

Faunal Zones

Only the Lower Cambrian beds of Sections 2 and 3 can be correlated on faunal evidence; the Late Cambrian age of fossil fragments in Section 3 that might have provided a faunal link with the Mount Hunter section is in some doubt.

Archaeocyatha are found at two horizons in Section 2, and the respective collections display slightly different regional affinities. The lower collection contains forms resembling those found in Australia, Antarctica and the southwestern United States; the upper assemblage is more characteristic of faunas of British Columbia and the Yukon Territory. However, they are both assigned to the Upper Olenellus subzone, of the Lower Cambrian. The upper collection contains Monocyathus, reported only once before in North America, and represented here by what is probably a new species.

Lower Cambrian trilobites of the Upper Olenellus subzone

consist mostly of western forms, but include specimens of Bonnia and Kootenia that are morphologically indistinguishable from eastern species.

Middle Cambrian zones from the Wenkchemnia-Stephenaspis to the Glossopleura zones are missing here, and the reason for their absence is unknown. The Bathyriscus-Elrathina zone is represented by two groups of trilobites, assigned to the Ogygopsis klotzi and Tonkinella stephensis faunules; these are normally found near the base and the top, respectively, of this zone. The presence of two new species of Ogygopsis is indicated.

Of the Upper Cambrian Series, all zones of the Dresbachian Stage, and the Elvinia zone of the Franconian Stage, are missing. A lower group of assemblages is assigned to the upper Conaspis zone and the Ptychaspis subzone of the Ptychaspis-Prosaukia zone (Upper Franconian), and a very sparse higher collection is probably representative of the Lower or Middle Saukia zone of the Trempealeauan Stage.

The Mount Hunter section passes upwards without apparent lithologic change into beds containing earliest Canadian fossils (Zone A or Zone B of Ross and Hintze's scheme). At fairly regular intervals upsection, distinctive assemblages typical of Zones B and D are found. Despite the considerable thickness of the Canadian section, no characteristic Zone C assemblage is seen.

Tectonic Interpretation

Although a changing vertical succession of rock types seen in one small area cannot by itself define the eastward or westward direction of marine transgression, the Murray Range sections are consistent with early Palaeozoic trends already firmly established by stratigraphic studies in other parts of the Cordillera.

From Windermere (late Precambrian) time to the end of the Early Ordovician epoch, marginal cratonal and miogeosynclinal seas spread towards the centre of the craton. This shift of marine environments is reflected in the present area in the upward transition from clean, well-sorted quartzose arenites to a thick succession of carbonate and argillaceous carbonate rocks. The trend seems to have been reversed in Middle (?) Ordovician time with renewed deposition of quartzite and quartz-sandstone, which is succeeded in turn by dolomite containing an Upper Ordovician biostromal assemblage.

A regional unconformity may separate Gog Group rocks from the underlying Miette Group, and another unconformity may be present at the transition from Lower Cambrian clastic to Middle Cambrian carbonate rocks, particularly in view of the absence of lower Middle Cambrian faunal zones. The Lower Ordovician Chushina Formation probably overlies the Upper Cambrian Lynx Formation disconformably in Section 3, but no corresponding erosional sur-

face was observed on Mount Hunter, where the systemic boundary is more arbitrarily placed.

The effect of the restricted regional uplift known as the "Peace River Arch" is not observed in the Precambrian portion of the section, the thickness of which is unknown because of faulting. Rocks of the Gog Group are thinner here than at Mount Robson, but uplift of the Arch had its most marked effect in Middle and Late Cambrian time, which is represented by a very greatly reduced section.

Eastward thickening of Lower Cambrian to Lower Ordovician rocks from Section 3 to Mount Hunter appears to be inconsistent with the general trend in the Canadian Cordillera, particularly conspicuous in the westward thickening of Lower Cambrian clastic rocks. More detailed stratigraphic information is needed to explain the contrary trend in the Murray Range.

Faunal Affinities and Biofacies Realms

It is likely that faunal migration was farther-ranging in Early Cambrian time than during any later part of the Cambrian and Early Ordovician. Lower Cambrian trilobite assemblages display affinities with faunas of eastern Canada and the United States, and the lower of two archaeocyathid collections contains genera more commonly found in the southern hemisphere. Eastern affinities are weaker in Middle and Upper Cambrian assemblages, and Lower Ordovician fossils in the Murray Range are of distinctly

Cordilleran character.

All the assemblages here described can reasonably be assigned to the intermediate extracratonic biofacies realm of Lochman-Balk and Wilson (1958). Apart from episodes of probable emergence and erosion, progressive encroachment upon the craton by shallow seas persisted throughout Late Precambrian, Cambrian and Early Ordovician time. This aspect of the present conclusions is summarized rather less briefly above (pp. 46, 49).

SYSTEMATIC PALAEOLOGY

LOWER AND MIDDLE CAMBRIAN

Phylum Archaeocyatha Vologdin, 1937

Class Monocyathea Okulitch, 1943

Order Monocyathida Okulitch, 1935

Family Monocyathidae Bedford and Bedford, 1934

Genus Monocyathus Bedford and Bedford, 1934

Monocyathus sp., new species?

Pl. 1, figs. 1, 2.

Long, narrow, single-walled, cylindrical cup; wall thickness one-fifth to one-quarter diameter of cup, and pierced by numerous coarse round pores normal to the cup axis. No specimen adequately displays pattern of pore arrangement, and none retains the spitz. Pores are up to 0.7mm in diameter. The form is represented by numerous specimens, many of them sub-parallel to one another and spaced from 2mm to 20mm apart. Largest preserved portion of a specimen is 40mm long, with a maximum diameter of 5mm.

Monocyathus porosus Bedford and Bedford is smaller, conical not cylindrical, and much thinner-walled in proportion to the diameter of the cup; M. contractus Hill (Hill, 1965, p. 52, pl. 1) is broadly conical, with "the growing edge . . . curved over above, leaving a narrow opening subcentrally . . .", and with large, oblique pores; the specimen of Monocyathus sp. reported by Greggs

(1959, p. 63, pl. 11, fig. 1) from Colville, Washington, is figured but not described, and little useful detail can be seen, but it appears to be thinner-walled than the present specimens. Hill writes "Zhuravleva . . . has listed twenty-three species of single-walled Archaeocyatha under her genus Archaeolyntus (Monocyathus)." (Hill, 1965, p. 51). Pending a thorough survey of the Russian literature, therefore, the writer is reluctant to propose a new name for this unusual form. If a new name is warranted, Monocyathus pinensis would appropriately commemorate discovery of the species in the Pine Pass map-area of British Columbia. The genus Monocyathus has been reported only once before in North America (Greggs, op. cit.).

Specimens: GSC 46421, nos. 16 (af, cf, df, ef), 17bb (polished longitudinal and transverse sections, and weathered transverse sections; thin sections provided no additional information).

Locality: Section 2A, approx. 1250' above base.

Class Archaeocyathea Okulitch, 1943

Order Ajacicyathida Bedford and Bedford, 1939

Family Ajacicyathidae Bedford and Bedford, 1939

Genus Ajacicyathus Bedford and Bedford, 1939

Ajacicyathus nevadensis (Okulitch)

Pl. 1, fig. 4.

Archaeocyathus nevadensis Okulitch, 1935, p. 101, pl. 1, figs. 7-9, pl. 2, fig. 3.

Ajacicyathus nevadensis (Okulitch), 1943, p. 55, figs. 18a, 18b, pl. 1, figs. 1, 2, 4; Okulitch, 1948, p. 341, pl. 53, fig. 1; Okulitch, in Cooper et al., 1952, p. 28, pl. 7, figs. 5, 6; pl. 9, fig. 4; Okulitch, 1954, p. 293, pl. 28, figs. 6, 7;

Okulitch, 1955, p. 49, pl. 2, fig. 2; Greggs, 1959, p. 63, pl. 11, fig. 7, pl. 12, figs. 10, 11, pl. 14, fig. 6.

Outer and inner walls simple, outer wall slightly thicker than inner, both rather irregularly and indistinctly perforate; parieties straight, thickened near outer wall in two specimens, imperforate at plane of section. An incomplete fragment with three well-preserved intersepts shows four very fine pores in outer wall between adjacent parieties.

	GSC	
	46424-7	46424-12
Diameter	0.4mm	1.25mm
Number of parieties	8	14
Parietal coefficient	20.0	11.2
Intervallum thickness, approx.	0.1mm	0.25mm

The species is represented in GSC 46424 by three very small individuals; parietal coefficient is thus unusually high for a form with so few parieties. Kawase and Okulitch (1957, p. 916) quote Zhuravleva's opinion that "the coefficient becomes constant only when the organism has reached maturity; therefore, it is not a reliable criterion to use in identifying . . . (A. khemtschikensis) . . . in the adolescent stages". The comment seems equally applicable to other species.

Specimens: GSC 46421, no. 11b (thin-section); 46424, nos. 7b, 12b (thin-sections).

Localities: Section 2A, approx. 1250' above base, and Section 2B 691-701' above base, respectively.

Genus *Archaeocyathellus* Ford, 1873
Archaeocyathellus ?walcotti Okulitch

Pl. 1, fig. 3.

Archaeocyathellus walcotti Okulitch, 1943, p. 61, pl. 3, figs. 2-5.

Inner wall simple, with indistinct but probably coarse pores; structures resembling stirrup pores seen at intersection of wall with at least two parieties; no structures project into central cavity. Parieties straight, also indistinctly perforate. Outer wall longitudinally furrowed at junction with parieties; may have up to 9 vertical rows of pores per intersept, but the appearance of perforation may be an accident of preservation, and to that extent the specific assignment is in doubt.

Archaeocyathellus walcotti is distinguished from *A. dwighti* and *A. renselaericus*, the genotype, by having more than two vertical rows of pores per furrow; *Archaeocyathellus? uniporosus* and *A. rarus* both have only one row of pores in each furrow of the outer wall.

Diameter of cup	8mm
Diameter of central cavity	4mm
Number of parieties	10
Parietal coefficient	1.25
Intervallum coefficient	2:4, or 0.5

Specimen: GSC 46421, no. 6b(i), thin-section.

Locality: Section 2A, approx. 1250' above base.

Family Ethmophyllidae Okulitch, 1943

Genus Ethmophyllum Meek, 1868

Ethmophyllum cooperi Okulitch

Pl. 1, fig. 5.

Ethmophyllum cooperi Okulitch, in Cooper et al., 1952, p. 29,
pl. 7, figs. 1, 2, pl. 9, fig. 4.

The species is identified by the complex vesicular inner wall, which is approximately half as wide as the intervallum. Parieties are simple, lacking pores; outer wall simple, with two or three vertical rows of fine pores between adjacent parieties. Intersepts rounded next to inner wall except where vesicular channel openings are cut by plane of section.

Vesicles of the inner wall form three ill-defined rows, but appear to be filled or displaced by solid tissue at a few points. Ethmophyllum whitneyi, by contrast, has a narrow inner wall with only one or two rows of vesicles. The genus Tercyathus Vologdin has a wide inner wall, but its structure is much more irregular and its parieties are far more numerous. Oblique sections of two individuals suggest that channels of the inner wall open into the central cavity in a regular arrangement of horizontal rows.

A near-circular section gives the following measurements:

Diameter	3.0 mm
Width of intervallum	0.75mm
Number of parieties	37
Parietal coefficient	12.3

Other specimens have from 35 to 39 parieties.

Specimens: GSC 46424, no. 7a (thin-section).

Locality: Section 2B, 691-701' above base.

Family Coscinocyathidae Taylor, 1910

Genus Coscinocyathus Bornemann, 1884

Coscinocyathus dentocanis Okulitch

Pl. 1, figs. 6, 7.

Coscinocyathus dentocanis Okulitch, 1943, p. 67, pl. 4, fig. 2;
Okulitch, 1948, p. 342, pl. 53, fig. 5; Okulitch, 1955b,
p. 51, pl. 3, figs. 5-7; Kawase and Okulitch, 1957, p. 916,
pl. 109, figs. 4-6.

The specimens have suffered some loss of detail as a result of dolomitization. Elongate, tubular, double-walled cups, slightly tapered. Inner and outer walls probably simple, but perforation obscure.

Intervallum contains numerous closely-spaced parieties, and up-arched tabulae spaced a little less closely than the

parieties; most of the resulting loculi are therefore oblong rather than quadrate, but the spacing of tabulae is not perfectly regular. Nevertheless, the specimens are clearly referable to C. dentocanis rather than C. rhyacoensis (= C. quadratus Bedford and Bedford?), in which loculi are distinctly quadrate.

One specimen exposed in longitudinal section on a weathered surface is approximately 50mm long, 18mm wide, the central cavity measuring 5mm at its maximum width. The weathered surface intersects an adjacent specimen at about 40° to the axis of the cup; its minimum diameter is 13.5mm; diameter of central cavity 6mm.

Specimens: GSC 46421, nos. 1cc, 10be, 13ee (handspecimens).

Locality: Section 2A, approx. 1250' above base.

Coscinocyathus ?rhyacoensis Okulitch

Pl. 1, fig. 8.

Coscinocyathus rhyacoensis Okulitch, 1948, p. 343, pl. 53, figs. 7, 8.

This species is distinguished from C. dentocanis by the closer spacing of tabulae, which gives rise to quadrate rather than oblong loculi. Only the number of rows of mural pores per intersept distinguishes it from C. quadratus Bedford and Bedford, but dolomitization has obscured the finer details of wall structure.

The largest specimen tentatively assigned to the species is about twice as wide as the holotype; diameter 22mm, diameter of central cavity 14mm, number of parieties at least 100.

Specimens: GSC 46421, nos. 2a? (thin-section), 11ce, 19, 23, 24 and 27ac (hand-specimens).

Locality: Section 2A, approx. 1250' above base.

Unidentified coscinocyathid cup

(?Coscinocyathus sp.)

Pl. 1, fig. 9.

Resembles Coscinocyathus dentocanis in its strongly up-arched, finely porous tabulae, and in its oblong loculi, but the inner wall is perforated by hexagonal pores, with one vertical row per intersept. Hexagonal outline of the pores is seen clearly only in thin-section; in a photograph, a more crescentic shape is imparted to them by partial infilling with opaque material. However, in a few pores this shape is in fact due to outward bulging of one wall of an adjacent pore.

Although the original description of C. dentocanis (Okulitch, 1943, p. 67) made no reference to porosity of inner or outer walls, a later account based on better specimens (Okulitch, 1955b, pp. 51-53) described the inner wall as a "coarse net consisting of elongated, rectangular openings".

Specimen: GSC 46421, no. 11e(i), thin-section.

Locality: as above.

Genus *Pycnoidocoscinus* Bedford and Bedford, 1936

Pycnoidocoscinus sp.

Pl. 1, figs. 12, 13.

The writer has not had access to the Bedfords' original description, and cannot attempt specific assignment.

A specimen seen in weathered transverse section, transverse thin-section and longitudinal polished section is poorly preserved, and details are badly obscured by dolomitization. However, it clearly displays tabulate and parietal structure resembling that of *Coscinocyathus dentocanis*; tabulae strongly up-arched; loculi oblong, not quadrate; inner wall pierced by coarse pores arranged in well-defined vertical rows, one per intersept, and in somewhat imperfect horizontal rows. The pores are sub-rectangular, but in the existing state of preservation it is impossible to see the "vertical rods in the middle of intersepts" that are regarded as diagnostic of the genus (Okulitch, 1955a, p. E14).

Outer wall with very prominent annulations, on which assignment to this genus is chiefly based.

Polished section is at least 88mm long, 25mm wide between

opposite crests of an annulation, with central cavity 12mm wide. A transverse thin-section of the same specimen is 23mm in diameter, central cavity 14mm in diameter, and shows at least 100 parieties.

Specimen: GSC 46421, nos. 3b (thin-section), 3 (polished section) and 3ad (weathered cross-section), all of the same individual.

Locality: Section 2A, approx. 1250' above base.

Order Metacyathida Bedford and Bedford, 1936

Family Archaeocyathidae Taylor, 1910

Genus Archaeocyathus Billings, 1861

Archaeocyathus atlanticus Billings

Pl. 1, fig. 11.

Archaeocyathus atlanticus Billings, 1861, p. 5; Okulitch, 1943, p. 68, pl. 5, figs. 1, 2, pl. 18, fig. 18c; Okulitch, 1948, p. 344, pl. 54, figs. 1, 2; Okulitch, 1954, p. 295, pl. 28, fig. 9; Okulitch, 1955b, p. 53, pl. 3, fig. 1; Greggs, 1959, p. 67, pl. 12, figs. 7-9, pl. 14, fig. 11.

Outer and inner walls perforate; intervallum considerably wider than diameter of central cavity, and with irregularly branching skeletal elements.

This specimen differs from the many published figures of the species only in the cellular aggregates of opaque material lining or filling many loculi in the intervallum, especially

near the outer wall. It resembles the "rounded, rectangular cells" described by Okulitch (1946, p. 275) in connection with Cambrocyathus amourensis and discussed by this writer elsewhere (vide Syringocnema sp.).

Diameter (shorter axis of elliptical section)	8mm
Diameter of central cavity	2mm

Specimen: GSC 46424, no. 17 (thin-section).

Locality: Section 2B, 691-701' above base.

Genus Protopharetra Bornemann, 1884

Protopharetra raymondi Okulitch

Pl. 1, figs. 9, 10.

Protopharetra raymondia Okulitch, 1935, p. 103, pl. 2, fig. 2.
Protopharetra raymondi Okulitch, 1943, p. 71, pl. 4, fig. 3,
 pl. 6, figs. 3, 4.

The species may be represented in several oblique sections, but at least one very small individual can safely be referred to it.

Cup about 2.5mm in diameter, with a central cavity about 0.6mm in diameter located slightly off-centre. Inner and outer walls thin, displaying no detail. Intervallum containing curved

bars and taeniae, but leaving a high proportion of free, interconnected spaces.

Specimens: GSC 46421, nos. 5c, 11e(i) (thin-sections; the smaller individual in 5c).

Locality: Section 2A, approx. 1250' above base.

Protopharetra ?dunbari Okulitch

Pl. 1, fig. 10.

Protopharetra dunbari Okulitch, 1943, p. 71, pl. 6, fig. 5, pl. 9, fig. 3; Greggs, 1959, p. 69, pl. 12, figs. 4, 5, pl. 14, fig. 1.

Resembling P. raymondi, but central cavity proportionally even smaller, and containing rather diffuse, fine vesicular material; intervallum filled with more robust curved rods and bars; interconnected pore space greatly reduced, with corresponding increase of isolated "lacunae" (Greggs' term). Porosity of outer wall cannot be determined.

The specimen is approximately 5mm in diameter in a near-circular transverse section. However, numerous other small specimens of similarly irregular form may also be referable to the species.

Specimens: GSC 46421, no. 5c (larger individual in thin-section, and others).

Locality: as above.

Family Pycnoidocyathidae Okulitch, 1950

Genus Pycnoidocyathus Taylor, 1910

Pycnoidocyathus amourensis (Okulitch)

Pl. 1, figs. 14, 15.

Cambrocyathus amourensis Okulitch, 1943, p. 76, pl. 9, fig. 3,
pl. 10, fig. 3, pl. 11, figs. 1-3, pl. 18, fig. 1b.

Pycnoidocyathus amourensis (Okulitch), Kawase and Okulitch, 1957,
p. 923, pl. 112, fig. 1.

The general shape of these specimens is not known; they are identified only in thin section.

Inner and outer walls appear to be thin, without visible porosity. Intervallum wide, containing numerous strong parietes, linked by synapticalae, dissepiments and taeniae. The smallest individual is 3.5mm in diameter; the largest would be approximately 20mm in diameter if complete. Diameter of central cavity generally about 0.25 that of the whole cup. Number of parietes varies from 12 in the smallest individual to about 55 or 60 (by extrapolation) in the largest.

The specimens compare closely with several of those figured by Okulitch (1943); parietes appear to be appreciably less porous than they are in specimens figured by Kawase and Okulitch.

Specimens: GSC 46421, nos. 6b(ii), 11e (i and ii), all in thin-section.

Locality: Section 2A, approx. 1250' above base.

Genus *Sigmocyathus* Bedford and Bedford, 1936

?*Sigmocyathus* sp.

Pl. 1, fig. 16.

An oblique longitudinal section offers details of the inner wall where it is oriented both parallel and transverse to the plane of the section (i.e. at the extremities and along the sides respectively of the elongate elliptical trace of the central cavity). In parallel section, the wall appears as a mesh of circular pores, and in transverse section as sigmoidally curved structures that overlap one another. It is impossible to be certain whether they are the annular curved plates that are characteristic of the genus, or whether they are sigmoidally curved circular canals analogous to those in the inner wall of *Ethmophyllum*. Only a very small part of the outer wall may be preserved, and shows no sign of sigmoidal plates; however, it appears to be coarsely crenulate.

Intervallum contains numerous parieties; in transverse section they appear to be linked by synapticulae at irregular intervals, and in parallel section they clearly show the 'tear-drop' perforations typical of *Sigmocyathus*. However, as the section

does not fully reveal the structure of the inner wall, assignment to this genus must be regarded as doubtful; as far as this writer knows, it has not been recognized previously in North America.

On the basis of similar inner-wall morphology Handfield (1965, p. 29, pl. 3, figs. 3-5) assigned to Sigmofungia sp. a specimen from the Sekwi Mountain map-area, Northwest Territories. However, a longitudinal section of his specimen does not disclose the 'tear-drop' perforations mentioned above, and the sigmoidally curved annular platforms are much finer, closer and steeper with respect to the inner wall than those in the present specimens.

This oblique section is 39mm long, 12mm wide, and the width of the central cavity, measured as the shorter axis of its elliptical trace, is 5mm.

Specimen: GSC 46424, no. 12a.

Locality: Section no. 2B, 691-701' above base.

Order Metacyathida Bedford and Bedford, 1936

Family Metacoscinidae Bedford and Bedford, 1936

Genus Archaeosycon Taylor, 1910

Archaeosycon vesiculosum Okulitch

Pl. 2, figs. 1, 3.

Archaeosycon vesiculosum Okulitch, 1943, p. 82, pl. 15, figs. 1,
2.

General shape obscured by exothecal overgrowth, and details to some extent destroyed by dolomitization.

Outer wall highly irregular, merging with exothecal tissue; perforation indeterminate. Inner "wall" better-defined in transverse section, but very poorly in longitudinal section, where it appears to be simply the inner margin of the series of strongly up-arched tabulae. Tabulae linked by irregular rods or plates, some of which originate as an abrupt thickening of adjacent tabulae. Space between tabulae commonly partitioned by curving and anastomosing dissepiments.

A transverse section suggests at first sight that the intervallum contains parieties that are rather more regular than is usual in Archaeosycon, and more typical of members of the family Coscinocyathidae. However, the trace of these parieties in longitudinal radial section is much less continuous than it would be if the parieties were simple, regular radial structures. They are therefore considered to be the "rudimentary or irregular", "very loosely constructed" radial parieties described by Okulitch (1955a, p. E17, 1943, p. 82 respectively). The presence of cystose dissepimental tissue in the intervallum distinguishes this species from Archaeosycon billingsi.

Outer wall, inner margin of tabulae, and parieties are so irregular that the calculation of intervallum and parietal coefficients has no significance; the specimen is at least 70mm long, possibly up to 40mm in diameter, with a central cavity up to 20mm in diameter. Intervallum contains at least 70 "parieties" or radial structures.

Specimen: GSC 46421, no. 14 (ad, bd, cd, hand-specimens; a and b, thin-sections).

Locality: Section 2A, approx. 1250' above base.

Order Syringocnemida Okulitch, 1935

Family Syringocnematidae Taylor, 1910

Genus Syringocnema Taylor, 1910

Syringocnema sp.

Pl. 2, figs. 2, 5-7.

Double-walled cup, width of intervallum and diameter of central cavity approximately equal. Details of inner and outer walls not clearly seen. Intervallum filled with a network of radial loculi. Sections of loculi displayed by structurally fairly simple specimens range from transverse, showing generally 3- or 4- to 6-sided outline, to longitudinal, in which loculi are delineated by parallel walls. Some loculi are isolated, some are connected with adjacent loculi by pores; these pores are seen much more rarely in transverse than in longitudinal sections,

where the wall of a loculus may be pierced by as many as seven pores. The irregular distribution of transverse and longitudinal sections of loculi in a cross-section of any individual cup suggests that they are curved, not straight.

Loculi that are interconnected by pores contain only clear crystalline calcite; by contrast, isolated loculi are lined or filled with cellular aggregates or clots of opaque to cloudy material; these are rounded, rectangular or sub-angular in outline, and are separated from one another by fine lines of clear material. They show no evidence of possessing organic structure themselves.

It is difficult to avoid the conclusion that the absence or presence of this material is directly related to the ease or difficulty of circulation in the intervallum. If the material is argillaceous and extraneous, it would naturally be trapped in 'dead-end' spaces; but in some loculi it is very evenly distributed as a thin lining, and is invariably broken up into small patches by clear interstitial calcite. If it is the product of organic processes such as excretion, it might be expected to concentrate in small globules or clots, which would be more readily flushed from loculi where circulation is most efficient, i.e. from those possessing numerous pores. If the small opaque aggregates were originally cells of living tissue, it is remarkable that they are not more uniformly distributed throughout the intervallum, because preservation appears to be excellent. On

the other hand, perhaps cells were easily detached from the skeleton after death, but remained in place wherever they were not exposed to vigorous circulation of fluids. The writer concludes that this opaque material may be the remains of cell tissue, but that there is not enough evidence to rule out other explanations.

Hill (1965, pl. 11, figs. 17, 18) figures oblique thin-sections of Syringocnema gracilis Gordon in which the traces of loculi (which she calls "tubuli") exhibit the same variation of pattern as they do in the present specimens. However, the skeletal elements of that species are more slender, and loculi more regularly hexagonal in cross-section than they are in these specimens. S. colvillensis Greggs (Greggs, 1959, p. 72, pl. 13, figs. 5, 6) has a very narrow central cavity; however, his sections show clearly that the radial loculi tend to be sub-horizontal near the outer wall, but curve rather sharply upwards or downwards near the inner wall. Despite the immediate impression of distinctive character, these specimens do not afford enough detail of the inner and outer walls to justify proposal of a new species.

Specimens: GSC 46424, nos. 21, 22 and 28 (i and ii), (thin-sections), and several hand-specimens.

Locality: Section 2B, 691-701' above base.

<u>GSC 46421</u>		South Australia	Antarctica	Sonora, Mexico	Inyo Co., California	Silver Peak, Nevada	Colville, Washington	Salmo, B.C.	Dogtooth Range, B.C.	Sinclair Mills, B.C.	Aiken Lake, B.C.	McDame, B.C.	Wolf Lake, Y.T.	Quiet Lake, Y.T.	Sekwi Mountains, N.W.T.	Troy, New York	Labrador
Ajacicyathus nevadensis				x	A	<u>A</u>	x	x	x	x	x	x					
Archaeocyathellus walcotti																	<u>A</u>
(Archaeocyathellus spp.)								x									
Archaeosycon vesiculosum							x		x			x					<u>A</u>
(Archaeosycon spp.)																	
Coscincocyathus dentocanis								x	<u>A</u>	x		A	A				
C. rhyacoensis									<u>A</u>								
C. spp.			x	x				x		x	x	x	x	x			
Monocyathus spp.		<u>x</u>	x				x										<u>A</u>
Protopharetra dunbari							x	x									<u>A</u>
P. raymondi						<u>A</u>											
(P. spp.)				x				x		x	x						
Pycnoidocoscincus spp.		<u>A</u>						x									
Pycnoidocycathus amourensis							x	x				x	x				<u>A</u>
(Pycnoidocycathus spp.)								x			x			x			
<u>GSC 46424</u>																	
Archaeocyathus atlanticus						x	x	x	x		x	x	x		x		<u>A</u>
Ethmophyllum cooperi					<u>x</u>												
(E. spp.)						x	x										
Sigmocyathus spp.		<u>x</u>															
Syringocnema spp.		x	x	x			x										

Symbols underlined denote type locality of species or genus: A = abundant x = presence reported
 Unnamed species not in parentheses are recorded as such in the faunal list for Section 2; those in parentheses indicate the distribution of named species of the genus not found in Section 2.

Distribution and age

The Archaeocyatha were collected from two localities approximately 922' apart stratigraphically in a composite section. There is no conclusive evidence of tectonic thickening of the section between these two horizons, but the possibility cannot be discounted.

GSC 46424:

The lower assemblage comprises five species, of which two, Sigmocyathus sp. and Syringocnema sp., are known chiefly or solely from South Australia and Antarctica. The latter genus has also been reported from Caborca, Mexico, and Colville, Washington. They may indicate later Early Cambrian age, on the basis of tentative correlation of their type-locality in South Australia with the lower part of the Lena Stage of the Siberian Platform (cf. Hill, 1965, p. 81). Ethmophyllum cooperi is known only from Mexico, but Ajacicyathus nevadensis is found in almost all archaeocyathid faunas of western North America as far north as Sinclair Mills, near Prince George, British Columbia; it is most abundant in Nevada and California, rare in southern B.C., and is not reported from the Yukon Territory. This occurrence therefore extends its known present geographic range about one hundred miles further north. It is probably more abundant in older than younger faunas, but is found in both collections from the Murray Range. Archaeocyathus atlanticus was first described from Labrador, and is widely distributed throughout North America, with the exception

of California, Mexico, and the central and southern Appalachian localities. It is generally considered characteristic of the lowermost archaeocyathid zones of the Lower Cambrian ("zones" sensu lato, because they are not yet clearly defined in North America).

GSC 46421:

Ten species are identified from the upper locality; some of them might suggest the earlier part of Early Cambrian time, but the weight of evidence is slightly in favour of a later Early Cambrian age. The above remarks on the comparatively late age of Syringocnema apply also to Monocyathus and Pycnoidocyathus, described originally from the same locality, the Ajax Mine at Beltana, South Australia. Coscinocyathus dentocanis and other species of Coscinocyathus are relatively abundant at several localities, such as Salmo, the Dogtooth Range, Sinclair Mills, Aiken Lake and the McDame area in British Columbia, and at Wolf Lake in the Yukon Territory, but they are not present at Colville. The Colville fauna is regarded as earlier than those of these other localities. Pycnoidocyathus amourensis and other species of the genus are found at all of the above localities. Species of Archaeosycon are seen in the Dogtooth Range and the McDame area, where the archaeocyathid zones are probably correlative in age and are considered to be the latest known occurrences in the Western Cordillera. Archaeocyathellus sp. occurs only in the Salmo fauna, which is of later Early Cambrian age, but is older than the Dogtooth fauna.

Coscinocyathus spp., Pycnoidocyathus spp. and Protopharetra spp. help to correlate the Aiken Lake, Sinclair Mills and Salmo faunas, whereas the Dogtooth and McDame faunas are considered younger because they do not include Protopharetra or Ethmophyllum, but do contain several forms such as Archaeosycon that are not found in any of the other assemblages. Protopharetra sp. and P. dunbari in turn link the Aiken Lake, Sinclair Mills and Salmo assemblages to the Colville fauna, considered the oldest because of the preponderant abundance in it of Archaeocyathus atlanticus and Protopharetra dunbari. Both Protopharetra and Coscinocyathus are comparatively well represented in the present collection, and one can safely say only that it seems to show greater affinity to later than to earlier Early Cambrian assemblages.

Because the relatively early age of the Colville fauna is well attested, it is rather surprising to find in it Monocyathus and the comparatively "advanced" (Okulitch, oral communication) form Syringocnema. In the lower of the two present collections, Syringocnema is clearly the predominant form, and together with Sigmocyathus makes it unlikely that the assemblage is as old as the Colville fauna. The wide stratigraphic separation of the lower and upper localities on Old Friend Mountain therefore seems all the more striking; but so little is known about the zonation of Archaeocyatha that one cannot assume that this separation is excessive and needs to be explained in terms of tectonism.

It is concluded that the upper of these two archaeocyathid assemblages is almost certainly later Early Cambrian in age, and that the lower assemblage is unlikely to be as old as the Colville fauna, in which Syringocnema is rare. The Colville Old Dominion limestone which contains the archaeocyathid fauna is underlain in turn by the Addy quartzite, which has yielded Nevadia, other olenellid fragments and brachiopods characteristic of the lowest part of the Olenellus zone (Okulitch, 1951, pp. 405-407).

Phylum Arthropoda

Class Trilobita Walch, 1771

Order Agnostida Kobayashi, 1935

Suborder Eodiscina Kobayashi, 1939

Family Pagetiidae Kobayashi, 1935

Genus Pagetia Walcott, 1916

Pagetia cf. P. bootes Walcott

Pl. 3, fig. 1.

Pagetia bootes Walcott, 1916, p. 408, pl. 67, figs. 1, 1a-1f;
Rasetti, 1951, p. 137, pl. 25, figs. 6-10.

P. cf. P. bootes Walcott, Rasetti, 1951, p. 137, pl. 33, figs.
9-11.

Two poorly preserved cranidia may represent the species. They differ from the specimens assigned to P. cf. P. ellsii in the faintness of radial ornamentation on the anterior border; very restricted depressed area between glabella, fixed cheeks

and border; more bluntly-tapered, less distinctly furrowed glabella; and more irregularly sloping raised portion of fixed cheeks. Palpebral lobes are barely discernible, ocular ridges absent. Occipital spine somewhat raised, but of unknown length. Pygidium not seen.

Specimens: GSC 46431, nos. 5, 12.

Locality: Section 3, 4390-4395' above base.

Age: Middle Cambrian; species originally described from the Burgess shale (Bathyriscus-Elrathina zone) in the upper part of the Stephen Formation, Mount Field, British Columbia.

Pagetia cf. P. ellsii Rasetti

Pl. 3, figs. 2, 3, 7, 8.

Pagetia ellsii Rasetti, 1945, p. 315, pl. 2, figs. 13-18; 1948b, p. 321, pl. 46, figs. 1-4.

According to Rasetti, this species differs from P. bootes Walcott chiefly in the shape and size of the preglabellar depression; P. bootes has only a narrow longitudinal median furrow, whereas in P. ellsii, a distance equal to the length (sag.) of the anterior border separates the tapered anterior ends of the raised fixed cheeks. Moreover, in all Rasetti's figures (1945, pl. 2, fig. 13; 1948b, pl. 46, figs. 1, 4) of P. ellsii, the radial ornamentation of the anterior border is much more distinctly impressed than in P. bootes (Rasetti, 1951, pl. 33, fig. 9), and the raised

border encloses a longer, wider frontal area and preglabellar field; this is produced partly by attenuation of tapered fixed cheeks adaxially, partly by a slight advancement of the anterior border in P. ellsii by comparison with that of P. bootes, thereby enclosing a crescentic depression.

In the present specimens, cranidial features are very well defined, although no individual is entire. Fixed cheeks (exclusive of frontal areas) and glabella are sharply tapered forward and strongly convex. Short palpebral lobes, approximately opposite midpoint of glabella, are clearly visible, and lead into faint ocular ridges which disappear altogether near axial furrows. Facial sutures are not seen. Glabella distinctly divided into three lobes by shallow lateral furrows; the fainter anterior pair is continuous across the axis, the posterior pair discontinuous but a little wider (exsag.), and constricting the glabella laterally. Frontal lobe triangular, short (sag.); second lobe of median length and width; posterior lobe short, but wide (transv.), and appears almost bilobed as a result of slight backward slant of first glabellar furrows and slight forward slant of deeper lateral portions of occipital furrow. Cranidial furrows are appreciably more distinct here than in any published figures of the species. Occipital ring is very narrow (transv.), and carries a long, very slender spine, somewhat elevated.

Radial notches in anterior border numerous, generally deep and sharp, terminating anteriorly in a deeper pit of the same

width; they do not reach the anterior margin, but are all sharply truncated at a uniform, very short distance from it.

The associated pygidia most likely to be conspecific with these cranidia are all strongly convex, with deep distinct border-, axial and ring-furrows; pleural lobes show only faint traces of furrows close to axis; axis has five rings, each having a faint node; terminal piece with longer, raised spine (interpreted from damaged specimens).

Specimens: GSC 46431, nos. 1, 3, 4, 5 (poorly exposed), 6, 8, 12, 13 and 16.

Locality: Section 3, 4390-4395' above base.

Age: Rasetti (1945, p. 315) describes the species from a "Lower Cambrian" boulder in the Sillery Formation near Lévis, Quebec, where it is part of an assemblage later (1948b, p. 317) found to be of early Middle Cambrian age.

Order Redlichiida Richter, 1933

Suborder Olenellina Resser, 1938

Family Olenellidae Vogdes, 1893

Subfamily Olenellinae Vogdes, 1893

Genus Olenellus Billings, 1861

The classification adopted by the Treatise is adhered to for present purposes; it is acknowledged that O. (Olenellus) Billings

and O. (Paedeumias) Walcott could be considered as subgenera, but the distinction will not be discussed here.

Olenellus gilberti Meek

Pl. 3, fig. 4.

Olenellus gilberti Meek, 1874, (manuscript).

O. gilberti (Meek), fide White, 1874, p. 7. (Copies Meek's manuscript description).

(Extensive revision of the species, and of specimens described and assigned to it, has taken place in recent years; no attempt is made here, therefore, to provide a comprehensive synonymy, which is a task for the specialist. The remainder of this partial synonymy is quoted, with full acknowledgment and minor changes in form, from Best (1959, p. 86), whose taxonomic revision of the Olenellidae is currently in preparation for the press).

O. gilberti Meek, Walcott (part), 1910a, pp. 324-331; pl. 36, figs. 1, 3, 4, 7(?), 16, pl. 40, fig. 8(?); (not pl. 36, figs. 2, 6, 7, 17=Paedeumias sp.; not pl. 36, figs. 11, 12, 14, pl. 43, figs. 5, 6= (?)Bristolia sp.; not pl. 36, fig. 15=Fremontia sp.).

Mesonacis gilberti (Meek), Walcott, 1916, p. 407; pl. 45, fig. 3.

Paedeumias robsonensis Burling, 1916, p. 53, pl. 1 (widely copied since by other authors).

O. gilberti Meek, Palmer, 1957, pp. 105-128, figs. 1, 2, 6-9; pl. 19, figs. 1-3, 6, 11, 12, 15, 16, 19.

The species appears to be represented in this collection by the impressions of three fragmentary cephalae, each containing

only one ocular lobe and half of the glabella. Four glabellar lobes and small part of frontal lobe seen; first and second lobes (occipital and pre-occipital) of equal length (transv.), slanting forwards towards axial furrow; 3rd lobe slightly shorter; 4th lobe approximately same length as first two, sharply curved back abaxially and confluent distally with 3rd lobe; very little of frontal lobe preserved, but appears to be no wider (transv.) than 4th lobe. Ocular lobes long, slender and crescentic, tapering very gradually posteriorly, originating anteriorly at posterolateral edge of frontal lobe, but separated from it by shallow furrow; bearing shallow furrow close to abaxial edge, not extending all the way to posterior tip. Glabella and eyes only moderately raised; palpebral area almost flat, or only very slightly convex.

This specific assignment is indicated by the length of the ocular lobes; those of O. thompsoni (Hall) may or may not reach posterior border, but those of O. gilberti invariably do (Best, *ibid.*, p. 87).

Specimens: GSC 46428, nos. 18, 20, 45.

Locality: Section 3, 3894-3900' above base.

Age: Early Cambrian; Best remarks (*ibid.*, p. 89) "O. gilberti appears to be one of the latest Olenellidae. It is definitely identical in the Pioche Formation of Nevada, the Mount Whyte of Jasper Park, Alberta, and the Mahto of Mumm Peak, Mount Robson, B.C."

Olenellid fragments, genus et. sp. indet.

Pl. 3, fig. 9.

Two broad flat fragments appear to represent the dorsal surface of cephalon, and another appears to be the imprint of an internal surface. Dorsal surfaces are flat, smooth, and bounded by a narrow but distinctly raised border. Antero-lateral and posterior borders, slender genal spine and very short metagenal spine are seen in the smaller specimen (46428-6), and show that the cephalon is almost perfectly semi-circular, with slight axial elongation. Larger specimen (46428-13) displays faint radial genal caecae. Internal impression shows broad doublure with fine sub-parallel terrace lines; remainder of specimen bears ornamentation which is finely reticulate over most of the surface, but merges into faint radial venation in some places (46428-46).

About a dozen other fragments of carapace, or impressions, display well-defined reticulate ornamentation. In some (e.g. nos. 14, 37) the lines are distinctly raised (or are seen as depressed lines in the corresponding impressions, e.g. no. 49); several show small granules or pits at the centre of meshes, but there is no reliable evidence of puntal control of the lines themselves.

None of these fragments is identifiable to genus, but it may be remarked that polygonal ornamentation is characteristic of Olenellus and Wanneria, both comparatively late Early Cambrian forms.

Specimens: GSC 46428, nos. 6, 7, 10, 11, 13-15, 18, 20, 32, 37, 40, 44-46, 48, 49; GSC 46429.

Localities: Section 3, 3894-3900' and 3915-3925' above base respectively.

Genus *Paedeumias* Walcott, 1910

Paedeumias transitans Walcott

Pl. 3, figs. 5, 10.

Paedeumias transitans Walcott, 1910a, pp. 305-310, pl. 34, figs. 1, 2, 4-7 only; Resser and Howell, 1938, p. 226, pl. 8, fig. 13.

Shaw (1955, p. 791) places *P. transitans* in synonymy with *Olenellus brachycephalus* (Emmons), defined therein for the first time although referred to by name in a previous paper (Shaw, 1954, pp. 1041, 1044). However, two of his figures (1955, pl. 75, figs. 1, 2, not 10) clearly show the median ridge between anterior border and frontal glabellar lobe that characterizes *Paedeumias*. The present writer agrees with Shaw's specific designation, but the name "*Paedeumias brachycephalus*" is not yet in the literature. No attempt is made now to list the numerous Appalachian and Cordilleran forms that are morphologically indistinguishable from *P. transitans* (R.V. Best, personal communication). Until a more satisfactory name is published, the latter has priority.

The species is represented by three, perhaps, four, incomplete

juvenile individuals, and a larger one that cannot be adequately exposed without endangering other specimens. The diagnostic anterior median ridge is clearly visible in the two largest individuals, but only faintly in the smallest juveniles. Assignment of the remaining specimen is more doubtful, as only the glabella and part of one ocular lobe are preserved.

Specimens: GSC 46429, nos. 4, 10-12.

Locality: Section 3, 3915-3925' above base.

Age: Latest Early Cambrian (type-locality, the Lower Parker Shale, northwestern Vermont); also found in the Pioche Formation, Nevada, the Kippens Formation, Bay St. George, Newfoundland, and the Buelna Formation, Sonora, Mexico (identical forms; Best, 1959, p. 114).

Subfamily Wanneriinae Hupé, 1953

Genus Wanneria Walcott, 1910

Wanneria sp.

Pl. 3, fig. 15.

Part of the genal extremity of a fairly large specimen is preserved as an impression of the dorsal surface, together with a very small fragment of the test.

Acute genal angle (not susceptible of precise measurement, but suggesting strongly swept-back posterior margin), and broad

cephalic border are diagnostic of the genus (*sensu stricto*). Identification is confirmed by coarse polygonal ornamentation on the genal platform, grading into elongate meshwork and subparallel terrace lines on the border; the polygonal meshes lack central granules. Genal spine lost.

Specimen: GSC 46429, no. 13.

Locality: Section 3, 3915-3925' above base.

Age: Later Early Cambrian.

Order Corynexochida Kobayashi, 1935

Family Dorypygidae Kobayashi, 1935

Genus *Bonnia* Walcott, 1916

Bonnia bicensis Resser

Pl. 3, fig. 14.

Corynexochus bubaris Walcott (part), 1916, p. 314, pl. 56, fig. 2a (only).

Bonnia bicensis Resser, 1936, p. 10; Rasetti, 1948, p. 15, pl. 3, figs. 1-15.

Rasetti describes in detail plesiotypes from Resser's type-locality, Bic, Quebec.

Assignment of the present specimens is confirmed by the following features: glabella gently expanding anteriorly, rounded-truncate in front, bounded laterally by straight axial furrows of moderate depth, and slightly constricted in front of antero-

lateral fossulae; posterior pair of lateral glabellar furrows short, deep and slanting backwards from axial furrows; second pair of glabellar furrows shallower, fainter; other pairs indistinct. Anterior border very narrow, frontal areas of fixed cheeks greatly reduced; occipital furrow moderately deep mesially, abruptly deeper laterally; occipital ring subtriangular and steeply elevated posteriorly, forming short blunt spine; palpebral lobes low, approximately one-third length of glabella, and set off by shallow palpebral furrows.

Surface ornamentation is conspicuous. Occipital ring and posterior portions of glabella and palpebral areas closely granulose; further forward, glabella and palpebral lobes are smoother and finely punctate; anterior slope of glabella covered with very fine concentric terrace lines. A fragmentary pygidium with granulose surface may also be referable to this species.

Specimens: GSC 46429, no. 4 (cranidium), 5 (pygidium).

Locality: Section 3, 3915-3925' above base.

Age: Early Cambrian, Upper Olenellus subzone.

Bonnia brennus (Walcott)

Pl. 3, figs. 11, 12, 16, 17.

Corynexochus brennus Walcott, 1916, p. 314, pl. 57, figs. 3-3b.

C. bubaris Walcott (part), 1916, p. 314, pl. 56, fig. 2b (only),
for distinctive ornamentation.

Bonnia brennus (Walcott), Resser, 1936, p. 7; Rasetti, 1948,
p. 16, pl. 3, figs. 16-25.

B. quebecensis Resser, 1936, p. 10.

The above references to C. bubaris Walcott and B. quebecensis Resser are quoted from the synonymy given by Rasetti (1948). They do not imply critical appraisal by the present writer.

Both Walcott and Rasetti include ornamentation as one of the diagnostic features of the species, and for that reason Rasetti disputes Walcott's identification of a fragment as B. bubaris (see synonymy above). Of about a dozen specimens in this collection assigned to B. brennus, only two possess any distinctive ornamentation. GSC 46428-37 has granulose ornamentation on palpebral areas and posterior half of glabella, and "fingerprint" lines on frontal lobe only. Nevertheless, the totality of other features so strongly matches published figures of the species that identification is more than merely tentative.

Glabella strongly but fairly uniformly convex in both directions; moderately expanded anteriorly, but slightly constricted in front of antero-lateral fossulae; axial furrows straight, shallow but distinct; posterior pair of lateral glabellar furrows shallow but generally distinct, particularly near axial furrow; other lateral glabellar furrows very faint; palpebral areas gently convex, not more than half as wide as glabella opposite

ocular lobes; preocular areas very short (exsag.) and sloping steeply towards anterior border, which is low and very narrow. Ocular ridges obscure in some specimens, but clearly visible in most; eyes fairly short, slightly curved, not as advanced or as oblique as in B. similis Rasetti. Occipital ring tapers laterally, but is rarely well enough preserved to determine presence or absence of "incipient occipital spine" (Rasetti's term). Occipital furrow fairly deep except mesially.

Position and arrangement of eyes, and shape of occipital ring, chiefly distinguish cranium of this species from that of B. similis, which it otherwise closely resembles.

The collection contains numerous pygidia that may more reasonably be assigned to this species than to any other. Some are slightly more transverse than others; in some, a fourth axial ring may be more easily seen than in others, in which the terminal piece and posterior axial ring are so poorly differentiated that they appear to be a single elongate segment. A small marginal spine posterior to the antero-lateral spine is visible in some, obscured or absent in others. All the specimens have a prominent, rounded rather than pointed terminal piece reaching posterior border; four pleural segments, of which the posterior-most is very small, almost obsolete; narrow, flat border, generally with very slight anterior deflection mesially; border furrow without depth, merely a break in slope of surface; shallow pleural furrows and very faint interpleural grooves; a pair of

small spines, backward-curving, at antero-lateral corners. One specimen (GSC 46428-24) displays very faint paired nodes on terminal piece and two posteriormost axial rings.

Rasetti's (1948, p. 16) diagnosis of B. brennus specifies "three segments and a terminal section . . . separated by increasingly shallow furrows", but in one of the two pygidia that he figures (pl. 3, fig. 19) a fourth ring may be distinguished, exclusive of the articulating half-ring. Moreover, the two pygidia (figs. 19, 20) display small but quite distinctive differences of outline.

Specimens: GSC 46428, nos. 2, 4, 6, 7 (larger specimen; smaller one doubtful), 9, 13, 24 (?), 28, 37, 43, all cranidia; nos. 5, 11, 13, 19, 24, 30, 32, 39 (may contain two species), 47 (?), 49 - pygidia.

Locality: Section 3, 3894-3900' above base.

Age: Later Early Cambrian.

Bonnia bubaris (Walcott)

Pl. 3, fig. 18.

Corynexochus bubaris Walcott (part), 1916, p. 314, pl. 56, fig. 2 (only).

Bonnia bubaris (Walcott), Resser, 1936, p. 10; Rasetti, 1948, p. 17, pl. 4, figs. 16-24.

Rasetti's description, in part:

"Glabella strongly convex in both directions, the longitudinal convexity being greater anteriorly. Glabella moderately expanding forward, almost straight-sided, with shallow but distinct posterior furrows and a trace of two other pairs. Border in front of the glabella very narrow. Occipital furrow deep; occipital ring with a slender upturned spine . . .

Pygidium with a relatively narrow, tapered axis that does not quite reach the marginal furrow, . . . Axis composed of three segments plus a terminal section, separated by increasingly shallow furrows. Pleural lobes with four wide, shallow furrows and as many distinct interpleural grooves. Border rather narrow, with two pairs of short spines.

"The surface of the glabella is covered with fine granules, the spaces between the granules being punctate . . . "

The cranidium herein assigned differs only very slightly from this description. Glabellar outline, distinctive posterior pair of lateral glabellar furrows, and sharply upturned occipital spine are considered to support the identification.

Glabella is less globose than that of B. occipitalis Rasetti, which also has a prominent occipital spine; and with the exception of the posteriormost pair of furrows, lateral glabellar furrows are less conspicuous than those of B. bicensis Resser or B. senecta (Billings). The glabella of B. brennus (Walcott) is more strongly expanded anteriorly. B. brennoides Rasetti and Bonia laevigata Rasetti possess a smooth glabella, with only the faintest trace of lateral furrows. Walcott's (1916) figure 2 clearly shows occipital spine, but does not adequately illustrate character of glabellar furrows.

The pygidium most closely associated with this cranidium

has four axial segments, not three, besides articulating half-ring and terminal piece; but Rasetti (ibid., pl. 4, fig. 19) shows a pygidium with at least four axial segments, not including terminal piece. A more serious difference is the absence of "post-axial ridge" mentioned by Rasetti; the terminal piece appears to reach posterior border, as in B. brennus (Walcott). Although pygidium and cranidium actually overlap in GSC 46428-36, they may still belong to different species. Other specimens from the same locality are assigned to B. brennus.

Specimens: GSC 46428, no. 36 (cranidium and, questionably, pygidium). A cranidium in 46428-16 may also belong to this species; critical diagnostic features are concealed, but the surface is finely granulate.

Locality: Section 3, 3894-3900' above base.

Age: Later Early Cambrian; all the species of Bonnia mentioned above are described by Rasetti (1948) from Lower Cambrian boulders in the Lévis conglomerate, Quebec.

Bonnia similis Rasetti

Pl. 3, fig. 23.

Bonnia similis Rasetti, 1948, p. 17, pl. 4, figs. 7-10.

The specimen closely resembles B. brennus, but is devoid of ornamentation. Glabella has greatest longitudinal convexity in frontal portion; preocular areas are shorter (exsag.) than in

B. brennus; palpebral lobes are shorter, and situated more obliquely and further forward than in B. brennus.

In these respects it accords fully with Rasetti's diagnosis of the species.

Specimen: GSC 46429, no. 7.

Locality: Section 3, 3915-3925' above base.

Age: Latest Early Cambrian; it is associated with Wenkchemnia sulcata and Kootenia spp. as well as olenellid trilobites and other species of Bonnia.

Bonnia tensa Resser

Pl. 3, fig. 13.

Bonnia tensa Resser, 1938, p. 66, pl. 3, fig. 46; Rasetti, 1948, p. 18, pl. 5, figs. 21-28.

This species is distinguished by its weakly convex, straight-sided glabella, moderately expanded and slightly truncated anteriorly, with shallow axial furrows and extremely narrow anterior border; deep antero-lateral fossulae, small frontal areas of fixed cheek, low palpebral areas and weak palpebral lobes. Lateral glabellar furrows very faint; occipital furrow shallow mesially, fairly deep laterally.

The present specimen conforms with this description in almost every respect, but the occipital furrow is only slightly deeper laterally than mesially. Posterior limbs approximately one-and-one-quarter times length (transv.) of occipital ring; rounded and fairly deeply furrowed as in B. bicensis. The specimen is clearly distinguished from B. bicensis by the lack of a deep, distinct posterior pair of lateral glabellar furrows, and by its comparatively smooth surface.

Shaw (1955, p. 781) places B. tensa in synonymy with Bonnia capito Walcott; but as his figures (pl. 73, figs. 15, 24) appear to include two different forms, Resser's designation is preferred here.

Specimen: GSC 46429, no. 3.

Locality: Section 3, 3915-3925' above base.

Age: Early Cambrian, Upper Olenellus subzone. Resser's holotype is from the Shady Formation of Virginia, which also contains archaeocyathine reefs (Resser, 1938, p. 36). Rasetti (1948) describes in detail plesiotypes from conglomerates at Grosses Roches, Quebec.

Genus Kootenia Walcott, 1888

Kootenia burgessensis Resser

Pl. 3, figs. 22, 25.

Kootenia dawsoni Walcott (part, 1918, p. 131, pl. 14, figs. 2, 3.
Kootenia burgessensis Resser, 1942, p. 27; Rasetti, 1951, p. 189,
 pl. 28, figs. 9-11.

Fragmentary pygidium with flat border and marginal spines, strongly convex pleural and axial lobes. Axis with articulating half-ring, terminal piece and four rings; four pleural segments, thoroughly fused, with shallow pleural furrows; interpleural furrows obsolete, the rims of pleural segments being marked only by very faint raised lines; anterior rim of segments slightly longer (transv.) than posterior, giving border furrows a stepped outline on the inner side.

Six pairs of marginal spines; longer, with deeper, narrower spaces between spines than in K. dawsoni; but fairly rapidly-tapering, and shorter, less slender, than in K. convoluta. It may be compared with the specimen figured by Rasetti (1951, pl. 28, fig. 11; less transverse than fig. 10).

Two associated cranidia may be conspecific with this pygidium; they are of generalized Kootenia type, and are not distinctive.

Specimens: GSC 46431, nos. 14 (pygidium), 1 and 4 (cranidia); nos. 2 and 3 are counterpart impressions of nos. 1 and 4.

Locality: Section 3, 4390-4395' above base.

Age: Probably early Middle Cambrian, possibly as late as the Bathyriscus-Elrathina zone; Resser's type-specimen is from the

Burgess Shale between Mount Field and Mount Wapta, British Columbia.

Kootenia cf. K. buttsi Resser

Pl. 3, fig. 19.

Kootenia buttsi Resser, 1938, p. 85, pl. 7, figs. 16, 17.

Resser defines his new species exceedingly briefly; but he notes the "long glabella" and the "presence of axial spines on the pygidium", the well-defined pleural furrows and six short blunt marginal spines.

The present specimen has the same number of pleural ribs and axial rings as the type-specimens, and the axis is abruptly arched in the transverse direction, with traces of short spines on the anteriormost axial rings. Despite the poor development of marginal spines, this specimen appears to be morphologically indistinguishable from K. buttsi.

Specimen: GSC 46429, no. 3.

Locality: Section 3, 3915-3925' above base.

Age: Although the holotype is from the Middle Cambrian Rutledge Formation of Alabama, this appears to be a wide-ranging form of comparatively poor value as a stratigraphic index. In the southern Appalachians, the pygidia of Middle Cambrian species of

Kootenia are rather less spinose than those of Early Cambrian species. GSC 46429-3 is associated with olenellid trilobites, Bonnia tensa, and B. bicensis.

Kootenia exilaxata Deiss

Pl. 3, figs. 20, 21, 24.

Kootenia exilaxata Deiss, 1939a, p. 100, pl. 17, figs. 23-26;
Lochman, 1952, in Cooper et al., p. 125, pl. 26, figs. 1-20.

Three species erected by Deiss (ibid., pp. 100, 102), Kootenia exilaxata, K. erromena and K. scapegoatensis, are very similar; all have more or less rectangular glabella, and slightly transverse pygidium with six pairs of marginal spines, four axial rings and three or four pleural segments. (Deiss describes the pygidium in terms of three axial rings and three pleural segments, but his figures leave room for a difference of opinion). They differ slightly in glabellar proportions, prominence of occipital spine, length and direction of pygidial marginal spines, and degree of taper of pygidial axis. Lochman places three of Deiss's species, including K. scapegoatensis, into synonymy with K. exilaxata.

One pygidium is now assigned to the species, and three associated cranidia are probably conspecific with the pygidium.

Pygidium appears slightly transverse, perhaps because of the comparatively slight curvature of its postero-lateral margins; length (sag.) is almost two-thirds width, exclusive of spines. Axis relatively narrow, gently-tapering, consisting of articulating half-ring, bluntly-pointed terminal piece and probably four axial rings. Pleural lobes moderately convex, sloping more steeply near border furrows; anterior pleural furrows deeper than posterior; pleural furrows persist as depressions across border furrow and border itself; interpleural furrows not visible. Spines directed more or less horizontally and straight backwards, although anterior pairs show a slight outward flare.

Cranidium has sub-rectangular glabella, only slightly rounded in front; length (sag.) of glabella and occipital ring approximately twice their width; anterior border narrow, not conspicuously raised, widening laterally into a flat frontal area of about the same length (exsag.) as that of the occipital ring. Deep, distinct antero-lateral fossulae; axial furrows deep, occipital furrow deeper laterally than mesially. Glabella more strongly convex longitudinally and transversely than in Deiss's figured type-specimens; ocular ridges and palpebral lobes indistinct in the present specimens. Posterior limbs long, rounded distally, and deeply furrowed; not swept backwards. Occipital ring slightly expanded mesially, and bearing short spine.

Surface of scant remaining portions of test is smooth, ornamentation being confined to faint sub-parallel terrace lines

on anterior border of one cranidium.

Specimens: GSC 46430, nos. 2, 7 and 15 (cranidia), 26 (pygidium).

Locality: Section 3, 4303-4308' above base.

Age: Early Middle Cambrian; Glossopleura-Kootenia zone, near the base of the Damnation Limestone, Scapegoat Basin, Lewis and Clark Range, Montana (Deiss, 1939a, pl. 2, fig. 2); and in Sonora, Mexico, it is found in Kootenia beds between two sets of Glossopleura-Sonoraspis beds in the Arrojos Hills, and about 300' up-section from Albertella beds in the Proveedora Hills (Cooper et al., 1952, p. 7 and p. 128).

Kootenia marcoui (Whitfield)

Pl. 4, figs. 1, 2.

Dikellocephalus? marcoui Whitfield, 1884, p. 150, pl. 14, fig. 7.

Kootenia marcoui (Whitfield), Resser, 1937, p. 16; Shaw, 1955, p. 786, pl. 74, figs. 1-4 (with remaining synonymy to 1955)

Three pygidia are assigned with some assurance to this species, and two cranidia closely associated with the pygidia are believed to be conspecific with them.

Pygidium semi-circular to slightly elongate in adult specimens; a smaller specimen is more transverse, with more acute antero-lateral angles. Pleural platforms moderately raised, sloping most steeply near narrow, flat postero-lateral border.

Axis gently tapering, more strongly convex posteriorly, and with stronger transverse curvature in the smaller than in the larger specimens. Pleural furrows rounded and deep, interpleural furrows very shallow and faint; axial furrows deep and distinct in larger specimens, shallow in the smaller individual. One pair of short, sharp, curved antero-lateral spines and six pairs of marginal spines, the latter broken and of unknown length; projection of remaining tapered portions suggests that they were fairly long. Six pleural segments; articulating half-ring, terminal piece and seven axial rings, several of which bear low nodes near their posterior edge; as many as three of the anteriormost rings may have been spinose.

Axial rings of a pygidium figured by Rasetti (1948, pl. 2, fig. 7) and compared with K. marcoui display exaggerated 'flattened M' form, of which there is only the faintest suggestion in the holotype pygidium illustrated by Shaw, and none at all in the present specimens. Shaw enumerates five pleural segments and six axial rings; his figures suggest that these numbers should be six and seven respectively. He has inferred rather than counted the number of marginal spines; both holotype and paratype pygidia are damaged and incomplete.

Associated pygidia are incompletely exposed in an extremely refractory matrix; glabella, palpebral lobes, posterior limbs and occipital ring are typically corynexochid. Glabella with three pairs of lateral furrows; posterior pair bifurcating

adaxially, anterior branch short, deep and transverse, posterior branch longer but shallower, with abrupt backward, then adaxial, inflexion producing sigmoidal pattern; second pair shorter and shallower but distinct; anterior pair very short, confined to steeply-sloping antero-lateral corner of glabella, producing slight constriction of frontal lobe. Test finely and closely granulose.

Specimens: GSC 46429, nos. 9 (cranidia and larger pygidia), 15 (Smaller pygidium).

Locality: Section 3, 3915-3925' above base.

Age: The holotype and Shaw's plesiotypes are from the Lower Parker Slate (uppermost Lower Cambrian) of Vermont. The species does not appear to have been described before from western Canada.

Genus *Olenoides* Meek, 1877

Olenoides serratus (Rominger)

Ogygia serrata Rominger, 1887, p. 13, pl. 1, figs. 2, 2a.

Olenoides nevadensis (Walcott, not Meek), Walcott, 1888, p. 165.

Neolenus serratus (Rominger), Matthew, 1899, p. 53.

N. granulatus Matthew, 1899, p. 55, pl. 2, figs. 1a-c.

Olenoides serratus (Rominger), Kobayashi, 1935c, p. 153; Rasetti, 1951, p. 189, pl. 27, figs. 1-3.

O. cf. O. serratus, Rasetti, 1948b, p. 339, pl. 52, figs. 9-11.

Pygidium semicircular; straight anterior margin makes obtuse

angle with anterior spines; gently tapering axis with four axial rings and bluntly-rounded terminal piece; anterior rings may have axial nodes or short spines; five pairs of long, slender marginal spines, four of them continuous with strong pleural ribs, not appreciably depressed at border furrow, which is much deeper mesially than laterally. Pleural furrows deep, rounded, running obliquely across pleural segment as usual in Olenoides; interpleural furrows shallow but very distinct.

The species is represented for certain by only one pygidium; several associated cranidia of Olenoides type may be conspecific with it, or with Olenoides maladensis that is also present at this locality.

Specimen: GSC 46430, no. 25.

Locality: Section 3, 4303-4308' above base.

Age: Early Middle Cambrian; type-locality of the species is Mount Stephen, British Columbia, where it is found in the Ogygopsis shale; Rasetti (1951, p. 116, Table 4) reports the genus from the Bathyuriscus-Elrathina zone only. ?Elrathina sp. is associated with this specimen in the same bed.

Olenoides maladensis Resser

Pl. 4, figs. 3, 4.

Olenoides maladensis Resser, 1939b, p. 46, pl. 10, figs. 27, 28.

Original description, in part:

"Only pygidia have been found . . . The axis is long and stout, terminating abruptly at the marginal furrow. Four axial rings and a terminal segment are clearly defined by rather broad furrows. Four pleura are clearly defined, each ending in a long, recurved spine. The rear pleuron is flexed back around the rear lobe of the axis. The anterior axial rings have blunt spines. Surface very granulose."

Two pygidia are assigned to this species. The larger specimen differs from Resser's holotype only in degree of surficial granularity; the terminal piece of the smaller individual is crossed by a shallow but distinct transverse furrow that becomes extremely faint laterally. Because there is no appreciable restriction of the axis at this point, it cannot be safely said that a fifth axial ring is present. The feature is regarded here as an instance of intraspecific variability.

Specimens: GSC 46430, nos. 5 and 6.

Locality: Section 3, 4303-4308' above base.

Age: Early Middle Cambrian. Resser's holotype is from the Ptarmigania strata of the northern Wasatch Mountains of Utah and Idaho; these beds are in limestone immediately underlying the Spence Shale member of the Ute Formation. The Ptarmigania fauna contains elements both of later Early Cambrian and early Middle Cambrian age, and most closely resembles the fauna of the Comet Shale, Pioche district, Nevada.

At the present locality, the species is associated with O. serratus, Elrathina sp., Kootenia exilaxata, Ogygopsis spp., etc.

Olenoides sp. or spp. indet.

Pl. 4, figs. 7, 8.

Five fragmentary cranidia are associated with the pygidia of O. serratus and O. maladensis within a 5' thickness of beds.

Glabella moderately convex, cylindrical, rounded in front, and touching anterior border, which is upturned, uniformly short (sag., exsag.), and more strongly curved mesially than laterally. Axial and anterior border furrows well-impressed in most specimens; occipital and posterior border furrows shallower. Three pairs of lateral glabellar furrows, generally shallow and short, the posterior pair obscurely bifurcated. Facial suture slightly divergent forwards, widely flaring behind palpebral lobes. Occipital ring and posterior limbs of fixed cheeks of equal width (transv.). Occipital ring generally not greatly expanded mesially, but bearing node or short spine. Palpebral areas about half as wide (transv.) as glabella; palpebral lobes lost in all specimens, but strong eye ridges run towards anterior corners of glabella at approximately 45° to the axis.

The five specimens display minor variations, and in view of their association with pygidia of two species, the cranidia themselves may represent more than one species.

Specimens: GSC 46430, nos. 1, 12, 14, 18 and 22.

Locality: Section 3, 4303-4308' above base.

Age: Early Middle Cambrian.

Unidentified pygidium.

Pl. 4, fig. 24.

Semicircular to slightly elongate, with gently backward-curving anterior margin, rounded antero-lateral corners and a slight forward inflexion of the posterior border mesially. Border is entire, except for very short blunt spine in line with distal end of anterior pleural furrow. Pleural lobes flat, axial lobe moderately convex; narrow, smooth postero-lateral border slightly upturned except at axis. Furrows generally shallow, although distinct; pleural deeper than interpleural furrows, and running diagonally across pleural segment from a point close to anterior edge proximally, almost to posterior edge distally. Axial furrows shallow; depressions between axial rings slightly deeper. Postero-lateral border furrow merely a change in slope of surface, with no depth. Faint paired nodes on axial rings.

Width (transv.)	21mm
Length (sag.)	18mm

This pygidium probably represents a new genus; the writer has found no form exactly like it, although it bears some resemblance to Mapania striata Endo and Resser (1937, pl. 35, fig. 19) in its narrow, smooth, entire border with mesial inflexion,

tapering axial lobe, and converging pleural and interpleural furrows. M. striata is from the Middle Cambrian Mapan Formation of Manchuria.

In its distinctive pattern of pleural and interpleural furrows, this form resembles Olenoides, and is quite different from other genera that may have pygidia with fairly flat pleural lobes and entire margin, such as Ogygopsis and Orria. However, Olenoides as defined invariably possesses marginal spines.

Specimen: GSC 46429, no. 1.

Locality: Section no. 3, 3915-3925' above base.

Family Ogygopsidae Rasetti, 1951

Genus Ogygopsis Walcott, 1889

Ogygopsis aff. Ogygopsis batis (Walcott)

Pl. 4, figs. 18, 22, 23.

Bathyriscus batis Walcott, 1916, p. 337, pl. 48, figs. 4, 4a.

Ogygopsis batis (Walcott), Palmer, 1964, p. F7, pl. 2, figs. 1-6.

The species is represented by at least three cranidia and eight pygidia. Before the publication of Palmer's (1964) paper on a Lower Cambrian trilobite fauna from Esmeralda County, Nevada, they seemed to represent an unusual or even a new species of Kootenia, unusual because of the meagre development of marginal

spines on the pygidium. It is now evident that they belong to the genus Ogygopsis; indeed, they resemble Palmer's figured specimens in every respect except one, namely, the presence of several more pairs of pygidial marginal spines.

Cranidia display the long, highly convex glabella, straight-sided or bowed slightly outward, that is typical of the genus; anterior border is narrow, uniformly curved, and not deflected by glabella; palpebral lobes moderately arcuate, located slightly posteriorly, and set off by shallow but distinct palpebral furrows. As in O. batis, the anterior border is well-defined and clearly separated from glabella, the pleural regions show fine polygonal network of terrace lines, and frontal lobe of glabella has "finger-print" terrace line ornamentation.

Pygidium has seven axial rings, articulating half-ring and terminal piece; axial rings carry a low but distinct node near their posterior edge, and ring furrows are wider (sag.) mesially than laterally. In these respects they resemble Palmer's figures exactly. Similarly, they have no more than six pleural furrows, although one specimen (GSC 46428-24) is teratologically deformed; a kind of defusion has taken place between the two anteriormost pleurae on the left-hand side, so that an extra furrow, as deep as a pleural furrow, extends half-way from axis to lateral margin. Ornamentation is faintly granulose rather than punctate. Pygidial margin bears from three to five pairs of short spines in addition to a strongly backward-curving pair

at antero-lateral corners.

The presence of marginal pygidial spines is of particular interest. The pygidial margin of the type species Ogygopsis klotzi has no spines; but all other species have at least one pair (Palmer, 1964, p. F7). Both spines and pleural furrows are said to be constant in number for each species; some have at least seven pairs, or as many as nine. Stratigraphically, the number of pleural furrows is of greater importance; "No Lower Cambrian specimens have more than six pleural furrows, whereas all Middle Cambrian specimens have seven pleural furrows" (Palmer, op. cit.).

In the present collection, number of marginal spines changes from one specimen to another, but the number of pleural furrows is constant. The writer is therefore inclined to regard the number of spines as being of subordinate importance for specific discrimination.

Specimens: GSC 46428, nos. 3, 35, 36 (cranidia); 1, 8, 10-12, 21, 24, 26 (pygidia).

Locality: Section 3, 3894-3900' above base.

Age: Ogygopsis ranges through Early and Middle Cambrian. O. batis is described by Palmer (op. cit.) from the lower part of the Saline Valley Formation of southwestern Nevada, where it is associated with Paedeumias granulatus Palmer, Wanneria cf. W. walcottana, and species of Zacanthopsis, Bonnia and Syspacephalus. The uppermost part of the Saline Valley Formation yields a Bristolia

fauna. In a resumé of species of Ogygopsis and their stratigraphic ranges, Nelson (1963, p. 247) lists O. batis as "upper Lower Cambrian (Inyo Mountains, Silver Peak, Goldfield, Miller Mountain)".

Ogygopsis, new species A?

Pl. 5, figs. 20, 23.

Pygidium elongate semi-circular to semi-oval, with backward-curving anterior margin, entire postero-lateral margins and very small antero-lateral spines. Pleural and axial lobes only weakly convex; axis about one-sixth total width (transv.) of pygidium near anterior margin. Axis comprises eleven rings, without spines or nodes, besides articulating half-ring and terminal piece; pleural lobes with eleven segments. Pleural furrows moderately deep, rounded; interpleural furrows very shallow but distinctly visible. No surface ornamentation. Posterior margin is indented mesially to a depth equal to approximately one-sixth of the total length (sag.) of the pygidium. Number of segments and depth of marginal indentation distinguish this form from any species so far seen.

Ogygopsis klotzi, the closest form, has a smoothly-curved uninflected posterior border; O. spinulosa Rasetti (1951, p. 192, pl. 21, fig. 4) has a short axis, denticulate margin, and no interpleural furrows; O. batis (Walcott) has low nodes or spines

on the axial rings, and only six pleural segments. O. typicalis (Resser) is a comparatively strongly convex form; it has eight well-defined pleural furrows, and its posterior border is only slightly inflected (Resser, 1939b, pl. 14, fig. 14). O. elongata (McLaughlin and Enbysk), based on badly-distorted specimens, is probably a synonym of O. typicalis (Palmer, 1964, p. F7; McLaughlin and Enbysk, 1950, p. 470, pl. 65, figs. 2, 9).

Specimens: GSC 46430, nos. 11, 23.

Locality: Section 3, 4303-4308' above base.

Age: The specimens are associated with Kootenia exilaxata and Chancia evax, of early Middle Cambrian age (Glossopleura-Kootenia zone in Montana, Glossopleura-Sonoraspis beds in Sonora, Mexico, etc.). In the Canadian Cordillera, the genus ranges from the Wenkchemnia-Stephenaspis zone up to the Bathyriscus-Elrathina zone (Ogygopsis shale) in the Mount Whyte, Cathedral and Stephen Formations.

Ogygopsis, new species B?

Pl. 5, figs. 1, 3, 4, 6.

The form is known from seven pygidia, three of them almost complete and four fragmentary.

Pygidium elongate semi-circular to semi-oval; anterior margin perpendicular to axis proximally, backward-curving distally;

posterior margin with very slight forward inflexion mesially in all but one of the specimens. Postero-lateral margin bearing at least nine short, sharp, backward-pointing spines; spines in line with anterior edge of pleural segments. Pleural furrows rounded in cross-section, moderately deep; interpleural furrows very shallow, distinct in smaller specimens, very faint in larger ones, commonly represented by only a slight concavity of the flat surface of the pleural rib. Ten, possibly eleven, axial rings and at least nine pleural segments. Most axial rings (e.g. anterior seven out of ten) carry low nodes near their posterior edge, which itself is faintly inflected forwards; furrows between rings are thereby slightly broadened (sag.) mesially.

The largest specimen is approximately 40mm wide, 31mm long (sag.), exclusive of spines; the smallest is 19.5mm wide, 15mm long.

In its fairly strong convexity and in the presence of axial nodes, this form resembles O. batis, but the latter has no more than six pleural segments. Marginal spines and strong convexity distinguish it from O. klotzi and O., new species A?. It is much more strongly spinose, and has a slightly longer axial lobe, than O. spinulosa, which is closely resembles in number of pleural segments and axial rings. O. typicalis has only a single pair of marginal spines. References are cited in the discussion of O., new species A?.

Specimens: 46430, nos. 4, 8, 10, 19, 22, 24 and 26 (GSC 46430).

Locality: Section 3, 4303-4308' above base.

Age: Same as for Ogygopsis, new species A?, with which it is associated; early Middle Cambrian.

Family Dolichometopidae Walcott, 1916

Genus Bathyuriscus Meek, 1873

?Bathyuriscus sp.

A single pygidium is transversely elongate, sub-elliptical with rounded lateral angles; pleural lobes very weakly convex, with shallow pleural and interpleural furrows, of which the former are slightly oblique; border of moderate width, sloping sharply upward towards entire margin; axis strongly convex, with at least four rings and long tapering terminal piece merging into posterior border. Such a strongly sloping border appears to be rare in Bathyuriscus, and identification is therefore only tentative.

A cranidium of generalized dolichometopid character associated with this pygidium can probably be referred to the same genus.

Specimen: GSC 46431, no. 4; no. 3 is the counterpart impression of no. 4.

Locality: Section 3, 4390-4395' above base.

Age: Probably early Middle Cambrian; it is associated with Pagetia spp., Chancia evax, and other forms that may range fairly widely within the Middle Cambrian.

Genus Wenkchemnia Rasetti, 1951

Wenkchemnia sulcata Rasetti

Pl. 4, figs. 10, 11.

Wenkchemnia sulcata Rasetti, 1951, p. 186, pl. 11, figs. 9-15.

Five incomplete cranidia are preserved. They correspond closely in almost all respects to Rasetti's description and figures. A short occipital spine was probably present, but the occipital ring is damaged in all specimens.

These cranidia are very similar also to specimens figured by Rasetti (1948a, pl. 2, fig. 16) as Dolichometopsis? minor Rasetti. However, if published figures may be relied on, the resemblance between D.? minor and Wenkchemnia sulcata is so strong that it suggests that they are probably conspecific, and in this writer's opinion neither of them should be assigned to Dolichometopsis. Poulsen's (1927, p. 256) definition of the latter genus emphasizes the "practically cylindrical glabella"; not only does Rasetti's "Dolichometopsis? minor" have a distinctly clavate glabella, but the character of the anterior facial sutures, and hence of the frontal areas of the fixed cheeks, is quite different

from that of Dolichometopsis (Poulsen, 1927, pl. 16, figs. 2-16).

Specimens: GSC 46428, no. 20; 46429, nos. 7 and 13.

Localities: Section 3, 3894-3900' and 3915-3925' above base respectively.

Age: Rasetti (1951) regards Wenkchemnia sulcata as characteristic of the lowest Middle Cambrian zone on Mount Whyte, Alberta, and Mount Stephen, British Columbia (Wenkchemnia-Stephenaspis zone). This by no means precludes the possibility of its occurrence in older beds in other parts of the Canadian Cordillera, and it is associated at the present localities with Bonnia, Olenellus, Ogygopsis and other typically Lower Cambrian forms.

?Wenkchemnia sp.

Two cranidia collected almost 500' up-section from GSC 46428 strongly resemble the specimens of W. sulcata already described. Posterior limbs are slightly wider (transv.), and there is a more abrupt angle between sloping and flat portions of frontal areas of fixed cheeks.

The specimens are closely associated with a pygidium tentatively assigned to Bathyriscus sp., but they have a distinctly sub-triangular occipital ring that may have carried a short spine. This is rare in Bathyriscus. They are not Poliella sp., which has only one pair of lateral glabellar furrows.

A very small pygidium, approximately 2mm long and 3mm wide, associated with these specimens has affinities both to Wenkchemnia (four axial rings and pleural segments) and to Poliella denticulata Rasetti (pleural segments curving backwards, axis very strongly tapered, and weakly spinose postero-lateral margin; cf. Rasetti, 1951, pl. 12, fig. 9); axial rings carry paired nodes. The specimen cannot be positively identified (GSC 46431, no. 10).

Specimens: GSC 46431, nos. 4 and 13.

Locality: Section 3, 4390-4395' above base.

Age: Probably early Middle Cambrian. The associated Kootenia, Pagetia, ?Bathyriscus and Dictyonina may range stratigraphically as high as the Bathyriscus-Elrathina zone, but Wenkchemnia is characteristic of the Wenkchemnia-Stephenaspis zone of Rasetti, 1951. Identification of the small pygidium as Poliella denticulata would be consistent with the earlier age.

Family Zacanthoididae Swinnerton, 1915

Genus Zacanthopsis Resser, 1938

Zacanthopsis contractus Palmer

Pl. 4, fig. 14, 15.

Zacanthopsis contractus Palmer, 1964, p. F10, pl. 3, figs. 4-6.

Zacanthopsis is distinguished from Zacanthoides and Pro-

zacanthoides by its comparatively slender glabella, longer (exsag.) and wider anterior area of fixed cheeks, shorter (transv.) posterior limbs of fixed cheeks, and absence of metagenal spines (Resser, 1938, p. 106; and Harrington et al., 1959, pp. 0227-231). Palmer (1964, p. F10) emphasizes "slender anteriorly expanded glabella and the wide fixed cheeks having long arcuate palpebral lobes whose anterior ends are distinctly separated from the axial furrows, . . ." A well-defined ocular ridge runs from prominent raised eyes to axial furrows, but is not confluent with anterior glabellar lobe, opposite which it terminates.

Zacanthopsis contractus, unlike Z. levis (Walcott), the type-species of Zacanthopsis, and Z. virginica Resser, is "distinctly narrower between the anterior sections of the facial sutures than between the palpebral lobes" (Palmer). This is its most striking diagnostic feature, and the one on which assignment of the present specimens is based.

The species is represented by at least ten individuals of various sizes. Preservation is incomplete, and in particular the anterior border, occipital spine and posterior limbs of fixed cheeks have suffered damage. Palmer's specimens have fine closely-spaced granules on the axial part of the glabella; in the present specimens they are so faint as to be indistinguishable from the effects of whitening with magnesium oxide.

Glabella and palpebral areas of moderate convexity; glabella approximately same width as palpebral areas posteriorly, expanded and bluntly rounded anteriorly; eyes and palpebral lobes strongly raised, ocular ridge distinct but much lower; palpebral lobes fairly long, transversely arched, with point of maximum curvature opposite distal termination of first (lp) lateral glabellar furrows. Axial furrows fairly deep, parallel behind and divergent in front of their mid-point (exsag.); occipital furrow deeper laterally than across axis, curving forward gently at axis and more abruptly near axial furrows. Four pairs of lateral glabellar furrows; first (lp) pair slanting backward from axial furrow, and bifurcating, with posterior branch more deeply impressed; second pair originating at strong lateral indentation of glabella, bifurcating symmetrically with respect to the transverse direction, but faintly; third pair slanting slightly forward, bifurcating and reuniting adaxially to form very shallow loop-shaped depression; fourth pair more faint, slanting more strongly forward, expanding adaxially to form shallow diffuse depression without raised centre.

Details of glabellar furrow pattern are very much better displayed by these specimens than by Palmer's illustrations (pl. 3, figs. 4-6); however, they compare so closely with his holotype that this difference is considered to be of no more than possible varietal significance.

Specimens: GSC 46428, nos. 2, 12, 26, 28, 29, 39, containing at least 10 specimens.

Locality: Section 3, 3894-3900' above base.

Age: Palmer (ibid., p. F10) reports that all known specimens of Zacanthopsis are from Lower Cambrian rocks. The specimens in this collection are associated with Olenellus gilberti and unassigned olenellid fragments.

Order Ptychopariida Swinnerton, 1915
 Suborder Ptychopariina Richter, 1933
 Superfamily Ptychopariacea Matthew, 1887
 Family Ptychopariidae Matthew, 1887
 Subfamily Antagminae Hupé, 1953
 Genus Eoptychoparia Rasetti, 1955
Eoptychoparia sp.
 Pl. 4, figs. 12, 13.

Four of the seven antagminid cranidia in GSC 46428 can probably be assigned to this genus.

Cranidium subquadrate, with anterior margin gently rounded; anterior facial sutures subparallel to slightly divergent forwards, palpebral lobes short, posterior limbs of fixed cheeks only slightly wider (transv.) than occipital ring and extending more or less at right angles to axis. Fixed cheeks and palpebral areas very gently convex; glabella only moderately raised.

Glabella slightly to moderately tapered anteriorly, rounded

to somewhat truncate in front, and bounded laterally by straight well-incised axial furrows; four pairs of lateral glabellar furrows, the anterior two pairs faint, the posterior pairs sharp, deeper and backward-sloping from axial furrows. Anterior border of fairly uniform width (sag. and exsag.), with no conspicuous thickening mesially; border generally prominently upturned. Preglabellar field equal to or slightly wider than anterior border (sag.). Ocular ridges well-defined and prominent in three of the four specimens, terminating opposite anteriormost glabellar furrow.

Genera of the Antagminae grade into one another, and are difficult to identify with certainty. However, the present specimens have much in common with Eoptychoparia normalis Rasetti and E. intermedia Rasetti (1955, pl. 3, figs. 5-11, 12-15).

Specimens: GSC 46428, nos. 8, 15, 20 (smaller cranidium) and 28; GSC 46429.

Locality: Section 3, 3894-3900' and 3915-3925' above base respectively.

Age: Discussed together with that of Piaziella sp., q.v.

Piaziella sp.

Pl. 4, fig. 20.

The genus Piaziella is distinguished from other genera of the Antagminae chiefly by the greater length of its postero-

lateral limbs and by having only three distinct pairs of lateral glabellar furrows.

The latter feature is seen clearly in Rasetti's figure of "Piazella pia" (1951, pl. 8, fig. 3), but less clearly in Walcott's original figure (Walcott, 1917, pl. 12, fig. 8) of the type-specimen of Ptychoparia pia, the genotype of Lochman's new genus. She re-figures Walcott's type-specimen (Lochman, 1947, fig. 6, p. 70), but it is barely recognizable as a representation of the same specimen.

Three cranidia are here tentatively assigned to the genus. All three have transversely wide posterolateral limbs, rather more strongly swept back than in figured specimens of Piaziella pia (Walcott). In this respect they resemble Walcott's Ptychoparia gogensis (1917, pl. 12, fig. 4). In one specimen the glabella is lost, but in the other two it appears to have no more than three lateral furrows.

Specimens: GSC 46428, nos. 17, 20 (large cranidium) and 50.

Locality: as for Eoptychoparia sp. above.

Age: Eoptychoparia is reported from Lower Cambrian assemblages in boulders of the Lévis conglomerate, Quebec (Rasetti, 1955).

"Piazella pia" was collected again by Rasetti (1951, p. 236) from Walcott's original locality, the Peyto Limestone member of the Mount Whyte Formation on Mount Stephen, British Columbia, i.e. from the Upper Olenellus subzone of the Lower Cambrian.

Family Alokistocaridae Resser, 1939

Genus *Chancia* Walcott, 1924

Original description, in part (Walcott, 1925, p. 80; Walcott, 1924c, p. 55, pl. 10, fig. 4 designates the genus and illustrates it with a drawing, but does not adequately describe it):

"Chancia is characterized by a wide cephalon and thorax. Fixed cheeks at the narrowest point nearly as wide as the glabella on the same line. Palpebral lobes moderately small and connected with the dorsal furrow near its front by an ocular ridge. Frontal limb wide, and marked by a strong transverse furrow that divides the wide rim from the border. Glabella tapering, marked by a rounded median ridge and apparently faint glabellar furrows, whose position and direction are similar to those of Ptychoparia".

Chancia evax Walcott

Pl. 4, figs. 16, 17, 21.

Chancia evax Walcott, 1925, p. 81, pl. 17, fig. 27; Resser, 1939a, p. 18, pl. 5, figs. 18, 19.

The thorax, on which Walcott chiefly relies to distinguish *C. evax* from the genotype *C. ebdome*, is missing. However, the genus is clearly identified by the very distinctive broad (sag.), concave anterior border, short preglabellar field, and virtually straight, or backward-inflected, anterior border furrow. The present specimens are rather more strongly convex than Walcott's holotype and Resser's plesiotype of the species appear to be, but otherwise they resemble the published figures very closely. The rounded median ridge and faint glabellar furrows noted by Walcott are easily seen. The surface of GSC 46431-9

is very finely punctate and granulose.

Specimens: GSC 46430, nos. 7 and 9; GSC 46431, no. 9.

Localities: Section 3, 4303-4308' and 4390-4395' above base respectively.

Age: Early Middle Cambrian; Walcott and Resser describe specimens from the Spence Shale of northern Utah and southern Idaho.

Genus *Elrathina* Resser, 1937

?*Elrathina* sp.

Pl. 4, fig. 8; pl. 5, fig. 8.

Four poorly-preserved cranidia and a fragment with several thoracic pleurae and axial rings are believed to be referable to this genus, but identification is only tentative. Several genera of the Alokistocaridae may easily be confused with one another if good material is lacking (e.g. *Alokistocarella*, *Arellanella*, *Pachyaspis*, even *Elrathiella*). The present specimens vary slightly in cranidial proportions, but all have the following features characteristic of the genus: forward-tapering glabella; forward-converging anterior facial sutures; rather weakly curved anterior margin; faint to moderately strong eye ridges; rapidly-tapering posterior limbs of fixed cheeks. Narrow straight thoracic pleurae are sharply geniculated.

Specimens: GSC 46430, nos. 14, 18, 22 and 25.

Locality: Section 3, 4303-4308' above base.

Age: Several species of Elrathina, including the type-species E. cordillerae, are reported by Rasetti from the Bathyriscus-Elrathina zone (Mount Stephen Formation) on Mount Stephen and Mount Field, British Columbia (Rasetti, 1951, pp. 221-224).

?Elrathiella sp.

Pl. 5, fig. 9.

One cranidium may represent this genus. It has a longer (sag.) and more strongly curved anterior border than ?Elrathina, appears to have slightly narrower (transv.) posterior limbs, and is generally subquadrate in outline, unlike ?Elrathina sp., q.v., which is more transverse.

Specimen: GSC 46430, no. 13.

Locality: as for ?Elrathina sp., above.

Genus Pachyaspis Resser, 1939

Pachyaspis typicalis Resser

Pl. 5, fig. 11.

Pachyaspis typicalis Resser, 1939b, p. 61, pl. 11, figs. 15-20; ibid., pl. 12, figs. 1-3.

One slightly damaged adult cranidium compares closely with

Resser's holotype and paratypes; it is almost one-third longer (sag.) than the types, but is almost identical in cranidial proportions, taper of glabella, curvature of anterior margin and depth of furrows.

Pachyaspis isabella Lochman

Pl. 5, figs. 5, 10.

Pachyaspis isabella Lochman, in Cooper et al., 1952, p. 154, pl. 26, figs. 21-29.

Two fairly well-preserved cranidia display the features that distinguish this species from P. typicalis Resser. Anterior margin slightly straighter; anterior border more strongly raised and sharply defined than in P. typicalis; glabella less strongly tapered; preglabellar field and anterior border approximately equal in length (sag.).

Lochman refers to "arcuate" glabellar furrows, but she does not mention the distinct bifurcation of the posterior pair that is visible in some of her figures. Even without magnification, the present specimens clearly display this bifurcation.

Specimens: GSC 46431, no. 2 - P. typicalis
GSC 46431, nos. 3 and 7 - P. isabella

Locality: Section 3, 4390-4395' above base.

Age: The type-specimen of P. typicalis is from the Ptarmigania

strata, immediately underlying the Spence Shale, in the northern Wasatch Mountains of Utah and Idaho. Pachyaspis isabella is described from the Arrojos Formation in the Proveedora Hills, Sonora, Mexico, where it is associated with Glossopleura leona, Kootenia exilaxata and other trilobites of fairly early Middle Cambrian aspect (cf. discussion of Kootenia exilaxata, p. 106). However, Rasetti (1951, p. 235) has found other species of Pachyaspis in the Bathyriscus-Elrathina zone of the Stephen Formation on Mount Odaray, near Field, British Columbia.

Unidentified alokistocarid trilobite.

Only small portions of the cranidium of a badly damaged specimen are preserved. Anterior margin strongly curved, anterior facial sutures divergent; anterior border flat or concave, border furrow, if defined at all, very broad and shallow. Conspicuous ocular ridges gently curved, meeting glabella near its antero-lateral corners. Eyes probably short, situated somewhat posteriorly. Glabella strongly convex, moderately tapered, bounded by axial furrows of irregular depth. Occipital furrow narrow (exsag.) and deeper laterally, broader and very shallow mesially. Maximum width (transv.) of palpebral areas equal to that of glabella opposite same point.

Surface sparsely but coarsely granulose.

The long concave frontal area, divergent anterior facial sutures and prominent eye ridges suggest that this form can be placed in the Family Alokistocaridae. It may be compared with Alokistocare cataractense Rasetti (Rasetti, 1951, p. 205, pl. 34, figs. 3, 4), and Chancia bigranulosa Rasetti (ibid., p. 213, pl. 22, figs. 1-6). Both Alokistocare and Chancia may attain the size of the present specimen (e.g. glabella approximately 11mm long).

Specimen: GSC 46431, no. 6 (no. 5 is the counterpart impression of no. 6).

Locality: Section 3, 4390-4395' above base.

Age: Alokistocare cataractense is from the Bathyriscus-Elrathina zone of the Stephen Formation, Park Mountain, near Field, British Columbia; Chancia bigranulosa is from beds on Mount Stephen stratigraphically above the Plagiura-Kochaspis zone but only tentatively assigned to the Albertella zone (Chancia bigranulosa faunule). As the specimen is not positively identified, one can say only that it tends to confirm an early Middle Cambrian age for the assemblage from this locality.

Unidentified ptychopariid trilobite.

Pl. 5, fig. 26.

Most of a cranidium and part of one free cheek are preserved, but the two pieces are probably displaced with respect to each other; in any case, character of the facial sutures

has been obscured by damage. A few fragmentary thoracic segments also remain.

Cranidium is conspicuously transverse; width between tips of posterior limbs is 31mm (by extrapolation), distance between distal ends of eye ridges 18mm, and between antero-lateral corners of fixed cheeks approximately 15mm; by contrast, length (sag.) is only 12mm. Anterior margin very gently curved; posterior margin for most of its (transv.) length is perpendicular to the axis, the lateral one-third being slightly swept back.

Glabella moderately tapered, sharply truncate in front; length including occipital ring 8.5mm, width of posterior lobe 6.5mm, width of frontal lobe 4.0mm. Preglabellar field and anterior border of equal length (sag.). Glabella slopes gently to preglabellar and axial furrows from prominent rounded median ridge; palpebral areas broad and flat, sloping towards glabella, but posterior limbs slope outwards; frontal areas slope steeply to shallow, rounded border furrow, which is narrower (exsag.) laterally than mesially, and exhibits the backward mesial curvature that is characteristic of the Antagminae.

Facial sutures poorly displayed; posterior portions very widely flaring; in front of eye ridges, sutures diverge slightly for a very short distance, curving back adaxially so that they cut anterior border at an angle of about 40-45° to the axis. Shape and length of palpebral lobes and eyes are not clearly seen.

Four pairs of lateral glabellar furrows; posterior pair (1p) fairly deep and broad laterally, bifurcating adaxially with posterior portion slightly longer (transv.) than anterior; second (2p) pair shorter, with slight widening or incipient bifurcation adaxially; third pair shallower, narrower, and slanting forward towards axis; fourth pair very short, shallow but distinct, slanting forwards parallel to the third pair, and originating at axial furrow immediately opposite adaxial termination of eye ridge. Occipital furrow shallower across axis than laterally.

Free cheek poorly defined; genal spine not advanced, genal angle acute, spine fairly rapidly tapering but length cannot be accurately estimated.

Thoracic segments narrow (exsag.), and similar to those of several alokistocarid genera such as Chancia, Elrathina, Alokistocarella, etc. Pleural tips or spines not preserved, and most of axial lobe lost; remaining portions suggest a tendency to exfoliation of the axial rings as in Elrathina and related genera.

Strong eye ridges, shape of anterior border, and pattern of glabellar furrows suggest affinity to the Antagminae (e.g. Onchocephalus, Piaziella, Poulsenia or Antagmus), or to the Alokistocaridae (e.g. Kochiella), but the cranial proportions do not correspond to those of any known genus. Identification, or erection of a new genus if necessary, cannot be attempted until better-preserved material is available.

Specimen: GSC 46430, no. 21.

Locality: Section 3, 4303-4308' above base.

Age: Probably early Middle Cambrian, possibly as late as that of the Bathyriscus-Elrathina zone.

Unidentified trilobites A to D.

A (-

Glabella parallel-sided, rounded in front; moderately convex, with faint median ridge; three pairs of shallow, short lateral furrows sloping backward towards axis; palpebral areas gently convex, as wide (transv.) as glabella; palpebral lobes long, robust, reaching axial furrow anteriorly without appreciable attenuation, flanked by shallow but sharp palpebral furrows; occipital furrow shallow, occipital ring expanded mesially, with low axial node on its posterior edge.

The specimen is probably Zacanthoides sp., but without posterior limbs, anterior border and frontal areas it cannot be identified. Zacanthoides ranges throughout the Middle Cambrian.

B -

Glabella sub-rectangular, slightly tapered and rounded in front; axial and preglabellar furrows almost uniformly deep; one, possibly two, pairs of shallow lateral furrows; border upturned, indistinguishable from preglabellar field and frontal area; low

transverse ridge midway between anterior margin and glabella may be impression of rostrum. Anterior facial sutures widely divergent. Palpebral areas small, sloping steeply towards axial furrows; palpebral lobes fairly short, strongly curved, and with their point of maximum curvature somewhat posterior to midpoint of glabella. Posterior limbs and occipital ring not seen.

Concave, wide-flaring frontal areas, and short palpebral lobes close to sub-rectangular glabella strongly suggest affinities to the Family Idahoiidae, all the genera of which are of Franconian or Trempealeauan age.

C -

Ptychopariid cranium, with tapered, moderately convex glabella; anterior margin much more abruptly curved mesially than laterally; anterior border concave, about three times length (sag.) of preglabellar field; eye ridges strong, eyes short, located opposite mid-point of glabella; posterior limbs deeply furrowed, no wider (transv.) than occipital ring.

This specimen resembles so many genera of ptychopariid trilobites in general character that identification is impossible in the absence of good material; the distinctive curvature of the anterior margin is reminiscent of the Family Pterocephaliidae (of Late Cambrian age).

D -

Small cranidium, sub-quant in outline, with strongly convex glabella and fixed cheeks; glabella cylindrical or very slightly tapered, bounded by straight deep axial furrows and distinct preglabellar furrow that is shallow mesially. Three pairs of faint, short lateral glabellar furrows; eyes short, eye ridges strong; frontal areas slope steeply down to deep but rounded anterior border furrow; anterior border raised, anterior margin rounded gently; anterior facial sutures obscure, either parallel or slightly divergent forwards. Surface with sparse granules.

The specimen bears a very strong resemblance to Xenocheilos minutum Wilson (Wilson, 1949, p. 44, pl. 9, figs. 11-13), which is reported as "rare" in the Elvinia zone of the basal Wilberns Limestone of Texas (Franconian).

Specimens: A and B - GSC 46432, no. 1.
C and D - GSC 46432, no. 2.

Locality: Section 3, approximately 4600' above base.

Age: Indications of Late Cambrian age would be more persuasive if specimens B, C and D could be identified to genus; their association with "Billingsella" tends to confirm Late Cambrian age, but the presence of "Nisusia" does not. The collection is probably no older than very late Middle Cambrian, but the evidence does not warrant any attempt to correlate the enclosing strata of Section 3 with the beds of Franconian age in the

Mount Hunter section.

Phylum Brachiopoda Duméril, 1806
 Class Inarticulata Huxley, 1869
 Order Lingulida Waagen, 1885
 Superfamily Lingulacea Menke, 1828
 Lingulid brachiopoda
 Pl. 5, fig. 25.

Shell phosphatic, very thin, weakly convex, evenly rounded anteriorly, sharply acuminate posteriorly, surface bearing sparse growth lines. Largest specimen 7mm long, 5mm wide. Several fragments of shell, one impression and one cast represent the form; no internal detail is seen.

Specimens: GSC 46430, nos. 19, 22 and 25.

Locality: Section 3, 4303-4308' above base.

Order Acrotretida Kuhn, 1949
 Suborder Acrotretidina Kuhn, 1949
 Superfamily Acrotretacea Schuchert, 1893
 Family Acrotretidae Schuchert, 1893
 Subfamily Acrotretinae Schuchert, 1893
 Genus Acrotreta Kutorga, 1848

Walcott (1912, p. 672) gives a comprehensive synonymy of the genus up to that date.

?Acrotreta sp.

Pl. 5, fig. 24.

The characteristic pedicle valve of Acrotreta, strongly conical, with flattened posterior face, may be represented in specimens GSC 46428, nos. 16 and 34, and GSC 46429, nos. 11-13. At least three casts and one mold of brachial valves bear a close generalized resemblance to many of the species figured by Walcott (1912).

Resser (1939b, pp. 21 and 22, pl. 1) reports similar specimens (assigned to A. sulcata and A. eucharis) from limestone immediately underlying the Spence Shale, of Middle Cambrian age, in the northern Wasatch Mountains of Utah.

The present specimens are subcircular, of moderate convexity, with the impression of a long, distinct median septum flanked by two shorter ridges; molds and cast all show faint traces of concentric growth ridges.

Specimens: GSC 46428, nos. 16, 34 (pedicle valves); 38 (brachial valves); 20 (internal mold of brachial valve); 22, 39, 40 (impressions of brachial valve exterior); 26, 28, 34 (internal casts of brachial valves); GSC 46429, nos. 11-13 (pedicle valves and impressions).

Localities: Section 3, 3894-3900' and 3915-3925' above base respectively.

Age: Most species of Acrotreta are of Middle or Late Cambrian age; its presence at this locality tends to confirm a later Early Cambrian age for the collection.

Order Obolellida Rowell, 1965

Superfamily Obolellacea Walcott and Schuchert, 1908

Family Obolellidae Walcott and Schuchert, 1908

Genus Obolella Billings, 1861

Obolella sp.

Brachial valve only is preserved. Valve circular, weakly convex, with fine closely-spaced growth lines; beak close to posterior margin; low internal median ridge expressed as shallow longitudinal furrow on external surface.

Specimen: GSC 46429, no. 11 (no. 12 is impression of the same valve).

Locality: Section 3, 3915-3925' above base.

Order Paterinida Rowell, 1965

Superfamily Paterinacea Schuchert, 1893

Family Paterinidae Schuchert, 1893

Genus Dictyonina Cooper, 1942

Dictyonina pannula (White)

Pl. 5, fig. 7.

Trematis pannulus White, 1877, pp. 36-37, pl. 1, figs. 4a and 4b (described and discussed originally by White in 1874).

Micromitra (Iphidella) pannula (White), Walcott, 1912, p. 361-364. text-fig. 32, pl. 4, figs. 1, 1a-1t, 3, 3a (with synonymy to 1912).

Dictyonina pannula (White), Cooper, 1942, cited in: Rowell, in Williams et al., 1965, p. H295, fig. 185, 4a-4e.

The unique reticulate ornamentation, consisting of small pits formed by intersecting oblique raised lines, identifies the genus. Species appear to be distinguished partly on the basis of relative prominence of oblique lines and concentric growth lines, and the present specimens are not significantly different from those figured by Walcott as Micromitra (Iphidella) pannula.

Specimens: GSC 46431, nos. 1, 3 and 7 (nos. 2 and 4 are counter-part impressions of nos. 1 and 3).

Locality: Section 3, 4390-4395' above base.

Age: The genus ranges throughout the Cambrian, and is of wide geographic occurrence. In western North America, Walcott reported D. pannula from the Ogygopsis zone on Mount Stephen, British Columbia, and from the Burgess Shale; he found it also in the Spence Shale (early Middle Cambrian) in southern Idaho, in the "Tonto" (sic) sandstone of the Grand Canyon, Arizona, and at several other localities; he also lists an Upper Cambrian locality in Georgia, and several Lower Cambrian localities in the eastern and western United States and Canada. Cooper (1952, in Cooper et al.) reports a Dictyonina sp., exactly resembling the present specimens, from the basal Tren Formation (Middle

Cambrian, above the Albertella and Kootenia zones) in Sonora, Mexico.

Genus Paterina Beecher, 1891

The genus is described thus by Cooper (1952, p. 38):

"Subcircular to subrectangular in outline; valves of unequal depth, the pedicle being the deeper; pedicle valve hemiconical, brachial valve moderately convex; surface marked by fairly regular elevated concentric lines. Pedicle valve with more or less strongly developed homoeodeltidium. Interior poorly known".

In most respects it resembles Micromitra Meek, but the surface of the latter is marked by irregular elevated radial lines crossing the concentric ones.

Walcott (1912, pp. 332-365) treats Paterina Beecher and Iphidella Walcott as subgenera of Micromitra; the writer prefers to accept the view of Cooper (op. cit.) who accords them generic rank.

Paterina sp.

Pl. 5, figs. 14-17.

Brachial valve roughly semicircular and moderately convex; of the six specimens in this collection, some are slightly shallower than others. Posterior margin very broadly obtuse-angled; interarea concealed or damaged in all specimens.

Two other specimens (GSC 46428-13, 14) are more strongly convex and hemiconical, and are therefore believed to be pedicle valves. In one of them (no. 13), the apex is damaged and the interarea could not be exposed; but in the other, slight reverse curvature of the posterior slope suggests presence of homoeo-deltidium.

All specimens display the strong, regular, elevated concentric growth lines that are characteristic of the genus. There is no sign of the radial lines that distinguish Micromitra.

Specimens: GSC 46428, nos. 13, 14 (possible pedicle valves); 10, 11, 18, 29, 34, 37; and GSC 46429.

Localities: Section 3, 3894-3900' and 3915-3925' above base.

Age: Probably later Early Cambrian; the specimens are associated with Olenellus gilberti, Zacanthopsis contractus, Helcionella, etc.

Class Articulata Huxley, 1869
 Order Orthida Schuchert and Cooper, 1932
 Suborder Orthidina Schuchert and Cooper, 1932
 Superfamily Billingsellacea Schuchert, 1893
 Families Billingsellidae Schuchert, 1893, and
 Nisusiidae Walcott and Schuchert, 1908

Pl. 5, figs. 18, 19.

Although the genera Billingsella and Nisusia are probably represented, the material does not permit positive identification. Impressions and very sparse shell fragments provide only external morphology.

"Billingsella" has a subquadrate brachial valve with straight hinge line and right-angled or very slightly alate cardinal extremities; it is gently convex, with a broad shallow sulcus; surface costellate to costate, with many faint and a few strong concentric growth lines; interarea probably apsacline.

Ornamentation of "Nisusia" is similar to that of "Billingsella"; but slightly coarser; growth lines tend to be more conspicuous, especially towards the shell margins. All specimens are sulcate, although in the largest individual the depression is so shallow that it can barely be detected. Specimens with the deeper sulcus are likely to be pedicle valves; there is little other means of distinguishing pedicle and brachial valves when the beak and hinge structures are not exposed, both valves of Nisusia being sulcate.

Specimens: GSC 46432.

Locality: Section 3, approximately 4600' above base.

Age: Billingsella ranges from Middle Cambrian to Early Ordovician; Nisusia, Early to Middle Cambrian. Trilobites associated with these specimens suggest a very late Middle Cambrian age.

Phylum Mollusca?

Class Calyptomatida Fisher, 1962

Order Hyolithida Matthew, 1899

Suborder Hyolithina Matthew, 1899

Hyolithid fragment

Pl. 4, fig. 19.

A single fragment is very tentatively assigned to this suborder. The specimen appears to be a thin shell, bearing sharply-defined growth lines and extremely delicate, tapering raised lines perpendicular to them but not reaching all the way from one growth line to the next. Approximately 14 growth lines are seen on this fragment, which is 3mm long and 2mm wide; i.e. average spacing between them is 0.214mm. In longitudinal cross-section they resemble the form of symmetrical ripple-marks, with adjacent sharp crests separated by a curved, shallow trough.

Specimen: GSC 46428, nos. 31 (shell) and 33 (impression).

Locality: Section 3, 3894-3900' above base.

Age: Later Early Cambrian in the present assemblage.

Phylum Mollusca

Class Cephalopoda ?

Order Volborthellida Kobayashi, 1937

Family Salterellidae Poulsen, 1932

Genus Salterella Billings, 1861

Salterella pulchella Billings

Pl. 5, figs. 21, 22.

Salterella pulchella Billings, 1861, p. 18; Shaw, 1955, p. 801, with synonymy to 1955 but without descriptions or figures; Lochman, 1956b, p. 1375, pl. 4, figs. 25-27.

Specimens are silicified, and abundant at this locality; a few cubic inches of calcareous dolomite contain hundreds of individuals.

Small, narrow cones, gently to strongly arcuate, with greatest curvature near apex. Outer surface finely rugose, but texture obscured by silicification; no trace of longitudinal ornamentation. Largest specimen is approximately 7mm long, 1.8mm wide at aperture.

In weathered and etched specimens details of the living chamber are hidden by accretions of silica; but a narrow central cavity generally remains unfilled. Longitudinal sections show that the living chamber is one-third to one-half the length of the shell, bluntly rather than sharply conical, rounded posteriorly. Numerous septa fill posterior portion of shell and are

traversed by a siphuncle that is generally somewhat off-centre. Silicification has tended to obliterate this fine internal septal structure, as it did the septal rugosity of the outer wall.

These specimens are narrower than Salterella mexicana Lochman (in Cooper et al., 1952, p. 85, pl. 15, fig. 14; pl. 16, figs. 7-11; pl. 17, figs. 1-5), and considerably narrower than S. expansa Poulsen (1927, p. 251, pl. 14, figs. 10-12; and 1958, p. 10, pl. 1, figs. 2, 3). Their curvature also contrasts with the straight-shelled form of S. mexicana and S. expansa.

Billings' (1861, pp. 17, 18) S. rugosa and S. pulchella are distinguished thus: S. rugosa is generally straight but may be slightly curved, and has "four to six imbricating sharp annulations, the edges towards the larger end". S. pulchella is "always a little curved, and when weathered does not present the sharp imbricating annulations . . ." of S. rugosa, and is generally longer than the latter. Walcott's figures (1886, pl. 13, fig. 2 and figs. 3, 3a) clearly contrast the two species; one of his figures of S. pulchella is that of Billings' type-specimen from a boulder in the Lévis conglomerate, Quebec.

Although the present specimens display some outer effect of septal structure, they do not possess the conspicuous imbricating annulations of S. rugosa; moreover, they are invariably curved. They are therefore assigned to S. pulchella.

Specimens: GSC 46427, weathered, polished and etched specimens.

Locality: Section 3, 3800-3820' above base.

Age: Early Cambrian. When Billings erected this species, little attempt had been made to work out the ages of the boulders in the Lévis conglomerate, itself of early Ordovician age. Boulders containing Salterella rugosa and S. pulchella proved to be of Early Cambrian age (Walcott, 1890). Walcott had previously (1886, p. 144) referred to specimens from Vermont as part of a Middle Cambrian assemblage, correcting this in his later work (1891) on the fauna of the Olenellus zone. Lochman (op. cit.) described drift specimens that she concluded must have been derived from the Middle Cambrian Arrojos Formation in the Proveedora Hills, Sonora, Mexico.

Apart from Walcott's and Lochman's references, as above, the genus Salterella has been reported only from Lower Cambrian rocks. Lochman (1956b, pp. 1350, 1351) places it in the lower faunule of the Elliptocephala asaphoides fauna of New York State, equivalent to the Upper Olenellus subzone of the Pacific province.

Class Gastropoda Cuvier, 1797

Subclass Prosobranchia Milne Edwards, 1848

Order Archaeogastropoda Thiele, 1925

Suborder Bellerophontina Ulrich and Schofield, 1897

Superfamily Helcionellacea Wenz, 1938

Family Helcionellidae Wenz, 1938

Genus *Helcionella* Grabau and Shimer, 1909

The Helcionellacea are "cap-shaped to coiled bellerophonti-form shells; commonly with strong rugae clearly defined on both interior and exterior; . . ." (Knight et al., 1960, p. 172). The genotype *H. subrugosa* (d'Orbigny) (Knight, 1941, pl. 3, fig. 1) is a very shallow, wide cone, its apex excentric, walls coarsely rugose; but this form no longer appears to be the one most commonly encountered. Most species are more elongate, more or less strongly coiled, and bear a distinct pattern of fine longitudinal and transverse striations in addition to coarse rugae or annulations.

Other genera have been confused with *Helcionella* even by experienced workers. Shaw (1957, p. 788, pl. 99, fig. 13) re-designated as *Coreospira? raymondi* specimens that he had previously assigned to *Helcionella*; his illustration confirms the similarity. On the other hand, *C. walcotti* Knight (1947, pl. 1, figs. 2a-d) and *C. rugosa* Saito, the genotype (Knight, 1941, pl. 5, figs. 4a-d) are much too tightly coiled to be mistaken for *Helcionella*. *Stenotheca* ("Crustacea incertae sedis" according to Shimer and Shrock, (1944, p. 701)) appears to lack the finer transverse and longitudinal ornamentation displayed by many species of *Helcionella*. (*Coreospira* is reported in the lower Middle Cambrian Ptarmigan Formation near Field, British Columbia (Knight, 1947, p. 1), and in the *Bonnia*, or uppermost, zone of the upper *Redlichia* shales of Korea (ibid., p. 1)).

Rasetti (1957, pp. 968, 969) presents a short but useful discussion of the problems of classifying Cambrian Mollusca, and in particular of the relationships of Helcionella, Coreospira, Oelandia and Scenella. It is evident that Helcionella (sensu lato) comprises a wide variety of forms.

Helcionella aff. H. arguta Resser

Pl. 5, fig. 2.

Helcionella arguta Resser, 1939, p. 23, pl. 1, figs. 38-41.

"Helcionella" arguta, Robison, 1964, p. 561, pl. 92, figs. 11-17
for outstanding illustrations.

Identification of the present specimens is hampered by their incompleteness; neither apex nor aperture is preserved or exposed in any of them, and the inner side of the whorl is only poorly seen.

Like Resser's species they are strongly coiled, although it cannot be seen whether they form "practically a complete whorl" (Resser, 1939, p. 23). Prominent annulations are separated by fairly deep furrows, and the surface is covered also by weak transverse and stronger longitudinal striations. Shells appear to be oval in cross-section throughout their length, but even in this respect they may not differ significantly from H. arguta, in which "the cross-section for most of the whorl is nearly circular but becomes flattened towards the mouth". This character-

istic is difficult to assess in only partly-exposed specimens.

The specimens are definitely not referable to the following species: H. insulcata Rasetti is too smooth, lacking coarse annulations; H. carinata Rasetti has its peripheral whorl surface flatly arched, lateral walls concave; H. burlingi Resser forms more than one complete whorl, and depressions are deeper on lateral than on peripheral whorl walls; H. aequa lacks annulations, and expands too rapidly from apex to aperture; H. subrugosa (d'Orbigny) is very shallow and wide; H. buttsi Resser and H. callahani Resser are not sufficiently strongly coiled.

Specimens: GSC 46428, nos. 12, 30, 32, 41, 45; and GSC 46429.

Localities: Section 3, 3894-3900' and 3915-3925' above base respectively.

Age: Early Cambrian. The presence of this species, if correctly identified, tends to confirm the late Early Cambrian age of GSC 46428; Resser's species was reported from the Ptarmigania strata (lowermost Middle Cambrian) in the northern Wasatch Mountains of Idaho and Utah. Robison (1964, pp. 512, 562) finds it in the upper Middle Cambrian Wheeler Shale and Marjum Formation (Bolaspidella assemblage zone, Bathyriscus fimbriatus subzone and lowest part of Bolaspidella contracta subzone) in the House Range and Drum Mountains of Utah.

UPPER CAMBRIAN

Class Trilobita Walch, 1771

Order Agnostida Kobayashi, 1935

Suborder Agnostina Salter, 1864

Family Micragnostidae Howell, 1935

In the Treatise, groups of agnostid trilobites that had previously (e.g. Shaw, 1951, p. 110; and Palmer, 1955, p. 88) been treated as subfamilies are raised to family rank. The Treatise classification is adopted here because in this instance the author of the change (B.F. Howell) is the same as the author of the older Subfamily Geragnostinae Howell, 1935. However, no reason is given for the revised classification, and it appears to introduce inconsistencies into the systematic position of Geragnostus (Micragnostus), a subgenus which may now be obsolete. This writer has found no reference to the subgenus later than the date of the Treatise, in which Howell appears to treat the diagnostic features of the subgenus as criteria for recognition of an entire family.

The families are compared thus (Treatise, pages 0176 and 0179):

Family Geragnostidae Howell, 1935:

"Glabella having essentially only a single long main lobe that is evenly rounded in front, well-developed transverse furrow lacking; pygidial axis short in most genera but divided

into 3 lobes".

Family Micragnostidae Howell, 1935:

"Glabella with two main lobes, anterior one evenly rounded at front; pygidial axis short, more or less segmented; surface of both shields smooth".

In Shaw's (1951, p. 110) view, the Subfamily Geragnostinae Howell, 1935 comprised species of Geragnostus and others, the glabella of which displayed transverse furrow "well marked or faint"; and Geragnostus spp. and G. (Micragnostus) spp. figured by Palmer and Shaw respectively show this furrow clearly. It is difficult to see how the revised taxonomy accommodates these species.

Genus Micragnostus Howell, 1935

Micragnostus Howell, 1935, p. 233.

Geragnostus (Micragnostus) Kobayashi, 1939, pp. 167-171.

Micragnostus Howell, Harrington et al., 1959, p. 0179.

The Treatise defines Micragnostus as follows:

"Glabella with 2 well-defined main lobes, pygidial axis distinctly trilobed but rather short and not expanded toward rear, not reaching border".

Micragnostus sp. cf. Geragnostus (Micragnostus)

bisectus (Matthew) var. typica Shaw

Pl. 6, fig. 3.

The species Geragnostus (Micragnostus) bisectus should now perhaps be designated Micragnostus bisectus in view of the revised classification.

Agnostus bisectus Matthew, 1892, p. 50, pl. 13, figs. 2a, b.

Micragnostus bisectus Howell, 1935, p. 233.

Geragnostus (Micragnostus) bisectus Kobayashi, 1939, pp. 168, 170, 183.

Geragnostus (Micragnostus) bisectus (Matthew) var. typica Shaw, 1951, p. 111, pl. 21, fig. 18, pl. 23, figs. 12-18.

Shaw (1951) includes in Micragnostus a range of forms, some of which have a trilobed pygidial axis that is distinctly expanded towards the rear. The Treatise definition quoted above would disqualify these forms from such assignment.

A well-preserved pygidium and a much smaller fragmentary cephalon are assigned to the genus.

The pygidium is distinguished by an exceptionally straight-sided and elongate axial lobe, separated from the posterior border by a distance slightly less than the length (sag.) of the border itself. Posterior margin of axial lobe is smoothly rounded, and concentric with the posterior border. Posterior border narrows and pleural lobes widen slightly towards antero-lateral corners of pygidium. Margin appears to be entire, lacking spines, but is imperfectly preserved and may have lost them. Axis itself is clearly trilobed, with an elongate mesial node occupying

entire length of second lobe, protruding slightly into posterior lobe. Anterior lobe divided longitudinally by faint, low forward extension of second lobe. Exfoliated surface of second lobe displays also a pair of shallow but distinct pits lying symmetrically about the axis, crescent-shaped, with their concave sides facing antero-laterally; posterior lobe shows similar, but smaller and very faint depressions. They bear some resemblance to the muscle scars described by Palmer (1955, pl. 20). Axial furrows are very sharp, of moderate depth; transverse furrows distinct but more shallow; and border furrow broad and shallow. Border broad except anteriorly, where it tapers; and border is only slightly raised.

The cephalon is assigned chiefly because it is so closely associated with the pygidium, but the following features confirm the identification: no preglabellar median furrow; glabella bilobed, with very distinct transverse furrow; anterior lobe rounded, very slightly wider (transv.) than posterior lobe; glabella straight-sided, axial furrows distinct; surface smooth. Basal glabellar lobes are probably present, but cannot be clearly seen.

Shaw (1951) has shown that dimensional proportions, and prominence of posterior axial lobe of the pygidium of Geragnostus (Micragnostus) bisectus may vary widely; extreme forms grade into one another without clear statistical separation of varieties. Study of numerous specimens might show that the unusually elon-

gate axial lobe of specimen 46419-2 was sufficiently distinctive to warrant erection of a new variety or species. The material is too sparse to permit this at present.

Specimen GSC 46419-2 differs from Geragnostus (Micragnostus) bisectus as described by Shaw (1951) in these respects: lack of marginal spines on pygidium, a somewhat more distinct transverse furrow between posterior and second axial lobes of pygidium; second axial lobe same width (transv.) as other two, hence with no 'pinched-in' appearance. These differences do not invalidate the generic assignment.

Specimen: GSC 46419, no. 2.

Locality: Mount Hunter section, within the interval 5516-5566' above base.

Age: Palmer (1955, p. 91) reports Geragnostus spp. from the Dunderberg Shale and from Units 1 and 2 of the Pogonip Limestone of Nevada, i.e. from a zone between the standard Aphelaspis and Elvinia zones, to beds a few feet below the Cambrian-Ordovician boundary as recognized in the Great Basin; and (1954) G. tumidus from the Aphelaspis zone in central Texas. Lochman (1964a) describes G. mundus from the Saukia zone, Williston Basin, Montana. Rasetti (1959, pl. 51, fig. 18) figures a Geragnostus sp. undet. that resembles remarkably closely the present specimen; it is said to be of Trempealeauan age. Shaw's (1951) specimens of G. (M.) bisectus are from the Morses Line Formation in northwest Vermont, and are probably late Trempealeauan in age. Geragnostus

was found in rocks of early Tremadocian age in Bolivia (Harrington and Leanza, 1943). The Treatise (pp. 0176 and 179) gives the age of Geragnostus as Lower Ordovician, and that of Micragnostus as Upper Cambrian to Lower Ordovician (sic). Kobayashi's (1936) Geragnostus (Micragnostus) subobesus is part of a Briscoia fauna from the northwest Yukon Territory, and is therefore of earlier Late Franconian age.

The present specimen is considered to be of Trempealeuan age, and if the late Trempealeuan faunal break reported by Lochman-Balk in the Williston Basin (1960, p. 40) persists to the northwest, it is possibly not younger than Middle Trempealeuan.

Family Pseudagnostidae Whitehouse, 1936

Genus Pseudagnostus Jaekel, 1909

Pseudagnostus josepha (Hall)

Pl. 6, figs. 11-13.

Aagnostus josepha Hall, 1863, p. 178, pl. 6, figs. 54, 55.

A. communis Hall and Whitfield, 1877, p. 228, pl. 1, figs. 28, 29.

A. neon Hall and Whitfield, 1877, p. 229, pl. 1, figs. 26, 27.

Pseudagnostus josepha (Hall), Kobayashi, 1935c, p. 108; Kobayashi, 1939, p. 157; Shimer and Shrock, 1944, p. 601, pl. 251, figs. 5, 6; Frederickson, 1949, p. 362, pl. 72, fig. 17; Lochman, 1950, p. 329, pl. 46, fig. 14; Nelson, 1951, p. 776, pl. 107, fig. 5; Bell, Feniak and Kurtz, 1952, p. 196, pl. 32, figs. 4a, 4b; Greggs, 1962, p. 91, pl. 15, figs. 9-12.

"Pseudagnostus josephus" (Hall), Wilson, 1954, p. 284, pl. 25, fig. 22.

Pseudagnostus communis (Hall and Whitfield), Palmer, 1955a, p. 720, pl. 76, figs. 1-3, 1954 (Mailed Jan. 15, 1955); Palmer, 1955b, p. 94, pl. 19, figs. 16, 19-21, pl. 20, figs. 4-11; Rasetti, 1961, p. 109, pl. 23, figs. 13-17; Bell and Ellinwood, 1962, p. 389, pl. 51, figs. 7-21; Lochman, 1964, p. 47, pl. 9, figs. 32-36.

P. prolongus (Hall and Whitfield), Palmer, 1955b, p. 98, pl. 19, figs. 17, 18, 22.

Hall defined Aagnostus josepha as follows (quoted in part from Lochman, 1950):

"Head semi-elliptical, a little wider than long; the sides . . . margined by a flattened or concave narrow limb; rather abruptly concave at the sides: the posterior margin, just within the angles, is produced on each side into a short spine.

"Glabella prominent, narrow, extending about two-thirds the length of the head, and crossed by a shallow furrow near its anterior end: the posterior lobe is marked by an oblique furrow on each side, and a small node on the summit of the anterior termination.

"Pygidium of the same form as the head, or a little wider: axis prominent, subquadrangular, wider than long, nearly one-third the length of the pygidium, bearing a node or spine on its posterior extremity; sides and body of pygidium . . . highly convex".

Palmer (1955a) regards the following features as diagnostic of P. communis (Hall and Whitfield):

"Cephalon somewhat expanded forward, strongly rounded at antero-lateral corners, . . . width and length about equal. Glabella well defined . . . strongly rounded in front; . . . Shallow first glabellar furrow . . . Shallow indentations marking the second glabellar furrow are present . . . about opposite poorly defined axial node. Basal lobes subtriangular, undivided. Preglabellar median furrow . . . Cheeks slope gently towards anterior margin and steeply . . . towards postero-lateral margin. Border . . . expanded slightly forward.

"Pygidium nearly parallel sided, broadly rounded posteriorly,

. . . width slightly greater than length. Anterior third of axial lobe parallel sided, . . . delineated posteriorly by a shallow transverse furrow. Prominent axial node situated just anterior to this furrow. Anterior half of pseudolobe moderately well defined by accessory furrows. . . Marginal furrow broad and shallow. Border . . . bearing pair of short, sharp marginal spines . . . "

Comparison of these two species as described and figured shows that they possess features in common that are of greater diagnostic importance than the presence or absence of pygidial marginal spines. These features are the broadly rectangular axial lobe with axial node, strongly flaring accessory furrows and expanded pseudolobe.

In assigning two poorly-preserved cephalia to P. josepha, Lochman emphasizes the presence of postero-lateral spines on the cephalic margin; this feature is not adequately illustrated (1950, pl. 46, fig. 14), and no other author except Hall appears to mention it. Palmer (1955a) does not even consider it in his discussion of agnostid terminology. Bell and Ellinwood (1962), placing P. josepha in synonymy with P. communis, are concerned only with pygidial spines. Their figured specimens (pl. 51, figs. 7-14) display node-like protruberances at postero-lateral corners of cephalon; but no allusion is made to them, and they are presumably considered to be posterior portions of the cephalic border. Greggs (personal communication, May 1965) concurs with Bell and Ellinwood, and suggests that Hall's original diagnosis of P. josepha may have erroneously attributed spines to

the cephalon instead of the pygidium.

Palmer distinguishes P. communis from P. laevis Palmer and P. prolongus (Hall and Whitfield) by the well-developed furrows that outline glabella and axial lobes of the pygidium, and from P. convergens Palmer by the tapering pygidium of the latter. He acknowledges, however, that variations in depth and distinctiveness of furrows depend largely on degree of exfoliation.

Lochman and Hu (1959), like Palmer, recognize P. communis, P. convergens and P. prolongus, but their figures do not clearly illustrate features by which the three may be differentiated.

Bell and Ellinwood (1962), describing material from the Wilberns Formation of Texas, note a gradation from specimens with distinct furrows to those with faint furrows; they therefore place P. prolongus in synonymy with P. communis. For reasons not disclosed they also place P. convergens in the same synonymy, ignoring Palmer's emphasis on the distinctively tapering outline of the pygidium. Palmer's species is admittedly based on only two specimens, a cephalon and a pygidium from the same rock-unit (Pogonip Limestone, Unit 1) but widely separated in distance and elevation. Only a statistical study based on larger collections will demonstrate whether the species is distinctive, or whether forms with a strongly tapered pygidium grade into forms with a more equant or semicircular pygidium.

Accordingly, P. convergens is omitted from the present synonymy.

The same authors place P. josepha (Hall) in synonymy with P. communis on the grounds that if the pygidium of P. josepha possessed marginal spines one would not expect to see them in specimens from the type-locality because they are preserved there in medium-grained sandstone, and such a delicate structure would not survive. By itself this reason scarcely justifies assigning such specimens to the spinose species P. communis. The species P. josepha stands or falls on the type-specimen, not on Hall's concept of it; if the specimen may have had pygidial marginal spines, then Hall's designation of the species as non-spinose (except for the cephalon) was in error, but the species remains valid. In that case, it accords with Hall's and later writers' concept of P. communis (Hall and Whitfield), and also has priority; the latter species should have been suppressed as a junior synonym. The question cannot be settled without study of the respective type-specimens, to which the present writer has not had access; he is therefore obliged to assume that P. josepha remains a valid species.

Greggs (1962, pl. 15, figs. 9-12) assigned to P. josepha specimens that conform in every respect with Palmer's description of P. communis, and are, moreover, distinctly spinose; but he is now convinced that these two and P. prolongus are conspecific.

P. prolongus is appropriately placed in synonymy with P. communis because Palmer's only diagnostic criterion is "the shallow nature of all furrows on the outer surface of the test" (Palmer, 1955b, p. 98). He adds that "Exfoliated specimens (of P. prolongus) cannot be differentiated with certainty from specimens of P. communis."

This writer suggests that Palmer's (1955b, p. 97) erection of the new species Pseudagnostus laevis also should have been challenged by Bell and Ellinwood; on the strength of the author's description and discussion, it appears to be merely an end-member of a range of forms assignable to P. communis.

The taxonomic status of P. communis and P. josepha appears still to be unclear.

Two cephalata and two pygidia represent this species in the present collection. Both cephalata are distorted and appear elongate; they are actually subequant, the smaller one being approximately 3.2mm long and 3.0mm wide. Borders of both cephalata are narrow posteriorly, expanded anteriorly, not strongly raised; dorsal and preglabellar median furrows sharper and deeper in smaller specimen, but distinct in both, especially where test is missing; first glabellar furrow visible in both, second expressed by faint indentation opposite axial node; basal glabellar lobes distinct in both.

One pygidium is semicircular to slightly transverse, more gently curving posteriorly than laterally; border widest, and bearing small marginal spines, at postero-lateral corners; border furrow most sharply defined near the axial line. Bilobed axis of pygidium well defined by axial and transverse furrows, as in Palmer's description of the species; accessory furrows somewhat larger, and pseudolobe more strongly raised, than in most figures of the species.

The other pygidium is modified semicircular in outline, moderately convex, sloping smoothly and gently to posterior margin, more steeply laterally. Border only very slightly raised, widest at postero-lateral corners of pygidium. Axis very poorly defined by weak furrows; approximately one-third length of pygidium, and bearing distinct node immediately anterior to weak transverse furrow that delineates axis posteriorly. Accessory furrows absent except for faint traces near axial furrows. Margin appears to be spineless.

Limestone containing specimens GSC 46420 nos. 5c and 5e is slightly deformed, with loss of diagnostic detail. Cephalic proportions and furrow depth cannot be relied on in this instance to distinguish P. communis from other species of Pseudagnostus.

Specimens: GSC 46409 no. 1; GSC 46420, nos. 5b, 5c and 5e.

Localities: Mount Hunter section, 5044' and 5015-5020' above base respectively.

Age: Both P. josepha and P. communis range through most of the Franconian Stage.

Greggs (1962) found the specimens he assigned to P. josepha in the Ptychaspis striata teilzone of the Ptychaspis-Prosaukia zone (Middle Franconian) on Mount Murchison, Alberta. Wilson's (1954) "P. josephus" came from a boulder containing a characteristically Middle Franconian assemblage (Marathon Uplift, Texas). In the Franconia Formation in Minnesota, P. josepha is found in in all zones except the Elvinia zone (earliest Franconian) (Bell, Feniak and Kurtz, 1952); it is the only Conaspis zone species found also in other zones in that area. In the Franconia Formation of the St. Croix valley (Nelson, 1951) it occurs at all horizons from the Conaspis zone to the Prosaukia subzone; in Little Rocky Mountains, Montana, Lochman (1950) found it only in the Ptychaspis-Prosaukia zone.

The species already known as P. communis ranges even more widely than P. josepha. Bell and Ellinwood (1962) report it in Elvinia and Ptychaspis-Prosaukia zones (Wilberns Formation, Texas). Rasetti (1961, p. 108) reports it in association with other species of Pseudagnostus, in an assemblage corresponding to that of the Dunderbergia faunizone described by Lochman and Wilson (1958), in the Dunderberg Shale of Nevada (Palmer, 1960), and in the Jubilee Limestone of British Columbia (Kobayashi, 1938), i.e. between the Aphelaspis and Elvinia zones at the Dresbachian-Franconian boundary.

It is evident that Pseudagnostus communis (sensu lato) by itself does not allow a more precise definition of age than Franconian, probably Middle Franconia.

Order Ptychopariida Swinnerton, 1915

Suborder Ptychopariina Richter, 1933

Superfamily Dikelocephalacea Miller, 1889

Family Idahoiidae Lochman, 1956

Genus Wilbernia Walcott, 1924

Original description in part (Walcott, 1925, p. 123):

"Glabella . . . rectangular in outline, rounded in front. Two pairs of glabellar furrows are usually visible on the inner surface of the test, . . faint or absent on the outer surface.

"Fixed cheeks about one-third as wide as glabella in advance of the eyes. Ocular ridges present or indicated on most specimens. Eyes moderately large, . . midpoint back of the middle of the glabella."

(Palpebral lobes are described as tending to be elevated).

"The facial suture diverges considerably in front of the eyes and is intramarginal for some distance. The postero-lateral limbs are long and narrow.

"Cranidium with a wide frontal limb, in which the border and rim occupy relatively varying portions of the whole . . rim always wide and well defined . . .

"The pygidia . . have a high, very convex axis, and approximately flat sides. . . axial rings clearly marked by deep furrows. . . A descending, narrow ridge connects the posterior end of the axis proper with a flattened border. . . Four or more lateral pleurae are visible in the tail. . . "

The range is given simply as "Upper Cambrian".

Walcott's concept of the genus has been freely interpreted by later authors. Anterior margin ranges from strongly curved (W. pero (Walcott) (Lochman and Hu, 1959, pl. 60, fig. 16); W. halli Resser (Bell and Ellinwood, 1962, pl. 54, fig. 16)) to weakly curved (W.? minuta Wilson (Wilson, 1954, pl. 25, figs. 1, 5); W. expansa Frederickson (Bell, Feniak and Kurtz, 1952, pl. 32, figs. 3a, 3b); W. explanata (Whitfield) (Lochman, 1950, pl. 46, figs. 15, 17)). Curvature of anterior margin and proportional lengths (sag.) of anterior border and preglabellar field vary even within a single species (W. halli Resser, as above); Bell and Ellinwood informally distinguish between two varieties, and confirm the distinction by tracing a progressive change in preglabellar field-to-anterior border ratio through the stratigraphic range of the species. Unless there is marked bimodal distribution, the varietal cut-off point must be very subtle, if not entirely arbitrary.

Bell, Feniak and Kurtz (1952, p. 188) noted the variation of this ratio, and commented "The variability of this species (W. halli Resser) is characteristic of the genus, which . . . is badly in need of detailed studies".

Lateral glabellar furrows may be strongly and distinctly impressed (W. halli Resser, as above), or very faint, as in the genotype W. pero (Walcott) (Walcott, 1925, pl. 15, fig. 22); but their depth and sharpness vary with mode of preservation.

The glabella of W. pero (Walcott) is parallel-sided in almost all specimens figured; that of W. halli Resser displays varying degrees of taper. Lochman and Hu (1959, p. 422) remark that the glabella is distinctly quadrate in large cranidia of W. pero, but is still slightly conical in smaller holaspid cranidia. Glabella may be rounded anteriorly, or tend to be truncate with rounded antero-lateral corners.

Occipital ring of some species bears a low but distinct node, and in others it is lacking.

Five cranidia, perhaps representing two species, are assigned to this genus. None of them matches in every respect the figures of species already described, and they may represent new species. However, all the cranidia are incomplete and have been deformed with the enclosing limestone; formal erection of new species based on the present specimens is certainly not warranted. Although they were referring to a specimen resembling W. pero, the remarks of Bell et al., 1952, p. 195, are relevant: ". . . until the genus Wilbernia is better understood than it is now, the erection of a new species (so clearly similar to the type species) seems unwise. The monographing of Wilbernia will be a difficult chore that must have as a basis large collections of accurately zoned specimens; "species" now identified in Minnesota and Wisconsin either are loosely conceived or based on very few specimens".

As Wilson (1954, p. 274) remarked of another species, the specimens are

"assigned with some hesitation to the genus Wilbernia, but the size and position of the palpebral lobes, the large cylindrical glabella, narrower fixed cheeks, and characteristic faint pits in the marginal furrow seem to show its affinity. The straightness of the marginal furrow, thick border, and general narrowness of brim differ from the general concept of Wilbernia but the present range of variation in the genus encompasses these characteristics".

Wilson's "characteristic faint pits" show how Walcott's concept of the genus has been enlarged by later writers. These pits are absent from the "shallow furrow" of Walcott's genotype, W. pero; and are consistently absent from later figures of W. pero (Walcott) and of W. expansa Frederickson. However, they are present in all the specimens from GSC localities 46409 and 46420.

Other features of the present specimens regarded as diagnostic of the genus are: distance of palpebral lobes from axial furrow; distinctness of ocular ridges; pattern of glabellar furrows, no pair of which is confluent, and all of which are isolated from axial furrows although approaching them closely; fairly strongly divergent anterior facial sutures; strong, wide (sag.) occipital furrow, slightly shallower adaxially than laterally.

Among other genera that the present specimens resemble slightly, Burnetiella is rejected because its glabella is too strongly tapered and rounded anteriorly, its surface generally coarsely granulate, and its anterior border very wide with

abruptly inflected margin; Glyptometopsis, because its anterior border is too narrow, glabella too rounded anteriorly, first pair (1p) of glabellar furrows confluent, and anterior facial sutures not widely divergent; Briscoia, because glabellar furrow pattern bears little resemblance to that of the present specimens, preglabellar field is too wide, and there is no associated Briscoia-type pygidium. Assignment to Briscoia was suggested by Rasetti's (1944) figures of B.? devinei (Billings), pl. 37, figs. 14, 1; Rasetti remarks (p. 240) that "posterior glabellar furrows do not unite across the glabella as is usual in Briscoia, but the difference does not seem to be important enough to exclude this species from the genus". On the contrary, not only does Walcott's (1925) genotype B. sinclairensis (pl. 20, figs. 1-10) clearly show confluent 1st (1p) glabellar furrows, but these furrows are commonly confluent in most genera of the Family Dikelocephalidae (Treatise, p. 0252).

Wilbernia sp. A

Pl. 6, figs. 1, 2, 6.

Cranidium moderately convex, fixed cheeks sloping gently anteriorly and posteriorly; glabella subquadrate, with rounded anterior corners, slightly tapered anteriorly, bounded by shallow but distinct axial and preglabellar furrows, with faint fossulae at anterolateral corners; lateral glabellar furrows slanting strongly forward abaxially, posterior (1p) pair alone being distinct; preglabellar area very narrow (sag.); anterior

border furrow very slightly curved, and bearing irregularly spaced elongate depressions; anterior border broad, slightly raised, tapering abaxially so as to suggest partly intramarginal facial sutures; anterior facial sutures moderately to strongly divergent. Eyes and palpebral lobes short, raised, with distinct ocular ridges terminating at axial furrow opposite second glabellar furrow; posterior limbs of fixed cheeks at least two-thirds as wide (transv.) as glabella, but very short. Occipital ring bears low but distinct mesial node. Surface of one partly exfoliated specimen very finely punctate.

Free cheeks and pygidium unknown; but pygidia tentatively assigned to Lauzonella sp. are closely associated with one of these cranidia. However, in pygidia of figured species of Wilbernia the flat posterior border invariably appears to taper adaxially, whereas the better-preserved of these pygidia has posterior border of uniform width.

Specimens: GSC 46420, nos. 1, 2, 11, 12.

Locality: Mount Hunter section, 5015-5020' above base.

Wilbernia sp. B

Pl. 6, fig. 7.

Resembles Wilbernia sp. A in every respect except the following: glabella distinctly narrower, more elongate; anterior border curves forward slightly, concentric with anterior edge of glabella; preglabellar field very narrow (sag.); anterior

facial sutures less strongly divergent than in Wilbernia sp. A, and palpebral areas proportionately narrower.

Specimen: GSC 46409, no. 1.

Locality: Mount Hunter section, 5044' above base.

Age: The genus ranges through the Conaspis and Ptychaspis-Prosaukia zones of the Middle Franconian Stage. W. halli is reported exclusively from the Conaspis zone; W. expansa from both zones; W. diademata, W. explanata and W. pero from the Ptychaspis-Prosaukia zone alone. W. pero has been precisely located in the Ptychaspis subzone by some authors (e.g. Lochman and Hu, 1959, who report it from the Ptychaspis granulosa teilzone of the Upper Mississippi valley section).

Extreme shortness (sag.) of preglabellar field as a proportion of total length of frontal area suggests a later rather than an earlier age. Grant (1962, p. 985) notes that specimens of W. pero occurring low in its stratigraphic range tend to have relatively shorter preglabellar field and longer border than those occurring higher; and he remarks that this is a trend common to several genera of the Family Idahoiidae.

A Middle Franconian age for this genus, and the same age for Pseudagnostus josepha (q.v.), confirm each other; and they suggest an earlier date for Lauzonella sp. and Loganellus logani (Devine) than authors have generally attributed to trilobites of the Hungaria magnifica fauna in eastern Canada; alternatively,

specimens in the present collection may be incorrectly assigned to the genera Lauzonella and Loganellus.

Genus *Saratogia* Walcott, 1916

?Saratogia cf. S. fria Lochman and Hu

Pl. 6, figs. 8-10, 15.

Saratogia fria Lochman and Hu, 1959, p. 422, pl. 59, figs. 1-11.

Assignment of the present specimens to this genus and species is not entirely satisfactory, and is based primarily on their resemblance to Bell and Ellinwood's figures (1962, pl. 53, figs. 13-21) taken collectively rather than individually.

Lochman and Hu's original description is quoted in part:

"Cranidium rectangular, glabella truncato-conical, low convexity, three pairs of faint glabellar furrows, . . . dorsal furrow shallow, occipital furrow wide, shallow, occipital ring broad with a flat, medium-length spine, and a small median node; preglabellar field $\frac{1}{2}$ the glabellar length (sag.), convex and downsloping, anterior furrow wide, shallow, anterior border one-half width (sag.) of preglabellar field, convex, horizontal; . . . palpebral area one-third glabellar width, slightly convex and downsloping, anterior facial suture running nearly straight forward, palpebral lobe medium-size, a little posterior to center of glabella, palpebral furrow shallow, eye ridge distinct, posterior area narrow, length unknown. . . " "Pygidium unknown".

Although the description defines the species, it lacks precision and does not tally with the authors' illustrations. The terms "medium-length" (of the occipital spine), "downsloping"

(direction unspecified), "medium-sized" (of palpebral lobes) are vague; and in most of their figures anterior facial sutures do not run "nearly straight forward", but diverge strongly. Axial furrows appear to be deeper and more distinct than the description suggests.

Present specimens differ from the above description thus: glabellar furrows are extremely faint, only the posterior pair being clearly distinguished; axial ("dorsal") furrow is very distinct, and in one specimen is fairly deep; preglabellar field ranges from slightly convex to slightly concave; anterior facial sutures are conspicuously divergent; and anterior border furrow is sharp rather than wide.

They exhibit the following features considered to be characteristic of the species: subcylindrical to slightly tapered glabella, rounded-truncate anteriorly, of low to moderate convexity, faintly furrowed; clearly defined axial and preglabellar furrows with shallow antero-lateral fossulae; preglabellar field approximately half length (sag.) of glabella, twice as long as anterior border, which is moderately convex; occipital ring with damaged base of strong node or spine; posterior limbs short (exsag.), each one slightly narrower (transv.) than glabella. (Posterior limbs are better displayed in specimen GSC 46408, no. 5 than in any figured specimens seen so far; and they bear a strong, fairly deep border furrow). Degree of divergence of anterior facial sutures compares closely with that of some of

Lochman and Hu's figured specimens (1959, pl. 59, figs. 3, 4 and 8). Bell and Ellinwood (1962, pl. 53, figs. 13-20) figure specimens of S. fria in which anterior facial sutures diverge at varying angles, curving gently between ocular ridges and anterior margin; in no instance do they run "nearly straight forward".

The pygidium of specimen GSC 46408, no 1 is assigned to S. fria partly because of its association with the three cranidia, partly because it resembles the pygidium figured by Bell and Ellinwood (ibid., pl. 53, fig. 21); but their specimen, in turn, was assigned primarily on the basis of association with cranidia already identified. In fact, it corresponds more to Lochman and Hu's (1959, p. 421) diagnosis of Idahoia than of Saratogia: "1) broadly ovate; axis convex, of medium length, tapered; 2) border wide, variable in slope, often concave" rather than: 1) narrow-transverse, axis convex, of medium width, tapered; 2) border very narrow, downsloping" (Saratogia). The border of specimens GSC 46408, no. 1 is both concave and downsloping, broad at lateral extremities and tapering adaxially; clearly it cannot be assigned without reference to the associated cranidia.

Lochman and Hu (ibid., pp. 420, 421) compare and contrast the genera Saratogia Walcott 1916 and Idahoia Walcott 1925; they conclude that "there are no truly significant generic distinctions between the cranidia of Idahoia and Saratogia". Most

figured species of Idahoia, however, appear to be distinguished by generally more elongate proportions, straight-sided tapered glabella rather abruptly truncate anteriorly, strongly divergent and usually straight anterior facial sutures, and a rather marked mesial inflexion of anterior margin, in some species also of the anterior border furrow.

The systematic position of these two genera does not appear to be satisfactorily defined; a redefinition by Grant is said to be in preparation for the press (Bell and Ellinwood, 1962, p. 391).

Specimens: GSC 46408, nos. 1, 3, 5, 6.

Locality: Mount Hunter section, 5160-5165' above base.

Age: Lochman and Hu's species is from a Ptychaspis-Prosaukia zone fauna from the Bear River Range in southeast Idaho; Bell and Ellinwood describe specimens of S. fria from the same zone in the Wilberns Formation of central Texas.

Superfamily Remopleuridacea Hawle and Corda, 1847

Family Loganellidae Rasetti, 1959

Genus Lauzonella Rasetti, 1944

Original description in part (Rasetti, 1944, p. 243):

"Cranidium depressed. Glabella subrectangular or trapezoidal, with glabellar furrows more or less impressed in the shape

of two or three pairs of pits of variable form. Occipital segment wide. Brim almost as wide as the length of the glabella, slightly concave, without rim. Eyes as in Levisella. Anterior facial sutures widely divergent, then curving inward . . .

"Pygidium of the Levisella type but with a relatively shorter and narrower axis and wider smooth marginal area."

The pygidium of Levisella is (ibid., p. 246) "similar to pygidia of Loganellus":

"Pygidium short and wide. Axis prominent, conical, with five or six segments, extending almost to posterior margin. Pleural lobes with about four pairs of ribs and a smooth, flat or concave marginal area. Surface usually smooth."

Although Rasetti stresses the similarity of pygidia of these two genera, his figures (ibid., pls. 37, 38) suggest variation in relief; outline, length of axial region, and degree to which pleural segmentation is extended into broad concave border.

(The term "preglabellar field" is preferred here to Rasetti's "brim").

Lauzonella sp.

Pl. 6, fig. 4.

A poorly-preserved cranidium and three pygidia are assigned to this genus.

Cranidium: long (sag.) concave frontal area, broadly-rounded antero-lateral angles, widely divergent anterior facial

sutures, and low subquadrate glabella are considered diagnostic.

Pygidia conform with Rasetti's general description of the Family Loganellidae (in Harrington et al., 1959, p. 0331); particularly characteristic features are the slightly concave, uniformly wide border, entire margin, short (sag.) wide subelliptical outline, and prominent axis of six segments including conical terminal piece that extends for a short distance across broad posterior border. Pleural and interpleural furrows extend very faintly into posterior border.

Lateral glabellar furrows of L. bröggeri (Clark) and, to a less degree, of L. planifrons (Billings) (Rasetti, 1944, pl. 37, figs. 10, 22-25) take the form of pits. By contrast, those of the present specimen are elongate depressions; the posterior pair are deepest, and slant antero-laterally, and the other two pairs are shallower and lie more transversely. Glabellae of the two species figured by Rasetti are narrower and more elongate (sag.) than that of specimen GSC 46420, no. 12, which is subequant, slightly rounded anteriorly. The pygidium of L. planifrons appears to have elevated, not flat, pleural areas; but Rasetti makes no special point of flatness or convexity of these areas, and the feature is not necessarily of generic significance.

These differences are not regarded as invalidating the present generic assignment; but if better material were available they would probably justify erection of a new species.

Ocular ridges, palpebral lobes, occipital ring and posterior limbs of fixed cheeks are either absent or too poorly preserved to permit more refined identification.

Assignment of the pygidia is open to question, and is based at least to some extent on their association with the cranidium identified as Lauzonella sp. Pygidia strongly resembling these specimens are figured by Rasetti (1959), for example, as Loganel-lus cf. L. similis Rasetti, by Lochman and Hu (1959) as Idahoia wisconsensis (Owen), and even by Lochman (1956), in very poorly preserved material, as Briscoia pertransversa Lochman.

The broad concave frontal area is displayed also by Pterocephalia, but absence of characteristic pygidia makes this identification unlikely (cf. Palmer, 1960, pl. 9, fig. 3). On the other hand, a large hypostome (GSC 46420, no. 4d) bears some resemblance to Palmer's (ibid., pl. 11, fig. 9) hypostome "Type D", which he says could have been borne by Pterocephalia elongata or two other species from the Dunderberg Shale, Eureka district, Nevada.

Specimens: GSC 46420, nos. 5, 11, and 12.

Locality: Mount Hunter section, 5015-5020' above base.

Age: Both species of Lauzonella reported by Rasetti (1944) came from boulders containing a Hungaria magna faunal assemblage; the Hungaria zone is placed only with difficulty in the standard St. Croix sequence, but its age may range from Middle Franconian

to Late Trempealeauan. Rasetti, following Resser, favours Trempealeauan age. Its presence in this collection confirms Franconian age for the genus.

Genus *Loganellus* Devine, 1863

Rasetti's description of the genus (1944, p. 246) is quoted in part:

"Glabella slightly conical, moderately convex, rounded in front. One to three pairs of oblique glabellar furrows not joined in the middle. Preglabellar area always narrow, sometimes absent at the center; rim always present, narrow. Eyes opposite the glabellar midpoint, small, distant from the glabella about one-fifth of the glabellar width; eye ridges faint. Anterior facial sutures widely divergent, straight almost to the anterior margin. Postero-lateral limbs narrowly triangular. . . ."

Loganellus logani (Devine)

Pl. 6, fig. 14.

Olenus? logani Devine, 1863, p. 95, figs. 1, 2.

Loganellus quebecensis Devine, 1863, idem.

Olenus? logani Billings, 1865, p. 201, figs. 185, 186.

Ptychoparia logani Walcott, 1884, p. 36.

Loganellus logani (Devine), Bassler, 1915, p. 754; Rasetti, 1944, p. 247, pl. 38, figs. 13, 14.

The species has less strongly divergent anterior facial sutures, and lesser concavity of glabella, than *L. macropleurus* Rasetti; narrower glabella, less strongly divergent anterior

facial sutures, and wider (sag.) occipital ring than L. similis Rasetti; narrower glabella, less strongly curved anterior margin and less sinuous occipital furrow than L. belli (Billings). The generic assignment of L.? duplicatus (Raymond) and L.? unisulcatus (Raymond) being in doubt, these two species are not discussed here.

A partly exfoliated cranidium is assigned to this species; it is only moderately well preserved, and some features are impaired by deformation. It bears a strong resemblance to specimens GSC 46420, nos. 1, 2 and 11 and the large cranidium of specimen GSC 46420, no. 12, but differs from them in the following respects: glabella more elongate, less quadrate, measuring 6.1mm in length, 4.5mm in maximum width; glabella rounded anteriorly rather than truncate; palpebral lobes and ocular ridges somewhat more advanced, approximately at level of glabellar mid-point (sag.); anterior portions of facial sutures less strongly divergent. Glabellar furrow pattern is imperfectly displayed, only the first pair (lp) being at all distinct. This is regarded as an accident of preservation, not a morphological feature. (In L. macropleurus Rasetti only one pair of glabellar furrows is said to be well impressed (Rasetti, 1944, p. 247). In every other respect, the specimen closely resembles Rasetti's figure (pl. 38, fig. 13).

Specimen: GSC 46420, no. 5a.

Locality: Mount Hunter section, 5015-5020' above base.

Age: At Lévis, Quebec, the species was found in a boulder containing other species characteristic of the Hungaia magnifica fauna; remarks on the age of Lauzonella sp. above refer also to this species.

Phylum Brachiopoda

Class Inarticulata Huxley, 1869

Order Lingulida Waagen, 1885

Superfamily Lingulacea Menke, 1828

Family Obolidae King, 1846

Subfamily Lingulellinae Schuchert, 1893

Genus Westonia Walcott, 1901

Westonia linguloides (Kobayashi)

Pl. 6, fig. 5.

Obolus (Westonia) linguloides Kobayashi, 1935, p. 44, pl. 8, figs. 23, 24.

Westonia linguloides (Kobayashi), Ulrich and Cooper, 1938, p. 56, pl. 2C, figs. 10, 14, 15.

As erected by Walcott in 1901 (p. 691), the subgenus comprises Obolidae that are "ovate, with ventral valve slightly acuminate; . . . Surface marked by concentric and radiating striae that are crossed by transverse, semi-imbricating, "ripple-embossed" lines" (Walcott, 1912, p. 450).

The present specimen does not correspond exactly with any

of the species figured and described by Walcott (1912); it most closely resembles Obolus (Westonia) stoneanus (Whitfield) (ibid., pl. 27, figs. 2, 2a-2g; pl. 49, figs. 2, 2a), but is rather more elongate-oval, and more distinctly acuminate; it appears to be a pedicle valve. The transverse striae display very small undulations in a few places, not confined to the axial portion of the valve; Walcott considered that the distribution of these undulations was of specific diagnostic value. Westonia ollia (Walcott) 1924a, pl. 121, figs. 8-10; and Howell, 1945, pl. 2, figs. 14-19) is more ovate, less sharply acuminate than the present specimen, and the fine undulations of the transverse striae are much less conspicuous.

Kobayashi remarks (1935a, p. 44) "the typical linguloid outline and the surface ornamentation of the Westonia stoneanus type are the distinctive characters of this species". W. stoneanus (Whitfield), however, possesses a distinctive outline and grows twice as long as W. linguloides. The present specimen is a little longer than Kobayashi's figured specimen (pl. 8, fig. 23; 7.5mm compared with approximately 6.15mm) but by no means twice as long; it compares very closely with his illustration.

Specimen: GSC 46419, no. 1.

Locality: Mount Hunter section, 5516-5566' above base.

Age: This specimen is associated with Micragnostus sp. cf. Geragnostus (Micragnostus) bisectus var. typica, believed to be

probably not later than Middle Trempealeauan in age. Kobayashi (ibid., p. 40) says only that his type-specimen, collected near the Alaska-Yukon Territory border, is "from a typical Pacific fauna of the late Upper Cambrian . . ."

The genus is very wide-ranging geographically; it is reported from the Lower Ordovician and Upper Cambrian in Nevada, the Upper Cambrian in Nova Scotia, New Jersey, Wisconsin, Texas and Alaska, and from the Middle Cambrian in Utah (Walcott, 1912, pl. 49).

ORDOVICIAN

Class Trilobitá Walch, 1771

Order Ptychopariida Swinnerton, 1915

Suborder Ptychopariina Richter, 1933

Superfamily Solenopleuracea Angelin, 1854

Family Solenopleuridae Angelin, 1854

Subfamily Hystricurinae Hupe, 1953

Genus Hystricurus Raymond, 1913

Raymond (1913) gives the following generic diagnosis:

"Glabella conical, tapering towards the front, outlined by deep furrows at sides and front. Glabellar furrows absent. Fixed cheeks long, extending nearly to the genal angles. Dorsal

furrows paralleled by a narrow convex ridge. Eyes of medium size, situated opposite the middle of the glabella. Cranidium with deeply concave border in front.

"Pygidium rounded, with concave border. Axial lobe prominent, with 5 rings, and there are five pairs of ribs on the pleural lobes. Surface smooth or pustulose.

"Type, Bathyurus conicus Billings."

Ross (1951) amplifies Raymond's description but at the same time restricts the generic concept; in particular he emphasizes (p. 40) the:

"relatively low, uninflated glabella, slender rather than broadly subtriangular postero-lateral limbs, and relatively long, horizontal, usually almost semicircular palpebral lobes with lunate rims set off by distinct palpebral furrows."

Ten cranidia are assigned to this genus although the writer is aware that they do not correspond with Ross's concept in at least one respect: posterior limbs of fixed cheeks (adequately preserved in only four specimens) tend to be broadly subtriangular. But the combination of other features produces a character so strikingly similar to that of specimens already figured that the one conflicting feature is believed to be of less than generic significance. If confirmed by abundant well-preserved specimens, it might call for erection of a subgenus. The fixed cheeks of most figured species admittedly possess rather slender posterior limbs (e.g. H. armatus and H. sulcatus Poulsen, 1937; H. crocotalifrons (Dwight) (Dwight, 1884)), but the specimen of H. conicus (Billings) figured by Raymond as representative of the genotype is incomplete in this respect. Moreover, by comparison

with other genera of the Family Solenopleuridae such as Sao, Acrocephalites, Pesaia, Paracrocephalites and Parasolenopleura (Treatise, p. 0277, fig. 8), in which posterior limbs are unequivocally subtriangular, those of the present specimens are clearly closer in character to Hystericurus. They may be compared in this respect with Hillyardina (Treatise, p. 0277, fig. 8) from which they differ, however, in other important features.

The convexity of the present specimens, particularly that of the glabella, compares closely with that of Ross's figured specimens; what Ross regards as "relatively low, uninflated" appears to this writer to be of medium to strong convexity. Objectivity is probably unattainable in making estimates of this kind, and Ross supports his differentiation of species by the most careful measurement of cephalic proportions whenever this is feasible. Estimates of "slenderness" or "subtriangularity" of the posterior limbs of the cranidium are likewise inevitably subjective and allow some latitude of interpretation. The term "relatively long", applied to palpebral lobes, is imprecise, and Ross measures this dimension in only one species (H. politus), which happens to be represented by specimens with unusually short palpebral lobes. The comparatively short lobes of specimens from GSC locality 46418 does not disqualify them from assignment to this genus.

Anterior facial sutures of the present specimens may diverge

a little more strongly than in most figured species of Hystricurus, but this feature is too poorly preserved to be of much diagnostic value. However, it clearly precludes assignment to the genus Parahystricurus Ross, the anterior facial sutures of which invariably converge.

General character of the cranidium closely resembles that of Onchopeltis Rasetti, but that genus possesses two pairs of distinct lateral glabellar furrows; no specimens from this collection show either glabellar furrows or the non-tuberculate patches that are said to represent them in the Hystricurinae. Ross (1951) remarks that the presence of glabellar furrows distinguishes Rasetti's genus from his own genus Parahystricurus.

Hystricurus sp.

Pl. 6, figs. 16, 17.

Of the ten cranidia assigned to this genus no two are exactly alike; differences are subtle and gradational, and do not permit division of the group into varieties.

Cranidium moderately inflated, glabella standing well above fixed cheeks, which slope steeply antero- and postero-laterally; glabella generally ovate-tapered, rounded anteriorly but tending to be truncate in some specimens, bounded by deep and distinct axial furrows, anteriorly by preglabellar furrow that may continue with uniform depth across axis or may be shallow at axial line;

conspicuous fossulae at antero-lateral corners of glabella; no furrows or non-tuberculate patches on glabella. Eyes and palpebral lobes short, crescentic and prominent in the few specimens showing them; palpebral furrow shallow but distinct and non-tuberculate; maximum width (transv.) of palpebral areas about one-third that of glabella at corresponding point. In some specimens faint ocular ridges connect palpebral lobes with axial furrows, but other specimens appear to lack them; they are commonly somewhat obscured by tuberculate surface of cranidium. Pre-glabellar field one-fifth to one-quarter length of glabella, bounded indistinctly in front by broad shallow anterior border furrow; in some specimens border furrow is more sharply defined by abrupt elevation of posterior edge of anterior border, but this variation is gradational and cannot be correlated with variations in other cranidial features. Anterior border less than half as wide (sag.) as preglabellar field; in most specimens border is gently convex and not strongly raised, but in some it appears narrower (sag.) , more sharply defined and steeply inclined towards border furrow. Occipital furrow moderately deep, distinct, and curving forward near axial furrow; occipital ring distinctly narrower (exsag.) laterally than mesially; no mesial spine or node on occipital ring.

Free cheeks not identified.

Cranidial surface coarsely tuberculate, closeness of tuber-

cles varying slightly; some specimens (GSC 46418, nos. 2, 3c, 6, 7a) are also finely granulose.

One pygidium (length 3mm, width 5mm) is closely associated with the cranidium of 46418, no. 1; it is too small to belong to the same moult stage of the same individual, but is probably assignable to the genus. It is subelliptical in outline, bluntly pointed laterally; posterior border entire, flat, narrow and tapering slightly adaxially; at least three pleural segments; axial region damaged, but reaches posterior border, which is slightly inflected at axial line. Pygidium only moderately convex, and not conspicuously tuberculate.

Specimens: 46418, nos. 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b.

Locality: Mount Hunter section, 6576-6581' above base.

Age: Ross's (1951) study of the Garden City Formation (Lower Ordovician) of northeastern Utah established twelve zones, which he designated A to L in ascending order. His eight named and nine unnamed species of Hystericurus range from zones A to F, and the species to which the present specimens correspond most closely, H. genalatus and H. paragenalatus, occur exclusively in zone B.

Ross places the Lower Ordovician-Middle Ordovician boundary between zones J and L, "possibly . . . a little lower", and regards as highly likely the correlation of his zones A and B with the Cass Fjord Formation of Greenland (Poulsen, 1927 and 1937),

i.e. of Tremadocian (Lower Canadian) age. He correlates zones A and B with the McKenzie Hill Formation of Oklahoma, and zone B with the Tribes Hill and Stonehenge Formations "of the East".

Kobayashi (1934) described two species of Hystericurus from South Chosen in a Clarkella fauna from the uppermost of three Lower Ordovician faunizones, equivalent to the Xenostegium fauna of the Mons Formation and the Megalaspis fauna of the Sarbach Formation of the Canadian Cordillera. In 1955 the same author reported Hystericurus cf. H. genalatus in a Symphysurina fauna from Jubilee Mountain in the lowest-but-one of eight faunizones established by Evans (1933) in the McKay Group of southeastern British Columbia. Ross (op. cit.) found two unnamed species of Symphysurina in zones A and C of the Garden City Formation; and on Mount Hunter, Symphysurina occurs 30' upsection from the present collection of Hystericurus.

These specimens are therefore believed to be of earliest Ordovician age.

?Hystericurus sp.

A single cranidium in GSC 46404, slightly damaged and partly exfoliated; strongly suggests affinity to a few of the specimens of Hystericurus sp. in GSC 46418, particularly 46418-1.

As in Hystricurus sp. the glabella tapers and is truncate anteriorly; its surface is tuberculate, although much less coarsely than in the specimens in GSC 46418; anterior facial sutures are divergent, but not strongly; it possesses distinct ocular ridges, terminating anteriorly just behind antero-lateral corners of glabella; preglabellar field is slightly longer (sag.) than anterior border.

In length (exsag.) and width (transv.) of palpebral area it resembles some species of Hystricurus but not others. Eyes are short (approximately one-quarter length of the glabella), and palpebral areas are not more than one-half width of the glabella at a point opposite middle of palpebral lobe. In species that have squat, strongly tapered or globose glabella, palpebral areas are commonly narrower than this.

The present specimen differs from those of GSC 46418 in the fineness of its tuberculate surface, more elongate glabella (excepting GSC 46418-1), narrower (sag.) occipital furrow, occipital ring less strongly tapering abaxially, less conspicuous fossulae, more pronounced ocular ridges, more sharply-defined anterior border furrow, and more abruptly upturned anterior border.

Notwithstanding these detailed differences, the general character of the cranidium still justified^s tentative assignment to this genus. It fairly closely resembles Hystricurus sp. aff.

H.? genacurvus (Hintze) (Berg and Ross, 1959, pl. 21, fig. 23), but differs in its truncate glabella and slightly broader (exsag.) posterior limbs of fixed cheeks. Strongest similarities are the comparative smoothness of carapace, distinct and fairly deep axial furrows smoothly continuous with preglabellar furrow of similar depth, fairly short crescentic eyes and palpebral lobes, and elongate glabella. It is not a perfect match with any of the species figured by Ross (1951).

It has points of similarity with Glabretina andrewsi Lochman (Lochman, 1965, p. 476, pl. 62, figs. 1-18), but the glabella of that species is uniformly rounded anteriorly. Preglabellar furrow of the present specimen is straight for at least one-half of its length. Moreover, the present specimen is found in close association with Lloydia (Leiostrigium) cf. L. manitouensis, whereas Lochman remarks (ibid., p. 477) that in Zone D collections from the subsurface Deadwood Formation in Montana " . . . specimens of Glabretina andrewsi . . . never occur in the limestone lenses containing Lloydia (Leiostrigium) cf. L. manitouensis . . ."

Specimens: GSC 46404, no. 20.

Locality: Mount Hunter section, 7472' above base.

Age: Forms associated with this specimen are thought to be part of a Zone D faunule, of Canadian (Early Ordovician) age. By itself it could belong to any of the standard Ordovician zones from A to F. H.? genacurvus, to which it is somewhat similar, is said to be characteristic of Zone C; the presence of that species

in a Zone D faunule is not impossible.

Superfamily Leiostegiacea Bradley, 1925

Family Leiostegiidae Bradley, 1925

Subfamily Leiostegiinae Bradley, 1925

Genus Lloydia Vogdes, 1890

Subgenus Lloydia (Leiostegium) Raymond, 1913

Leiostegium Raymond, 1913, p. 68.

Lloydia (Leiostegium) Raymond, Harrington et al., 1959, p. 0313.

Lloydia bituberculatus (Billings) and Leiostegium quadratus (Billings), type species of the genera Lloydia and Leiostegium respectively, are now regarded (Lochman, 1965, p. 477) as members of a single gradational group of species. Subgenera L. (Lloydia), L. (Leiostegium) and others have been erected (Treatise p. 0313) to allow for wide variability of the group both in eastern and Cordilleran faunas. It is presently under study by Rasetti, and as Lochman remarks (ibid., p. 478), until the results of his work are published " . . . it will not be possible to determine which of the variable features are . . . of subgeneric and which are of specific value."

Raymond (1913, pp. 66 and 68) contrasts the tapering glabella of Lloydia with the quadrate glabella of Leiostegium; and in Lloydia the eyes are closer to the axial furrows than they

are in Leiostegium. Otherwise his descriptions suggest very little difference between the two. His figure of L. quadratum (pl. 7, fig. 17) shows transverse markings on the glabella that may be short ridges, discontinuous across the axis; but they are poorly defined, and are not described in the text, nor are they illustrated by any later writers.

It is no longer possible to apply strictly the terms "quadrate" and "tapering" with confidence when trying to distinguish between these two subgenera. Berg and Ross (1959, p. 114) assign to L. (Leiostegium) manitouensis specimens with tapering glabella and small palpebral lobes; Lochman (1965, pp. 478-480) assigns to ~~The same~~ subgenus specimens with perceptibly tapering glabellae. The glabella of Ross's Leiostegium sp. (1958, pl. 83, figs. 21, 22, 25) is even more distinctly tapered. Whatever Raymond's original intent, his definition of the genus (now subgenus) has been very broadly interpreted by later writers.

L. (Leiostegium) manitouensis (Walcott)

Pl. 6, figs. 18, 19, 24.

Leiostegium manitouensis Walcott, 1925, p. 104, pl. 23, figs. 12-19.

L. manitouense Walcott, Ross, 1951, p. 105, pl. 27, fig. 1.

L. manitouensis Walcott, Ross, 1957, p. 489, pl. 43, figs. 18-20.

L. (Leiostegium) manitouensis Walcott, Berg and Ross, 1959, p. 14, pl. 21, figs. 10, 13, 17, 24.

Lloydia (Leiostegium) cf. L. manitouensis (Walcott), Lochman, 1965, p. 478, pl. 62, figs. 35-41.

Walcott's original description stressed the quadrate glabella, two pairs of anterior pits, "small frontal border" and "size and position of the eyes". As already noted, the term "quadrate" need not exclude from this assignment specimens with slightly tapered glabella.

The species is represented in this collection by ten cranidia and twenty-two pygidia from GSC locality 46416, and three cranidia and nine pygidia from GSC locality 46404, 76' higher in the section than locality 46416. All specimens are incomplete, and to some extent exfoliated. Deeper furrows in exfoliated specimens are contrasted with the shallower corresponding furrows in those that retain the carapace.

Cranidium only moderately convex; ranging in length (sag.) from approximately 6mm to more than 18mm, and in width of posterior fixed cheeks (transv) from not more than 8mm up to 24mm. Glabella evenly up-arched, except for slightly abrupt change of curvature across axis (as seen in transverse section) in some specimens, and slight steepening towards anterior border furrow. Some possess an extremely faint single pair of lateral glabellar furrows, located posteriorly. Occipital furrow deeper, sharper and slightly forward-pointing near axial furrows, but shallow and wider across axis. Axial furrows fairly sharp, straight, and very slightly convergent anteriorly. Anterior border furrow of moderate depth, rounded laterally, sharper adaxially, and deflected forward a little by anterior end of glabella. Anterior

facial sutures divergent forwards, but tending to be subparallel near anterior margin; posterior facial sutures strongly flared, making rounded-acute angle with posterior cranial border, itself somewhat swept back. Eyes and palpebral lobes damaged in all specimens, but appear to be small, and palpebral area narrow (transv.).

Pygidium semicircular to subtriangular, i.e. posterior margin strongly curved at axial line, less strongly abaxially. Anterior margin of some specimens shows fairly abrupt forward curvature, closer to lateral tip than to axial furrow; but this feature is of questionable importance because it may be only apparent, and due to an accident of preservation. Pygidium moderately convex, posterior axial segments and terminal piece more strongly convex. Posterior border furrow shallow, anterior border furrow deeper but rounded; axial furrow sharp, straight, and fairly deep where exfoliated. Transverse furrows of axis shallow, deeper in exfoliated specimens; anteriormost furrows most distinct, posteriormost more faint. Terminal piece slopes steeply backward, reaching posterior border furrow which is generally indistinct at axis. All specimens except one (GSC 46416, no. 40) possess six or seven axial rings. Width of pygidium ranges from 8mm to 24.5mm, its length from 5.7mm to 18.5mm. Anterior width of axial lobe as much as 0.35, or as little as 0.18, of the total width of the pygidium, but most commonly 0.30 to 0.33. In the most transverse specimen, the length is 0.56 the width; in the most elongate this ratio is

0.75; the average value is 0.67. The latter ratios refer to the whole pygidium.

Fragmentary free cheeks associated with these specimens possess smoothly-curving antero-lateral margins, continuous with fairly long and strongly-tapering genal spines; anterior and posterior border furrows shallow but distinct, defining border of uniform width. Anterior facial suture curves sharply towards axis as it crosses border, and is intramarginal for very short distance; this is consistent with cranidial specimens, in which antero-lateral tips of fixed cheeks are rounded, but in which it is impossible to say at what exact point the facial suture gives way to the anterior margin proper.

Specimens: GSC 46416, nos. 5, 10-12, 15-19 (cranidia); 1, 12, 13, 15, 26-38, 40, 41, 48, 49 (pygidia); 28, 40 (free cheeks); GSC 46404, nos. 3, 13, 14 (cranidia); 2, 4, 5, 13, 14, 19 (pygidia); 10, 18 (associated free cheeks).

Locality: Mount Hunter section, 7396' and 7472' above base respectively.

Age: Walcott (1925, p. 104) describes specimens from the basal Manitou Limestone in Colorado, and from the Chushina Formation on Mount Extinguisher, near Mount Robson, British Columbia, both collections being of "Ozarkian" age. Ross (1951, p. 106) reports the species in Zone D of the Garden City Formation in Utah, and Berg and Ross (1959, pp. 113-114) in the same zone of the Manitou Formation in Colorado; they remark that the genus probably ranges up into Zone G of the standard Ordovician

succession, but that in association with Kainella it is a good index to Zone D. Collection GSC 46416 contains two pygidia of Kainella, and is thus assigned with some confidence to Zone D. Lochman comments (1965, p. 469) that "the species is a good Zone D guide fossil for Cordilleran cratonic assemblages", but even in miogeosynclinal assemblages it is more likely to be found in a Zone D fauna than elsewhere.

Superfamily Remopleuridacea Hawle and Corda, 1847

Family Remopleurididae Hawle and Corda, 1847

Subfamily Richardsonellinae Raymond, 1924

Genus Kainella Walcott, 1925

Kainella flagricauda (White)

Pl. 6, figs. 20, 25.

Dicellocephalus (?) flagricauda White, 1874, p. 12.

Kainella flagricauda (White), Kobayashi, 1953, p. 45, pl. 3, fig. 5 (with synonymy to 1953); Lochman, 1965, p. 480, pl. 62, figs. 19-28.

Dicellocephalus inexpectans Walcott, 1884, p. 90, pl. 1, fig. 10.

Kainella inexpectans (Walcott), Kobayashi, 1953, p. 44 (with synonymy to 1953).

Three incomplete cranidia in GSC 46416 have the subquadrate anteriorly rounded glabella, widely-flaring anterior facial sutures and shallow pitted border furrow that are typical of the genus. Preglabellar field is slightly narrower than in some

figured examples of K. flagricauda, and the usual radiating anastomosing ridges (genal caeca?) are absent or indistinct.

The two pygidia in GSC 46416 are likewise incomplete, and the overall proportions are not seen. The pygidia are definitely not as transverse as in K. orientalis Rasetti (1943, p. 102), and they possess only four axial rings, not six as in K. billingsi (Walcott). Axial rings display the "flattened M" form characteristic of Kainella; and the terminal piece in one specimen has a sharply-defined prow-like ridge that drops steeply to the posterior margin from an elevation slightly higher than that of the rearmost axial ring. Two distinct pleurae, curved strongly backwards and adaxially, terminate in spines that are not as long and slender as those of K. billingsi. Specific identification relies strongly on a resemblance to Lochman's figured specimens (1965, pl. 62, figs. 19-28), one of which is White's holotype pygidium from Nevada. (Lochman places K. inexpectans (Walcott) in synonymy, and certainly Kobayashi (1953, p. 44) does not describe any distinctive features that would justify regarding it as a separate species.)

Specimens: GSC 46416, nos. 22, 23, 24 (cranidia); 20 and 21 (pygidia).

Locality: Mount Hunter section, 7396' above base.

Age: In association with Lloydia (Leiostegium) manitouensis the genus is considered a good index of Zone D of the Lower Ordovician (Berg and Ross, 1959, p. 114). According to Kobayashi

(1953, as above) K. inexpectans is found in the Lower Pogonip Group of the Eureka district, Nevada; and K. flagricauda (White) (1877, p. 66) was originally described from "strata of the age of the Quebec group of Canada: Schellbourne, Schell Creek range, Nevada". Kobayashi also collected K. flagricauda from the Good-sir Formation on First Mountain, near Sinclair Canyon, British Columbia. Lochman (1965) and Ross (1957) report K. flagricauda and Kainella sp. from Zone D of the subsurface Deadwood Formation of the Williston Basin, Montana (see discussion below).

Kainella spp.

Pl. 6, figs. 21, 22, 26.

GSC 46404 contains one small fragmentary cranidium, and part of the pygidium of a larger specimen. The cranidium displays most of the features characteristic of the genus, i.e. widely-flaring anterior facial sutures, radiating genal caeca, semicircular eyes and sharply-defined, relatively deep palpebral furrow, subquadrate glabella slightly rounded anteriorly, one distinct and one fainter pair of lateral glabellar furrows slanting forward towards axial furrow, and preglabellar area slightly wider (sag.) than anterior border. Occipital furrow is more or less uniform in depth and width, and curves gently forward abaxially. Occipital ring tapers abaxially. Posterior limbs of fixed cheeks are missing.

Pygidium possesses two or three strong, curved, spinose

pleurae, and in general aspect strongly suggests this generic identification. It is too poorly preserved for more precise description.

Two of the cranidia figured by Ross (1957, pl. 43, figs. 24, 27) from the Lower Ordovician Deadwood Formation of the Williston Basin, Montana, closely resemble the small specimen in GSC 46404, no. 21. Ross does not attempt to identify to species. However, Lochman (1965, pp. 480-482) assigns his specimens to K. flagricauda (White), which she redescribes in detail from the holotype and numerous plesiotypes.

A fragmentary pygidium in GSC 46415, no. 1 can be referred to this genus with little doubt; "flattened M" character of axial rings, and long backward-curving spinose pleurae, are enough to identify it. But the number of pleurae is uncertain. Two can be seen; one of them is short, slender, and barely distinguishable from the posterior apron behind the axial lobe, the other has a long deep depression that is probably a pleural, not interpleural, furrow. If another pleura existed, it is either strongly depressed; or it has been damaged and removed without leaving any trace.

Although very little of the pygidium is preserved, the specimen is clearly not conspecific with that in GSC 46404, no. 6; moreover, GSC 46415 occurs more than 300' higher in the section than GSC 46404.

Two specimens of particular interest are found in GSC 46402, no. 2 and 3, ten feet up-section from GSC 46415. They are both incomplete; although one specimen is much larger than the other, they represent individuals of approximately the same size.

By correlating the two specimens, a terminal piece and five axial rings can be counted. There are at least three pleural segments of approximately equal width (anterior segment is not clearly defined). Interpleural furrows are shallow, narrow, and tending to be intermittent. Pleural furrows are distinct and deep; second pleural furrow is interrupted at about its midpoint. A deep furrow truncates the rearmost pleura and is confluent anteriorly with axial furrow at a small angle; the specimen is not sufficiently complete to reveal whether this is a pleural or interpleural furrow.

Terminal piece is missing from larger specimen, and is poorly displayed in the smaller; but it appears to be unusually small, especially in view of the great width of the pleurae. Most of the pygidial margin is lost, but the rounded indentation between anterior and second pleurae is clearly visible, and appreciably aids generic identification.

Specimens: GSC 46416, nos. 20, 21 (pygidia); GSC 46404, no. 21 (cranium), no. 6 (pygidium); GSC 46415, no. 1 (pygidium); GSC 46402, no. 3 (impression of smaller specimen and original of larger), and no. 2 (impression of larger specimen).

Localities: Mount Hunter section, 7396', 7472', 7776' and 7786' respectively above base.

Age: In so far as GSC 46416 and 46404 both contain the association of Lloydia (Leiostegium) manitouensis with Kainella, the same remarks concerning age apply to both collections. In cratonal assemblages they are unequivocally Zone D fossils, although in geosynclinal sites they range widely in the Lower Ordovician (Lochman, 1965, p. 471). Ross's remarks (1957, p. 467) concerning long-range correlations of this faunal zone are of great interest. "The assemblage is clearly equivalent to the "D" zone of the Lower Ordovician of Utah and Nevada, the lower part of the Manitou Formation of Colorado, part of the Lower Ordovician of the Northeastern States, the lowest division of the Ordovician in Argentina (Harrington, 1938, p. 279-281; Kobayashi, 1935), part of the Lower Ordovician of Korea (Kobayashi, 1953), part of the Mons Formation of the Canadian Cordillera (Walcott, 1928, p. 273, 284, 331, 332, 359), and part of the McKay group of British Columbia (Evans, 1933, p. 126-129). This zone is apparently equivalent to the strata . . . "

from which Lochman described plesiotypes of K. flagricauda when she assigned Ross's specimens to the same species. His designation of the same assemblage as belonging to Zone A (1957, p. 470) is presumably in error.

GSC 46415, no. 1 cannot be dated more closely than "Early Ordovician". Kainella here occurs 10' down-section from a collection containing another species of Kainella and genal spines that are referred to Symphysurina, most species of which commonly occur in the lowermost zones of the Lower Ordovician. However, GSC 46415 was collected more than 300' above beds containing

reliable Zone D guide fossils, and there is no evidence of repetition of section. The presence of Kainella spp. at this horizon, and in GSC 46402 ten feet higher, suggests that Zone D may be represented by a considerable thickness of section on Mount Hunter, i.e. of the order of at least 400'.

Unidentified free cheek (?Kainella sp.)

A closely-spaced network of fine raised lines extends across exfoliated surface of ocular platform; the pattern is not radial, but transverse and slightly backward-trending. Genal angle is acute; posterior and lateral border furrows shallow, rounded and fairly wide; border itself gently convex and bearing faint pattern of Bertillon lines parallel to margin. Genal spine not preserved.

Anteriorly, free cheek appears to be bounded by very widely-flaring suture; a distinct forward steepening of ocular platform towards this line suggests that it is not merely a transverse fracture. If it is indeed a facial suture the specimen may reasonably be referred to Kainella sp. Anterior portions of the facial sutures of Kainella are very strongly transverse, and collection GSC 46415 contains a pygidium definitely assigned to that genus. Lochman (1964b, pl. 63, fig. 36) figured a free cheek of Euloma cordilleri Lochman with identical delicate genal caeca; but its facial suture is only slightly divergent anteriorly.

Specimen: GSC 46415, no. 2.

Locality: Mount Hunter section, 7776' above base.

Suborder Asaphina Salter, 1864

Superfamily Asaphacea Burmeister, 1843

Family Asaphidae Burmeister, 1843

Subfamily Symphysurinae Kobayashi, 1955

Genus Symphysurina Ulrich in Walcott, 1924

Symphysurina cf. S. spicata Ulrich

Pl. 7, fig. 20.

Ampyx? Walcott, 1884, pl. 12, fig. 19 (pygidium only, not described.)

Symphysurina spicata Ulrich in Walcott, 1925, p. 113, pl. 21, figs. 12-18.

S. spicata Ulrich, Kobayashi, 1936, p. 164, pl. 21, fig. 15 (pygidium only); Lochman and Duncan, 1950, p. 352, pl. 52, figs. 8-12.

S. (Symphysurina) spicata Ulrich, Kobayashi, 1955, p. 430, pl. 3, figs. 8-9.

Two very poorly preserved cranidia are referred to this species; although posterior limbs of cranidia are poorly defined, the specimens strongly resemble Walcott's figures (1925, pl. 21, figs. 12 and 13).

Cranidium smooth, moderately convex, microscopically punctate (visible in whitened specimens under fairly low magnifica-

tion only); axial and anterior border furrows effaced, anterior border with Bertillon, or terrace, lines; anterior margin rounded, not acuminate; palpebral lobes semicircular, flat, approximately one-sixth length of cranidium, with their midpoint somewhat posterior to midpoint (sag.) of cranidium. Anterior facial sutures parallel or very slightly divergent; posterior facial sutures diverge strongly, but may recurve sharply to define postero-lateral limbs, which do not appear to extend beyond the continuation of a line tangential to both palpebral lobe and antero-lateral corner of cranidium.

Posterior margin fairly strongly curved behind axial region, and swept back abaxially; a distinct forward inflexion of the margin corresponds to the point at which the axial furrow, so shallow as to be almost absent, would reach the posterior margin. Mesial node level with midpoint of palpebral lobes very faint in larger specimen, invisible in the smaller one. Length of larger cranidium: 15.5mm; of smaller one: approximately 4.5mm.

Ulrich's description (in Walcott, 1925) of S. spicata does not mention a mesial node, but the generic description (ibid., p. 108) includes "median tubercle small but constantly present, situated between the eyes, . . .". However, the literature contains numerous figures of Symphysurina spp. in which the mesial node is unrecognizable; as in the present larger specimen, it may be more easily detected in partly exfoliated material.

Punctation of these specimens is extremely faint, and they are perhaps better described as pseudopunctate if fine depressions cannot be positively identified as punctae. Lochman (1964, p. 471) remarks that a group of punctate species of Symphysurina is "distributed in miogeosynclinal areas from northeastern Greenland to the Cordilleran region of Canada and Montana", but S. spicata is not included in her list. On the other hand, the group does include S. elegans Poulsen, a Greenland form to which the present specimens bear a strong resemblance. But in S. elegans the axial furrow is quite distinct posterior to palpebral lobes, and perceptible in front of them; in S. spicata it is not. In S. elegans, also, antero-lateral corners of the cranidium are rather more angular than they are in the present specimens (Poulsen, 1937, pl. 2, figs. 11-18).

Specimens: GSC 46417, nos. 1, 2.

Locality: Mount Hunter section, 6606-6611' above base.

Age: All the species of Symphysurina described by Walcott (and Ulrich) (1924b, 1925) are of "Ozarkian" age; two of them (but not S. spicata) come from the Sarbach Formation (Upper Canadian) of southern Alberta (Ulrich and Cooper, 1938, p. 119, reassigning Walcott's original locality. This reassignment is mentioned by Ross (1951, p. 30) but it is not immediately evident from Ulrich and Cooper that such reassignment has taken place).

Ross (1951, pp. 114-116, pls. 23, 28) reports unnamed

species of Symphysurina from Zones A and C of the Garden City Formation of northeastern Utah; as noted elsewhere (see Hystri-
curus sp.) these are probably correlative with the Cass Fjord Formation of Greenland, of Early Canadian (Tremadocian) age.

Symphysurina sp.

Two collections from the same locality contain a total of four specimens of long curved genal spines of highly distinctive character.

Proximally, they expand smoothly into the broad sloping platform of the free cheeks. A very small portion of the facial suture may be preserved in GSC 46402, no. 4, but is of little positive diagnostic value; however, its apparent course is consistent with that of Symphysurina. The spines are up to 17.5mm long, measured from distal tips to point of most rapid expansion proximally; and at that point they are up to 4mm wide. They are elliptical in cross-section. Characteristic row of pits on doublure of free cheeks is not exposed. Exfoliated surface of specimen GSC 46402, no. 4 bears four or five extremely faint furrows anteriorly, sub-parallel to the presumed trace of anterior facial suture. There are no recognizable cranial fragments of Symphysurina in these two collections.

GSC 46415 contains one genal spine, similar to the others in cross-section and curvature, but without broad shoulders. It is not as reliably assigned to this genus as the specimens

in GSC 46402 and 46414.

Specimens: GSC 46415, no. 3 (doubtful); GSC 46402, no. 4; GSC 46414, nos. 3, 4, 6.

Localities: Mount Hunter section, 7776' above base (GSC 46415), and 7786' above base (the other two collections).

Age: Symphysurina spp. are reported in Zones A to C of the Garden City Formation, Utah (Ross, 1951, pp. 114-116, as above), but the genus may well range higher in the Lower Ordovician. These localities are more than 300' stratigraphically above that of a Zone D assemblage in the same (Mount Hunter) section. Walcott (1924b, p. 37) remarks that the genus is found throughout 1400' of the Mons Formation; it is not clearly stated whether he is referring to any particular locality, or whether he is speaking about the Mons Formation generally.

Unidentified pygidium (?)

Pl. 7, fig. 16.

Only the axial lobe and a small part of the pleural lobes are preserved. The axis is smoothly rounded, of very low convexity; axial furrows nonexistent or marked only by gentle change in slope of surface. A very faint, almost imperceptibly raised, line runs parallel to axial furrow about 0.5mm adaxially from it. An almost equally faint depression separates that line from the segmented portion of the axial lobe.

Five axial rings of very shallow chevron shape, pointing backward; distal extremities faintly node-like, proximal ends virtually obliterated. Exfoliated surface of specimen GSC 46402, no. 5 appears to be very finely punctate. Corresponding structures are shown by inner surface of carapace, preserved in specimen 46402, no. 1; carapace appears to be between 0.3 and 0.5mm thick.

The specimen may belong to a member of the Family Illaeniidae (Order Ptychopariida, Suborder Illaenina, Superfamily Illaenacea), many of which have broad and smooth, or very faintly segmented, pygidia.

Specimen: GSC 46402, nos. 1, 5 (counterparts).

Locality: Mount Hunter section, 7786' above base.

Order Phacopida Salter, 1864

Suborder Cheirurina Harrington and Leanza, 1957

Family Pliomeridae Raymond, 1913

Subfamily Protopliomeropinae Hupe, 1953

Genus Pliomeroides Harrington and Leanza, 1957

?Pliomeroides sp.

Pl. 6, fig. 28.

No more than the occipital ring and parts of the first and

second (1p, 2p) glabellar lobes are preserved.

Occipital ring fairly strongly arched, tapering and curling slightly forward abaxially; bearing low but distinct node near posterior edge on axial line. Occipital furrow sharp, narrow and of moderate depth. First pair of lateral glabellar furrows deep, sharp, and discontinuous across axis, their adaxial ends separated by approximately one-third width of glabella; from their point of origin near axis they run forward and slightly abaxially, almost immediately curving strongly towards axial furrow. In this respect the specimen differs from Protopliomerops sp., in which lateral glabellar furrows are more uniformly transverse, i.e. their proximal extremities curve only weakly.

The specimen was extracted with difficulty from very finely crystalline limestone, and is almost entirely exfoliated; but remnants of carapace near axial and occipital furrows bear fine tubercles.

Axial furrow defining left half of first glabellar lobe appears to incline slightly towards axis at its anterior end; assuming bilateral symmetry, this tapering of the first glabellar lobe is unusual in the Pliomeridae. Of genera figured in the Treatise (pp. 0439-443), only Pliomeroides and Metapliomerops display it. They are both Lower Ordovician forms. This identification, necessarily very tentative, is suggested by Ross's (1958, pl. 84, figs. 5, 7) illustrations of Pliomeroides sp. from a

limestone-filled pocket in pillow lavas of the Ordovician Valmy Formation in Nevada.

Specimen: GSC 46404, no. 8.

Locality: Mount Hunter section, 7472' above base.

Age: The specimen is associated with Lloydia (Leiostegium) manitouensis, Kainella sp., and ?Hystricurus sp., indicative of Zone D of the Lower Ordovician.

Unidentified genal spines

Pl. 6, fig. 23.

Broad, tapering biconvex with low convexity, thinly lens-like in cross-section, and one surface slightly more convex than the other. One specimen is distinctly flatter near one (longitudinal) edge than near the other, and displays an aerofoil-type cross-section. Part of carapace of one specimen is preserved, but is not exposed except in cross-section. The spines appear to lack ornamentation. All specimens are fragmentary; the largest (GSC 46414, no. 5) is 35mm long, and tapers from 10mm to 3.5mm in width. The others are smaller, but of similar proportions.

Specimens: GSC 46402, no. 1; GSC 46414, nos. 1, 5.

Locality: Mount Hunter section, 7786' above base.

Unidentified hypostome

Pl. 7, fig. 18.

The specimen is slightly deformed. General outline bluntly oval, slightly wider and blunter anteriorly than posteriorly; anterior wings only partly preserved. Median body consists of large, strongly convex oval anterior lobe, separated from much smaller posterior lobe by deeply-impressed median furrow; the latter is discontinuous across axis, the two arms of it forming an incomplete acute-angled 'V' that divides posterior lobe into two almost separate parts. Border furrow very shallow antero-laterally, deepening between median body and raised lateral shoulders, and forming very deep, abrupt pit postero-laterally. Border wide, smooth and convex dorsally at anterior wings; narrow and slightly raised laterally and postero-laterally, reduced posteriorly. Surface of hypostome very faintly punctate; border bears faint pattern of closely-spaced fine lines.

Dimensions:

Length, measured along axis	7mm
Width at lateral shoulders	5.1mm
Probable width at anterior wings, measured from axis to tip of more completely preserved wing, and doubled	8mm
Depth of median body	approx. 1.75mm

Specimen: GSC 46420, no. 5d.

Locality: Mount Hunter section, 5015-5020' above base.

Phylum Brachiopoda

Class Inarticulata

Order Acrotretida Kuhn, 1949

Suborder Acrotretidina Kuhn, 1949

Superfamily Siphonotretacea Kutorga, 1848

Family Siphonotretidae Kutorga, 1848

Genus Schizambon Walcott, 1884

Schizambon ?discoidea (Walcott)

Pl. 7, fig. 19.

Acrotreta discoidea Walcott, 1924, p. 497, pl. 109, figs. 13, 14.Schizambon discoidea (Walcott), Ulrich and Cooper, 1938, p. 62, pl. 4D, figs. 11-13.

Only a single specimen has been found in GSC 46418; it appears to be the impression of a brachial valve, but retains sparse fragments of the original shell. Outline subcircular, slightly pointed posteriorly; valve moderately convex; evenly-spaced growth lines merge laterally and posteriorly, and are lost close to apex. Absence of typical pedicle opening of the Siphonotretacea at or near apex suggests that this is a brachial valve. Ornamentation mostly lost; but faint traces of radiating rows of "fine . . . lines broken by concentric lines of growth" (Walcott, 1924, p. 497) tend to confirm the identification. Lochman (1964b, p.463) refers to these as "short spines", but Walcott is careful not to do so. S. borealis also is said to bear "minute spines or granules" (Ulrich and Cooper, 1938, p. 61). Valve is approximately 6.5mm long and almost 6.0mm wide.

Specimen: GSC 46418, no. 11.

Locality: Mount Hunter section, 6576-6581' above base.

Age: First described from the "Ozarkian" Chushina Formation, near Mount Robson, British Columbia. Lochman (1964, (b), p. 456) has found it both in Zone A and Zone B assemblages in the Upper Cambrian and Lower Ordovician Deadwood Formation of the Williston Basin, Montana. S. borealis is given "Upper Ozarkian" age by Ulrich and Cooper, who erected the species and reported it from the Yukon Territory and Alaska; but Lochman (1964a, p. 50) also reports it in a Saukia zone fauna (Upper Cambrian) of the basal Deadwood Formation.

Class Articulata

Order Orthida Schuchert and Cooper, 1932

Suborder Orthidina Schuchert and Cooper, 1932

Superfamily Orthacea Woodward, 1852

Family Eoorthidae Walcott, 1908

Genus Apheoorthis Ulrich and Cooper, 1936

Apheoorthis ocha (Walcott)

Pl. 7, fig. 12.

Eoorthis ochus Walcott, 1924, p. 509, pl. 117, figs. 10-13;
Kindle, 1929, p. 145, figs. 1, 2.

Apheoorthis ocha (Walcott), Ulrich and Cooper, 1938, p. 85, pl. 10C, figs. 11, 12; Lochman, 1964, p. 454 (listed, but not figured or described).

Small orthoid shell, wider than long, alate with acute car-

dinal angles; brachial valves distinctly sulcate, pedicle valves not identified; plicae coarse medially, of less amplitude laterally, grading to costate and costellate nearer cardinal angles; plicae themselves are very finely costellate; multiple finer, and a few coarser, growth lines run parallel to shell margin, reversing their curvature near alate lateral extremities.

Not only do these specimens satisfactorily correspond with Ulrich and Cooper's figures, but they demonstrate the features most strongly emphasized in Walcott's description of Eoorthis ochus. These are the "uniform fine, radiating, elevated striae" on the slopes of the coarse plicae, "the striae also extending over the cardinal slope on the postero-lateral surface of the valves"; and the advanced development of these plicae ("sharp radiating surface fascicles") compared with those of e.g. E. fascigera.

Specimens: GSC 46407, no. 1.

Locality: Mount Hunter section, 6137-6138' above base.

Age: Walcott (1924a) described this species from the Mons Formation, Brisco Range, southeastern British Columbia. He did not locate his specimens precisely in a measured section, and it is therefore impossible to say exactly from which part of the Mons Formation they came. However, as he designates their age "Ozarkian" it is likely that they were found fairly high in the section.

The term "Mons" is discussed in some detail by Greggs (1962,

p. 60), who proposed that it be abandoned in favour of the formational names Bison Creek, Mistaya and Howse River, to designate the three highly distinctive rock units that compose Walcott's type-section at Glacier Lake, Alberta. If Walcott's Eoorthis ochus was described from beds corresponding to Greggs' Howse River Formation, then it is probably of early Canadian (earliest Ordovician) age.

Lochman (1964b, p. 454) lists A. ocha in a Zone C or Zone B assemblage from the subsurface Deadwood Formation, Williston Basin, Montana.

Apheoorthis aff. A. vicina (Walcott)

Pl. 7, figs. 5-7.

Eoorthis vicina Walcott, 1924a, p. 512, pl. 112, figs. 6-9.

Apheoorthis vicina (Walcott), Ulrich and Cooper, 1938, p. 86, pl. 9B, figs. 3, 4, 8; Lochman, 1964b, p. 467, pl. 66, figs. 28-31.

Several of the specimens in GSC 46418, nos. 1, 10 and 11, are interior impressions of the pedicle valve, and some are interior surfaces of original shell material. Affinity with A. vicina is suggested first of all by general resemblance, but particularly by the distinctive shape of the pseudospondylium.

The valves are generally a little larger than those of

Apheorthis ocha. These also are alate with straight hinge line and acute cardinal angles. Hinge line is invariably the widest part of the valve, but ratio of hinge line to length of valve is not constant. Other variants are the degree of fasciculation of costae and costellae, and the prominence of growth lines. Most valves display a few coarser growth lines separated by many finer ones. Curvature of growth lines reverses itself between axis and alar extremities. In a few valves the growth lines are barely visible.

Sulcus in pedicle valves generally consists of a fairly broad, shallow, but distinct depression, commonly with a low raised portion along the axial line. No brachial valves have been recognized. In some specimens displaying internal surface of the original valve a single pair of adductor scars is visible; they are narrow, expanding elongate marks lying at about 30° to each other, symmetrical about axis of valve, with a few fine concentric loop-shaped lines terminating them anteriorly (resembling in plan a series of concentric terminal moraines of a glacier). They are about half as long as the costae or costellae along which they lie.

In general outline the present specimens tend to be more transverse than those figured by Walcott (1924a, pl. 112, figs. 6-9), and by Ulrich and Cooper (1938, pl. 9B, figs. 3, 4, 8), with more-or-less straight hinge line and strong reversal of

growth line curvature near alar extremities. In some valves, a few costae close to the axis are almost coarse enough to suggest assignment to A. oklahomensis (cf. Ulrich and Cooper, 1938, pl. 9C, figs. 9-15); pseudospondylia of the latter species and of A. vicina are similar.

Specimens: GSC 46418, nos. 1, 10 and 11.

Locality: Mount Hunter section, 6576-6581' above base.

Age: Early Ordovician: "Lower Ozarkian" according to Walcott, who reports it (1924, p. 512) from the lower part of the Mons Formation in Alberta, and from the Mons Formation in the Brisco Range, near Sinclair Canyon, British Columbia; it is reported also from the Chushina Formation, near Mount Robson, and poor specimens resembling A. vicina have been found in a Zone B assemblage in the Deadwood Formation of the Williston Basin (Lochman, 1964b, p. 455).

Family Orthidae Woodward, 1852

Subfamily Orthinae Woodward, 1852

Genus Nanorthis Ulrich and Cooper, 1936

Nanorthis aff. N. hamburgensis (Walcott)

Pl. 7, fig. 9.

Orthis hamburgensis Walcott, 1884, p. 73, pl. 2, fig. 5.

Not Orthis hamburgensis Walcott, Winchell and Schuchert, 1893, Geol. Minn., vol. 3, p. 440, pl. 33, figs. 14-16.

Nanorthis hamburgensis (Walcott), Ulrich and Cooper, 1938, p. 89, pl. 12F, figs. 19-26.

Affinity to this species is recognized on the evidence of external morphology alone; the genus Nanorthis externally resembles Dalmanella and Diparelasma (Ulrich and Cooper, 1938, p. 88), and identification is necessarily tentative in the absence of internal features.

GSC 46418 contains one, possibly two, pedicle valves and the impression of a valve too poorly preserved to distinguish pedicle from brachial. The latter specimen does, however, display the costellation, convexity and subcircular outline characteristic of the genus.

These specimens conform with Ulrich and Cooper's (1938) description particularly in the following respects: outline subcircular; hinge shorter than width of widest part of shell; cardinal extremities not well displayed but appear to be obtusely angular; lateral margins gently curved, anterior outline more strongly convex; pedicle valve with "suggestion of a median fold", but lacking distinctive median costa that would render the fold "subcarinate"; beak slightly protruding over interarea, but interarea structures concealed. The largest valves in GSC 46418 are both about 6mm wide and 5mm long; cf. Walcott's type-specimen (pedicle valve only), which is 7mm wide, 6.5mm long.

Specimens in GSC 46416 closely resemble those in GSC 46418;

costae and costellae are better preserved, but the hinge-line is not well displayed. In GSC 46416, nos. 1, 15, 42, 45, 46, 12, and 60 contain either original shells or impressions of pedicle valves; of these, nos. 12 and 20 possess a low fold, the others are merely rather more sharply convex along the axis. Nos. 6, 22, 24, 31 and 49 have brachial valves, all with shallow but distinct sulcus. These valves are so alike in all other respects that the relative prominence of sulcus or fold cannot be said to constitute a criterion for specific differentiation. This writer prefers to regard it as an example of intraspecific variation.

GSC 46404 contains well-preserved specimens, particularly in nos. 6, 7, 12, 17, 18 and 21. Both fold and sulcus are well developed in some specimens, inconspicuous in others. GSC 46404 also contains the largest specimen, a brachial valve approximately 8.5mm wide and at least 7mm long, which is only weakly convex but has distinct, though very shallow, sulcus. Specimens in GSC 46415 can probably be assigned to this species, but material is sparse and poorly preserved.

Specific assignment of all these specimens is in doubt only because similar forms are referred by Lochman (1965, pl. 61, figs. 20-28) to Nanorthis putilla (Walcott). Moreover, GSC 46418 and GSC 46416 are separated by 820' of section. Lacking access to type specimens, the writer has found it impossible to distinguish reliably between N. hamburgensis and N. putilla on the

basis of published figures and descriptions alone. Lochman, for example, stresses regularity of bifurcation of costellae, and the "low but definite sulcus and fold", of N. putilla; Ulrich and Cooper (1928, p. 90) likewise note that "fasciculation of costellae" at the front of N. putilla "has more regularity" than that of N. hamburgensis. Comparison of their pl. 12F, figs. 19-26, with those of Walcott's (1924a, pl. 114, figs. 6, 7; pl. 115, fig. 9) Eoorthis putillus (Nanorthis putilla) does not reveal as strong a contrast between the two species in this regard as one might expect. Furthermore, Orthis hamburgensis was erected by Walcott in 1884 (p. 73, pl. 2, fig. 5) forty years before the same author erected Eoorthis putillus. Where any confusion may arise, the older species is to be preferred.

Specimens: GSC 46418, nos. 10a, 10b and 11a; GSC 46416, nos. 1, 15, 42, 45, 46, 12 and 20 (pedicle valves); 6, 22, 24, 31, 49 (brachial valves); GSC 46404, nos. 6, 7, 12, 17, 18 and 21; GSC 46415, no. 3.

Localities: Mount Hunter section, 6576=6581', 7396', 7472' and 7776' respectively above base.

Age: According to Ulrich and Cooper (1938) the genus Nanorthis is confined to "Upper Ozarkian and perhaps Lower Canadian" rocks (p. 88). N. hamburgensis was originally described from the Goodwin Limestone of Nevada, and later from the Manitou Limestone of Colorado. These formations are "Ozarkian" and "Upper Ozarkian" respectively in Ulrich's terms; an early Canadian age, confirming that of other genera in collection GSC 46418, is certainly within the known range of the species.

Nanorthis cf. N. hamburgensis is reported by Ross (1951, p. 19) from a Zone C assemblage in the Garden City Formation. On other evidence, collections at GSC 46416 and 46404 are considered to belong to Zone D. In the Williston Basin N. putilla "makes its first appearance in the Zone "D" assemblage and continues upward into the Zone "G" assemblages" (Lochman, 1965, p. 469). Walcott first reported N. putilla from the Chushina Formation, Mount Robson, British Columbia. It is evident that Nanorthis hamburgensis and forms closely resembling it range throughout the Early Ordovician.

Order Pentamerida Schuchert and Cooper, 1931
 Suborder Syntrophiidina Ulrich and Cooper, 1936
 Superfamily Præambonitacea Davidson, 1853
 Family Clarkellidae Schuchert and Cooper, 1931
 Clarkellid? brachiopoda, unidentified

Pl. 7, figs. 1-4.

Syntrophiids are strongly biconvex brachiopods with prominent fold and sulcus in brachial and pedicle valves respectively. The Clarkellidae may be smooth or ribbed, but even the smooth-shelled forms display somewhat fibrous surface texture. Most of the species figured by Ulrich and Cooper (1938) are more transverse than elongate in plan view, but few are as strongly transverse as the present specimens.

These consist of three pedicle valves and one brachial valve, with several fragmentary portions of shells. Only the external morphology is known. They are smooth-shelled, somewhat fibrous, displaying faint growth lines near anterior and lateral edges. Hinge line is short, more or less straight, and overridden posteriorly by short inconspicuous beak. Delthyrial structures not seen. Sulcus prominent, enclosed by wide-flaring ridges, and forming long sharply-pointed tongue anteriorly; fold forms correspondingly conspicuous rib on brachial valve. Brachial valve presents strongly tri-lobed appearance, is rather more elongate than the two pedicle valves.

Without internal features it is impossible to identify reliably individual genera of the Clarkellidae. The specimens could almost equally well be referred to Clarkella, Syntrophina, or Diaphelasma. They strongly resemble Syntrophina missouriensis Ulrich and Cooper from the Williston Basin, figured by Lochman (1964b, pl. 64, figs. 29-31). But even the family assignment is uncertain, for the Clarkellidae are by no means the only brachiopods with such prominent sulcus and fold.

Specimens: GSC 46418, nos. 8, 8a (pedicle valves); 8b (brachial valve); GSC 46416, no. 47 (pedicle valve).

Locality: Mount Hunter section, 6576-6581' and 7396' above base respectively.

Age: Specimens in GSC 46418 are of the same age as the Hystericurus sp. from the same locality, i.e. of Early Canadian age.

Similarly, on evidence of association, specimen GSC 46416, no. 47 is considered to be part of a Zone D assemblage.

Phylum Mollusca

Class Gastropoda Cuvier, 1797

Subclass Prosobranchia Milne Edwards, 1848

Order Archaeogastropoda Thiele, 1925

Suborder Pleurotomariina Cox and Knight, 1960

Superfamily Pleurotomariacea Swainson, 1840

Family Raphistomatidae Koken, 1896

Subfamily Ophiletinae Knight, 1956

Genus Ophileta Vanuxem, 1842

Subgenus Ophileta (Ozarkispira) Walcott, 1924

Ophileta (Ozarkispira) leo Walcott

Pl. 7, figs. 8, 10, 11.

Ozarkispira leo Walcott, 1924, pp. 37, 38, fig. 6; Knight, 1941, p. 224, pl. 18, figs. 1a-1c.

Ophileta (Ozarkispira) leo Walcott, Knight et al., 1960, p. 1200, fig. 113, 3a, 3b.

Walcott erected the genus and species simply by figuring his type-specimen, giving no description. Knight (1941, pp. 224, 225, pl. 18, figs. 1a-1c) provides both detailed description and photographs of Walcott's type-specimen.

The present specimens are broken, but appear to conform

closely with Knight's description. They are "small, low-spired, widely phaneromphalous, discoidal . . ."; whorl profile is about twice as deep as wide; parietal and outer whorl faces parallel, with very slight abaxial vertical convexity, sloping inward (adaxially, abapically) at possibly $65-75^{\circ}$ from the vertical; basal whorl face lies at acute angle to outer whorl face, and slopes inward and upward at an angle distinctly steeper than that of the umbilicus itself, so that its inner margin is in contact with outer whorl face of adaxially-adjacent whorl slightly above the lowest point on that whorl, and umbilical suture is correspondingly distinctly entrenched; thus Knight's statement that the basal whorl face lies at an angle "in conformity with the umbilical surface" cannot be strictly accurate, and his photograph of the type-specimen confirms this point (pl. 18, fig. 1c). Kobayashi's figures of O. leo (1955, pl. 1, fig. 6a-c) do not illustrate this feature; matrix material obscures the umbilicus of his specimen. The parietal and outer whorl walls of the present specimens slope rather more steeply than those of Kobayashi's figured specimen.

Details of aperture and lip are unknown; upper surface of helicocone is not exposed, but upper whorl face can be seen to be slightly arched.

Specimens: GSC 46415, nos. 4 and 5.

Locality: Mount Hunter section, 7776' above base.

Age: Walcott reported Ozarkispira leo from the Mons Formation, "Ozarkian" in age, on Fossil Mountain, near Lake Louise, Alberta; and from Stoddart Creek in the Stanford Range, British Columbia, 901' below the top of the Mons Formation. Kobayashi (1955, p. 394) correlates beds containing an Ozarkispira faunule in the McKay Group of British Columbia with Triarthrus and Asaphellus zones of the southern Andes, of "Upper Tremadocian" age (p. 391), and with Zone F of the Pogonip Group and Garden City Formation of Utah and Nevada.

Order ?Archaeogastropoda Thiele, 1925

Superfamily Pseudophoracea S.A. Miller, 1889

Family Planitrochidae Knight, 1956

Genus Raphistomina Ulrich and Schofield, 1897

Raphistomina sinclairensis Kobayashi

Pl. 7, figs. 13-15, 17.

Raphistomina sinclairensis Kobayashi, 1955, p. 405, pl. 1, figs. 2a-c, 3.

GSC 46416 contains at least 20 specimens, of which only one is sufficiently complete and free of its matrix to display both upper and lower surfaces. GSC 46402, collected 390' higher in the section, contains two specimens probably referable to this species.

The specimens conform with Kobayashi's description (1955, pp. 405-406) in the following respects: shell discoidal, with very low spire; coiled dextrally; periphery acutely angulate; upper whorl surface gently convex, slightly depressed adaxially along suture; lower whorl surface strongly convex, umbilicus fairly broad, and forming an angle less acute than that in the genotype Raphistomina lapicida (Salter), figured by Knight (1941, pl. 19, figs. 1a, b). The largest specimen is 23.5mm in diameter (cf. Kobayashi's 24mm). Aperture is not preserved or exposed in any of the specimens. Extremely faint lines that may be growth lines, prosocline near periphery of whorl, are seen on one specimen in GSC 46416, no. 1; however, they are not visible on any of the larger specimens.

Some variation is observed within the group. Sutures may be more or less sharply incised on upper surface; upper whorl face shows very slight concavity close to periphery in some but not in others; spire is generally shallow, but in some specimens upper surface is almost flat except for peripheral slopes of outer whorl. Despite these differences, all the specimens are believed to be conspecific.

Two specimens in GSC 46402 are referred to this species with some reservation. They are not well preserved, but the umbilicus of the smaller specimen appears to be rather more acute-angled than in those of GSC 46416. In this respect it resembles Raphistomina lapicida (Salter) (Knight, 1941, pl. 19, fig. 1b).

Specimens: GSC 46416, nos. 1-5, 7-9, 13, 14, 21, 22; GSC 46402, nos. 11, 12 (doubtful).

Localities: Mount Hunter section, 7396' and 7786' above base respectively.

Age: Stratigraphic position of the genotype R. lapicida is the "Black River group, Ordovician" (Knight, 1941, p. 296). If this corresponds to the Blackriveran Substage (Mohawkian Stage, Champlainian Series), then the genotype is indicative of later Middle Ordovician age. However, Kobayashi (1955, Table 4 on p. 366) lists R. sinclairensis as part of a Kainella-Evansaspis fauna, but refers elsewhere (p. 369) to a distinct Ozarkispira-Raphistomina faunule. The latter would belong to the uppermost of the four zones which Walcott (1924b, p. 37) distinguished in the Mons Formation.

The specimens in GSC 46416 are associated with trilobites that are reliable indicators of Zone D of the Lower Ordovician.

FAUNAL LISTS AND SECTION LOCALITIESMount Hunter section

Top: Lat. 55 16'30" North: Long. 122 25'30" West.

Base: Lat. 55 18'00" North: Long. 122 24'00" West.

<u>GSC #</u>	<u>Above base</u>	Upper Ordovician
46399	480' above top of meas'd sec.	<u>Catenipora</u> sp. <u>Palaeophyllum</u> sp.
		Ordovician, position uncertain.
46400	8276'	Worm-casts
46401	8142-8160'	No organic remains.
46412	7961-7966'	No identifiable organic remains.
46413	7951'	No identifiable organic remains.
		Lower Ordovician, upper Zone D
46402, 46414	7786'	<u>Kainella</u> sp. <u>Raphistomina ?sinclairensis</u> Kobayashi <u>Symphysurina</u> sp.
46415	7776'	<u>Kainella</u> sp. <u>Nanorthis</u> aff. <u>N. hamburgensis</u> (Walcott) <u>Ophileta (Ozarkispira) leo</u> Walcott <u>?Symphysurina</u> sp.
46403	7756'	Specimen lost in etching.
		Lower Ordovician, lower (?) Zone D
46404	7472'	? <u>Hystericurus</u> sp. <u>Kainella</u> sp. <u>Lloydia (Leiostegium) manitouensis</u> (Walcott) <u>Nanorthis</u> aff. <u>N. hamburgensis</u> (Walcott) <u>?Pliomeroides</u> sp.

- 46416 7396' Clarkellid? brachiopods
Kainella flagricauda (White)
Lloydia (Leiostegium) manitouensis (Walcott)
Nanorthis aff. N. hamburgensis (Walcott)
Raphistomina sinclairensis Kobayashi
- 46405 7296' Specimen lost in etching.
 Lower Ordovician, Zone B?
- 46406 6742' Specimen lost in etching.
 Lower Ordovician, Zone B
- 46417 6606-6611' Symphysurina cf. S. spicata Ulrich
- 46418 6576-6581' Apheoorthis aff. A. vicina (Walcott)
 Clarkellid? brachiopods
Hystricurus sp.
Nanorthis aff. N. hamburgensis (Walcott)
Schizambon ?discoidea (Walcott)
 Lower Ordovician, Lower Zone B? Zone A?
- 46407 6137-6138' Apheoorthis ocha (Walcott)
 Upper Cambrian, Trempealeauan, Lower or
 Middle Saukia zone
- 46419 5516-5566 Micragnostus sp. cf. Geragnostus (Micrag-
nostus) bisectus (Matthew) var. typica
 Shaw
Westonia linguloides (Kobayashi)
 Upper Cambrian, Franconian, uppermost Conas-
pis zone and lower Ptychaspis-Prosaukia
 zone (Ptychaspis subzone)
- 46408 5160-5165' ?Saratogia cf. S. fria Lochman and Hu
- 46409 5044' Pseudagnostus josepha (Hall)
Wilbernia sp. B

- 46420 5015-5020' Lauzonella sp.
Loganellus logani (Devine)
Pseudagnostus josepha (Hall)
Wilbernia sp. A
- 46410 4868' No identifiable organic remains.
- 46411 4126-4250' No identifiable organic remains.

Section 2A

Top: Lat. 55 14'00" North: Long. 122 35'00" West.

Base: Lat. 55 14'15" North: Long. 122 35'30" West.

Lower Cambrian, Upper Olenellus subzone

- 46421 1250' Ajacyathus nevadensis (Okulitch)
Archaeocyathellus ?walcotti Okulitch
Archaeosycon vesiculosum Okulitch
Coscincyathus dentocanis Okulitch
Coscincyathus ?rhyacoensis Okulitch
?Coscincyathus sp.
Monocyathus sp., new species?
Protopharetra ?dunbari Okulitch
Protopharetra raymondi Okulitch
Pycnoidocoscinus sp.
Pycnoidocyathus amourensis (Okulitch)
- 46422 1197-1200' Unidentifiable archaeocyathid.
- 46423 1022-1023' Unidentifiable archaeocyathid.

Section 2B

Top: Lat. 55 14'45" North: Long. 122 35'00" West.

Base: Lat. 55 15'00" North: Long. 122 35'30" West.

Lower Cambrian, Upper Olenellus subzone

- 46424 691-701' Ajacyathus nevadensis (Okulitch)
Archaeocyathus atlanticus Billings
Ethmophyllum cooperi Okulitch
?Sigmocyathus sp.
Syringocnema sp.

46425 approx. Unidentifiable archaeothids.
621' in
talus

Section 3

Top: Lat. 55 05'30" North: Long. 122 12'30" West.

Base: Lat. 55 07'45" North: Long. 122 09'30" West.

Probably Upper Cambrian

46432 4600' Billingsellid and nisusiid brachiopods
?Zacanthoides sp.
Unidentified pterocephaliid? or idahoiid?
trilobites

Middle Cambrian, Bathyriscus-Elrathina zone,
Tonkinella stephensis subzone?

46431 4390-4395' ?Bathyriscus sp.
Chancia evax Walcott
Dictyonina pannula (White)
Kootenia burgessensis Resser
Pachyaspis isabella Lochman
Pachyaspis typicalis Resser
Pagetia cf. P. bootes Walcott
Pagetia cf. P. ellsi Rasetti
?Wenkchemnia sp.
Unidentified alokistocarid trilobite

Middle Cambrian, Bathyriscus-Elrathina zone,
Ogygopsis klotzi subzone

46430 4303-4308' Chancia evax Walcott
?Elrathiella sp.
?Elrathina sp.
Kootenia exilaxata Deiss
Lingulid brachiopods
Ogygopsis, new species A?
Ogygopsis, new species B?
Olenoides maladensis Resser
Olenoides serratus (Rominger)
Olenoides sp.
Unidentified ptychopariid trilobite

Lower Cambrian, Upper Olenellus subzone,
upper part

- 46429 3915-3925' ?Acrotreta sp.
Bonnia bicensis Resser
Bonnia similis Rasetti
Bonnia tensa Resser
Eoptychoparia sp.
Helcionella aff. H. arguta Resser
Kootenia cf. K. buttsi Resser
Kootenia marcoui (Whitfield)
Obolella sp.
Olenellid fragments
Paedeumias transitans Walcott
Paterina sp.
Wanneria sp.
Wenkchemnia sulcata Rasetti
Unidentified pygidium, cf. Mapania striata
Endo and Resser

- 46428 3894-3900' ?Acrotreta sp.
Bonnia brennus (Walcott)
Bonnia bubaris (Walcott)
Eoptychoparia sp.
Helcionella aff. H. arguta Resser
Hyalolithid fragments
Ogygopsis aff. O. batis (Walcott)
Olenellus gilberti Meek
Olenellid fragments
Paterina sp.
Piaziella sp.
Wenkchemnia sulcata Rasetti
Zacanthopsis contractus Palmer

Lower Cambrian, Upper Olenellus subzone,
lower part

- 46427 3800-3820' Salterella pulchella Billings

Lower Cambrian or Precambrian

- 46426 3236' No organic remains.

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APPENDIX

SUMMARIZED DESCRIPTION OF SECTIONSMount Hunter Section

Overlying beds consist of dolomite of Upper Ordovician age(?); GSC locality 46399 is approximately 480' above top of measured section.

Mount Wilson Formation equivalent? M. - U. Ord.

8165-9766' Quartzite and quartzose sandstone, beds from a few inches to 3' thick, commonly cross-bedded in some parts of the unit, some of the quartz-sandstone with carbonate cement; occasional non-calcareous shale interbeds; includes 124' of dolomite, limestone and a covered recessive interval (8880-9004'); minor beds of quartz pebble conglomerate throughout the unit

Chushina Formation L. Ord.

6711-8165' Limestone, with minor dolomite and shale; limestone is generally argillaceous and silty, commonly but not invariably laminated, with nodular and small lens-like bodies of crypto-crystalline less argillaceous limestone; some of the unit is strongly sheared, or displays phyllitic foliation grading almost into slaty cleavage; thin beds of limestone pebble conglomerate occur at 7295' and several places downsection,

at irregular intervals; 19' of dolomite near top of unit almost immediately underlying the Mount Wilson (?) equivalent quartzite.

6084-6711' Limestone, alternating: thick-bedded, massive, finely- to crypto-crystalline, in places oolitic; and thin-bedded, laminated, silty and argillaceous.

5800-6084' Limestone, generally very finely crystalline, silty and argillaceous, with boudin-like 'nodules' of purer limestone; mostly thin-bedded, with more massive beds downsection; forms east slope of Mount Hunter. Lower limit of Chushina Formation arbitrary.

Lynx Formation U. Camb.

5658-5800' Limestone, as in lower part of Chushina Formation, above.

5165-5658' Not measured in detail; limestone as in overlying unit.

4967-5165' Alternating: massive limestone, cryptocrystalline and slightly silty; and black shale, slightly phyllitic to rubbly-weathering, containing calcareous concretionary masses.

Stephen and Eldon Formation equivalent (?), M. Camb.

4493-4967' Dolomite, finely to cryptocrystalline, more silty in lower part of unit, beds up to $2\frac{1}{2}$ ' thick, but thinner, and platy-weathering, in some places; minor fissile black shale, and occasional beds of black chert

that do not persist laterally.

4443-4493' Interbedded dolomite and slate; unit highly distinctive on account of contrasting rusty-brown-weathering dolomite and black slate.

4115-4443' Dolomite, mostly silty, laminated; but lower half contains abundant coarsely-crystalline, vuggy-weathering dolomite.

Gog Group L. Camb.

4053-4115' Covered.

3674-4053' Interbedded silty dolomite and brick-red shale and siltstone; dolomite reddish to pinkish light-grey and buff; shale black-brown to brick-red, commonly with desiccation cracks; a highly distinctive, conspicuous unit.

1814-3674' Quartzite and quartzose sandstone; quartzite white to pink, very pure, with cross-bedding accentuated by colour variations; quartzose sandstone slightly porous, generally non-calcareous; minor interbeds of fissile shale. Interval 2882-3023' has approx. equal amounts of quartz sandstone, as above, and finely fissile, laminated, non-calcareous siliceous siltstone; oscillation and interference ripple-marks with fine desiccation cracks in some places. Lower parts of unit progressively less 'pure' quartzite and quartz sandstone, with increasing proportion of platy-weathering mudstone interbeds.

The interval 2396-2458' is covered.

Miette Group Precamb.

- 1738-1814' Covered.
- 900-1814' Interbedded quartzite, sandstone and shale; quartzite with fine black laminations, cross-bedded; shale is black, non-calcareous, and slaty in places.
- 476- 900' Covered.
- 0- 476' Slate, grey, fissile, non-calcareous, forming platy talus.

A thrust fault brings Miette Group rocks over limestone of Triassic age.

Section 2A

Top of section is an irregularly undulating erosion surface roughly parallel to bedding; upper collection of Archaeocyatha made at 1250', approximately 50' stratigraphically above top of measured section; thickness of uppermost beds estimated in dense fog, with questionable accuracy.

- 1167-1200' Dolomite, slightly calcareous, medium- to finely-crystalline; bedding thickness indeterminate; virtually massive.
- 1111-1167' Covered, except for 9' of dolomite as above.

- 1018-1111' Dolomite, calcareous and silty, medium- to coarsely-crystalline, thin- to medium-bedded; finely oolitic in lowermost 5' of unit.
- 978-1018' Covered.
- 923- 978' Limestone, argillaceous, sheared and phyllitic, with 'pencil' or rod-like fracture habit; probably thin-bedded.
- 896- 923' Dolomite as above.
- 832- 896' Mostly covered, but with some finely-crystalline silty limestone in sparse outcrops.
- 456- 832' Shale, sandstone and siltstone, with minor quartzite; shale predominates in the upper part, siltstone in the lower; shale is non-calcareous, siltstone slightly calcareous; generally thin- to medium-bedded, slabby and platy-weathering.
- 255- 456' Limestone, medium-bedded, with faint silty and argillaceous lamination; minor highly calcareous quartzose sandstone and siltstone, some cross-bedded.
- Foot 352 of Section 2A is approximately equivalent to Foot 725 of Section 2B; bedding can be traced visually, with only slight interruption, from one section to the other.
- 0- 255' Shale, non-calcareous and fissile, and calcareous argillaceous siltstone interbedded with minor silty and shaly siliceous limestone. Lowermost 30' covered.

Section was measured from top to base; measure-

ment discontinued within covered interval.

Section 2B

Top of section is an erosional surface.

- 614- 701' Limestone, silty and argillaceous, bedding indeterminate except for occasional silty laminations; minor shale interbeds, generally fissile.
- 408- 614' Shale, non-calcareous, with minor limestone interbeds near top, minor quartz sandstone nearer base.
- 86- 408' Shale, pale bluish-grey to brown, non-calcareous, irregularly fissile; lowermost 12' of quartz sandstone with parting planes of micaceous blue-black shale in places.
- 51- 86' Slate, black, fissile, with minor interbeds of calcareous siltstone.
- 0- 35' Quartzite and quartz sandstone, with minor interbeds of black slate as above decreasing downsection.

Section appears to be underlain by several hundred feet of black slate, underlain in turn by fairly 'pure' quartzite and quartz sandstone.

Section 3

The section is overlain by argillaceous dolomite

the age of which is not established; it displays strong cleavage at a high angle to bedding.

Chushina Formation L. Ord.

- 6081-6568' Quartzose sandstone, dolomitic, and sandy dolomite, in varying proportions; quartz sandstone not sufficiently homogeneous to be correlated reliably with the Mount Wilson (?) equivalent on Mount Hunter. Quartz sand content decreases downsection, but is locally abundant in thin layers and streaks.
- 5730-6081' Dolomite, finely- to coarsely-crystalline, generally thin-bedded; slightly argillaceous and platy-weathering in some places.
- 5375-5730' Limestone, generally fairly thin-bedded; alternating laminated, silty, and non-laminated, less silty, beds; resembles the 'nodular' limestone above 6711' on Mount Hunter.
- 5295-5375' Limestone, mostly massive and comparatively resistant, with minor argillaceous thin-bedded recessive limestone.
- 5071-5295' Limestone, siltstone and shale in intercalated units from 5' to 75' thick; limestone is slightly sandy to silty; siltstone and shale are calcareous, fissile and phyllitic in some places.
- 5005-5071' Limestone, argillaceous and silty, alternating laminated and non-laminated layers up to 6" thick.

An erosional surface appears to separate these beds from underlying limestone of similar character, and is tentatively selected as the Upper Cambrian-Lower Ordovician boundary.

Lynx Formation, U. Camb.

4650-5005' Uppermost 15' consists of limestone as from 5005-5071' above. Underlying limestone is distinguished only by varying proportion of quartz sand-grain and argillaceous content. Lowermost part of unit includes 42' (4816-4858') of interbedded limestone and dark grey slightly calcareous shale, thin-bedded and platy-weathering.

4579-4650' Conspicuous and distinctive unit of interbedded limestone, silty and argillaceous, and non-calcareous black shale, which produces a very dirty talus; vertical exposures present ribbon-like pattern of contrasting resistant and recessive layers.

Stephen and Eldon equivalent ? M. Camb.

4268-4579' Limestone, argillaceous and slightly silty, thin-bedded and platy-weathering. Unit includes 48' of dolomite (4469-4517') which is strongly resistant, and 50' of calcareous, very fissile black shale (4419-4469').

Gog Group L. Camb.

- 3963-4268' Quartzite, quartz sandstone and siltstone, coarse- to medium-grained, mostly non-calcareous; very minor interbeds of calcareous and dolomitic siltstone and black shale in uppermost 100'.
- 3883-3963' Limestone with minor siltstone interbeds, and some coarse quartz sand-grain content; contains a Bonnia-Olenellus fossil assemblage.
- 3725-3883' Siltstone, argillaceous and non-calcareous, platy and flaggy-weathering; a few thin interbeds of calcareous dolomite near the top contain Salterella.
- 3248-3725' Quartzose sandstone and quartzite, with very minor dolomite.
- 3155-3248' Limestone, partly dolomitic, with calcareous dolomite near top of unit.
- 2536-3155' Quartz sandstone and quartzite, fine- to coarse-grained, generally thick-bedded; some quartzite is exceptionally pure and massive; not conspicuously cross-bedded.

Miette Group Precamb.

- 1958-2536' Interbedded black shale and quartz sandstone; shale greatly predominates throughout most of unit, except for 31' (2250-2281') of fairly massive white quartzite.
- 1547-1958' Quartzite and quartzose sandstone with minor

shale interbeds; the interval 1754-1810' is covered.

825-1547' Interbedded siltstone and shale, the siltstone slightly predominating; mostly thin-bedded.

0- 825' Quartzite, quartz sandstone and siliceous siltstone; intervals 582-614' and 84-177' are covered.

The measured section is underlain by phyllitic argillaceous limestone, over which the Precambrian clastic rocks have been thrust.

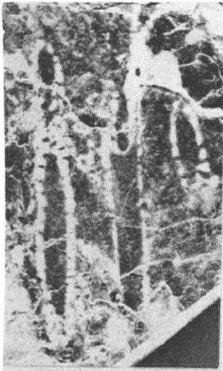
Note: In the foregoing description, "quartz sandstone" and "quartzose sandstone" have been treated as synonymous terms.

PLATE 1

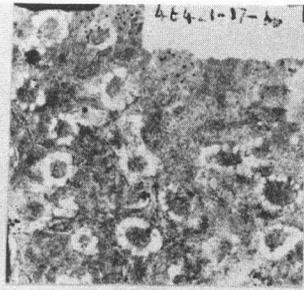
Fig.

1	<u>Monocyathus</u> , n. sp.?, polished section, X1, GSC 46421, 16af	p. 62
2	<u>Monocyathus</u> , n. sp.?, weathered surface, X1, GSC 46421, 17bb	62
3	<u>Archaeocyathellus ?walcotti</u> Okulitch, thin-section, X2, GSC 46421, 6b(i)	65
4	<u>Ajacicyathus nevadensis</u> (Okulitch), thin-section, X2, GSC 46424, 12	63
5	<u>Ethmophyllum cooperi</u> Okulitch, thin-section, X5, GSC 46424, 7	66
6	<u>Coscinocyathus dentocanis</u> Okulitch, weathered sur- face, X1, GSC 46421, 13ee	67
7	<u>Coscinocyathus dentocanis</u> Okulitch, weathered sur- face, X1, GSC 46421, 10be	67
8	<u>Coscinocyathus ?rhyacoensis</u> Okulitch, thin-section, X2, GSC 46421, 2a	68
9	<u>Coscinocyathus</u> sp., and <u>Protopharetra raymondi</u> Okulitch (small specimen), thin-section, X2, GSC 46421, 11e(i)	69, 72
10	<u>Protopharetra raymondi</u> Okulitch and <u>P. ?dunbari</u> Okulitch, thin-section, X2, GSC 46421, 5c	72, 73
11	<u>Archaeocyathus atlanticus</u> Billings, thin-section, X2, GSC 46424, 17	71
12	<u>Pycnoidocoscinus</u> sp., polished section, X1, GSC 46421, 3	70
13	<u>Pycnoidocoscinus</u> sp., thin-section, X2, GSC 46421, 3b	70
14	<u>Pycnoidocyathus amourensis</u> (Okulitch), thin- section, X5, GSC 46421, 11e(ii)	74
15	<u>P. amourensis</u> (Okulitch), thin-section, X5, GSC 46421, 11e(i)	74
16	? <u>Sigmocyathus</u> sp., thin-section, X2, GSC 46424, 12	75

PLATE 1



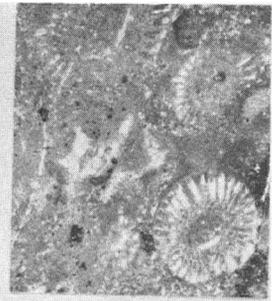
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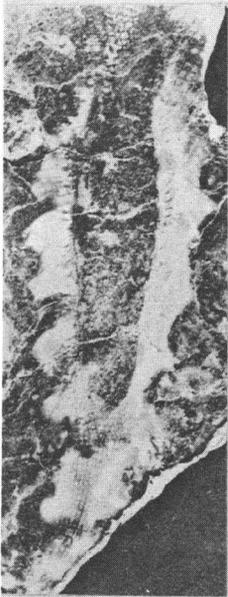
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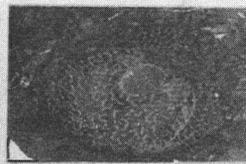
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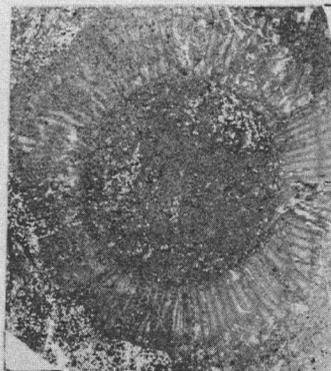
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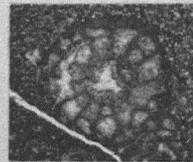
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PLATE 2

Fig.

- 1, 3 Archaeosycon vesiculosum Okulitch, thin-section,
X2, GSC 46421, 14a and 14b p. 76
- 2, 6 Syringocnema sp., thin-section, X5,
GSC 46424, 22 78
- 4 Exothecal tissue associated with Syringocnema sp.,
thin-section, X5, GSC 46424, 28(i)
- 5 Syringocnema sp., thin-section, X5,
GSC 46424, 28(i) 78
- 7 Syringocnema sp., thin-section, X5,
GSC 46424, 21 78

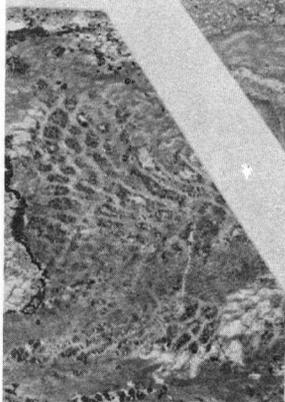
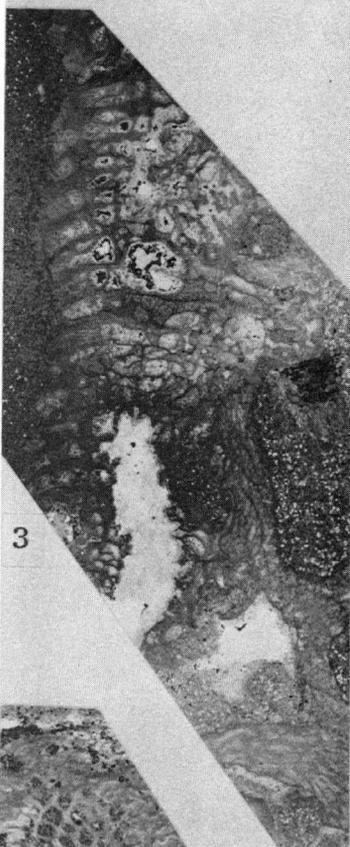
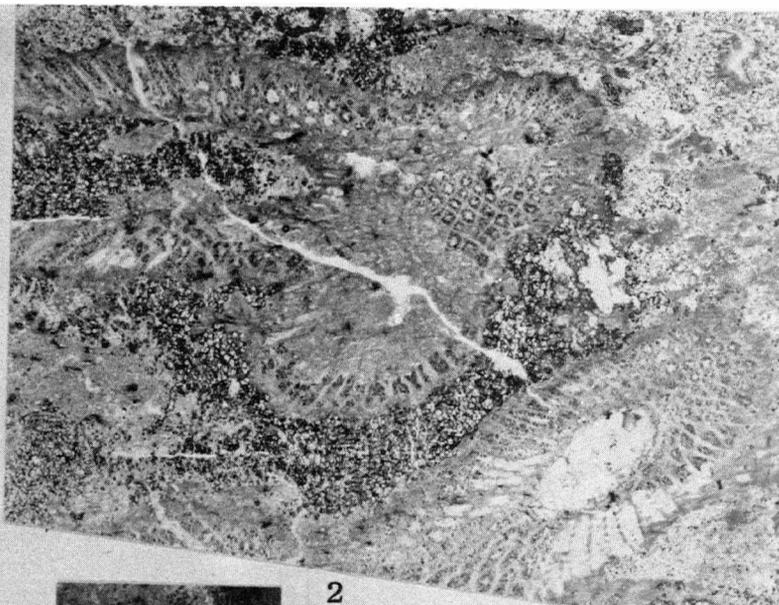


PLATE 3

Fig.

1	<u>Pagetia cf. P. bootes</u> Walcott, cranidium, X4, GSC 46431, 12	p.	84
2, 3	<u>Pagetia cf. P. ellsii</u> Rasetti, cranidia, X4, GSC 46431, 1		85
4	<u>Olenellus gilberti</u> Meek, fragment of glabella and ocular lobe, X2, GSC 46429, 13		88
5	<u>Paedeumias transitans</u> Walcott, impression of frontal area, showing genal caeca and median ridge, X2, GSC 46429, 10		91
6	Pygidium associated with <u>Pagetia cf. P. bootes</u> , X4, GSC 46431, 12; shows traces of pleural furrows.		
7, 8	<u>Pagetia cf. P. ellsii</u> , pygidia, X4, GSC 46431, 8 and 4 respectively		85
9	Reticulate ornamentation on olenellid pleural spines, showing raised dots in centre of meshes, X2, GSC 46429, 1		90
10	<u>Paedeumias transitans</u> Walcott, impr. of cranid., X2, GSC 46429, 4		91
11, 12, 16, 17	<u>Bonnia brennus</u> : all X2; 11, cranid., GSC 46428, 31; 12, cranid., GSC 46428, 28; 16, pygidium, GSC 46428, 24; 17, cranid. and assoc'd. pygid. of different individuals, GSC 46428, 13		94
13	<u>Bonnia tensa</u> Resser, Cranid., X2, GSC 46429, 3		100
14	<u>Bonnia bicensis</u> Resser, cranid., X2, GSC 46429, 10		93
15	<u>Wanneria</u> sp., genal angle with terrace lines and reticulate ornamentation, X2, GSC 46429, 13		92
18	<u>Bonnia bubaris</u> (Walcott), cranid., X2, GSC 46428, 36		97
19	<u>Kootenia cf. K. buttsii</u> Resser, pygid., X2, GSC 46429, 3		103
20, 21, 24	<u>Kootenia exilaxata</u> Deiss, X2; 20, cranid., GSC 46430, 2; 21, pygid., GSC 46430, 26; cranid., GSC 46430, 7		104



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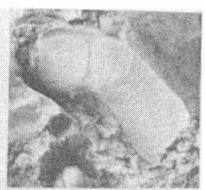
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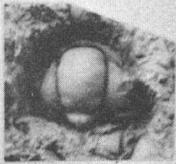
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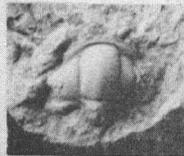
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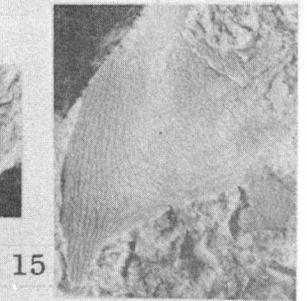
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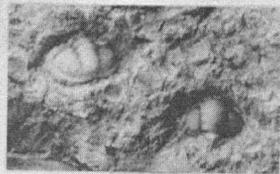
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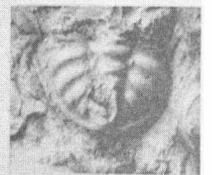
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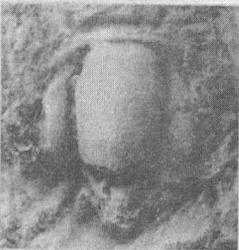
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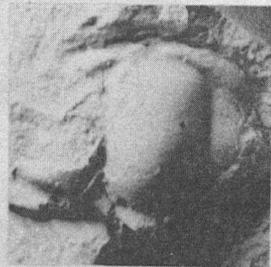
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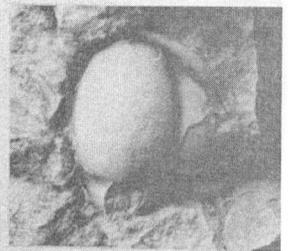
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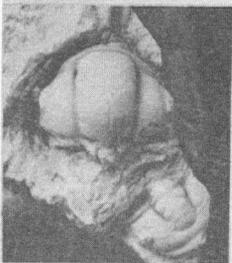
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PLATE 3 (continued)

- 22, 25 Kootenia burgessensis Resser, cranid. and
pygid., X2, GSC 46431, 1 p. 101
- 23 Bonnia similis Rasetti, with Eoptychoparia sp.,
cranidia, X2, GSC 46429, 7 99

PLATE 4

Fig.

1	, 2	<u>Kootenia marcoui</u> (Whitfield), cranidia, X1, GSC 46429, 9	p. 106
3		<u>Olenoides maladensis</u> Resser, pygid., X1, GSC 46430, 5	109
4		<u>O. maladensis</u> Resser, pygid., X2, GSC 46430, 6 .	109
5, 6		<u>Kootenia marcoui</u> (Whitfield), pygidia, with (fig. 6) pygid. of <u>Bonnia</u> sp., X1, GSC 46429, 9	106
7		<u>Olenoides</u> sp., cranid., X1, GSC 46430, 12 . .	111
8		<u>Olenoides</u> sp., with ? <u>Elrathina</u> sp., cranidia, X1, GSC 46430, 14	pp.111, 129
9		? <u>Bathyriscus</u> sp., cranid., X2, GSC 46431, 13; cf. Pl. 5, fig. 12 for pygidium	
10		<u>Wenkchemnia sulcata</u> Rasetti, cranid., X2, GSC 46429, 7	120
11		<u>W. sulcata</u> Rasetti, cranid., X2, GSC 46428, 20 .	120
12, 13		<u>Eoptychoparia</u> sp., cranidia, X2, GSC 46429, 7 and 8 respectively	125
14, 15		<u>Zacanthopsis contractus</u> Palmer, cranidia, X2, GSC 46428, 39 and 26 respectively . . .	122
16, 17		<u>Chancia evax</u> Walcott, cranidia, X1 and X2 , GSC 46431, 9 and 46430, 9 respectively . .	128
18		<u>Ogygopsis</u> aff. <u>O. batis</u> (Walcott), cranid., X2, GSC 46428, 35	113
19		Hyalithid fragment, X2, GSC 46428, 33	146
20		<u>Piaziella</u> sp., cranid., X2, GSC 46428, 20 . .	126
21		<u>Chancia evax</u> Walcott, cranid., X2, GSC 46430, 7	128
22, 23		<u>Ogygopsis</u> aff. <u>O. batis</u> (Walcott), pygidia, X2, GSC 46428, 12 and 26	113
24		Unidentified pygidium, X2, GSC 46429, 1 . . .	112



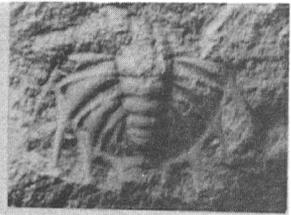
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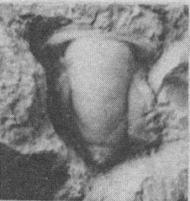
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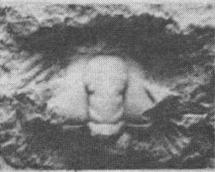
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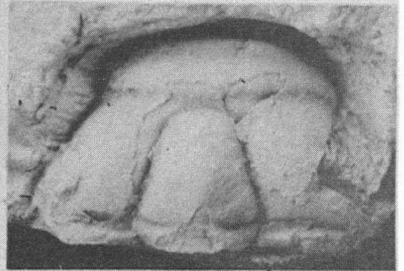
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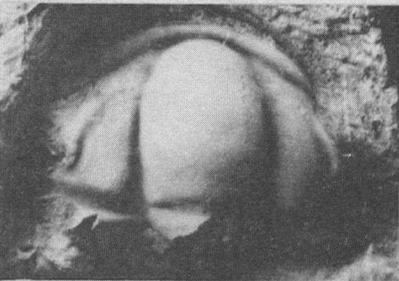
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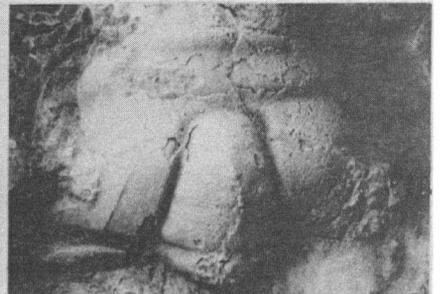
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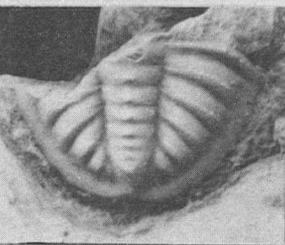
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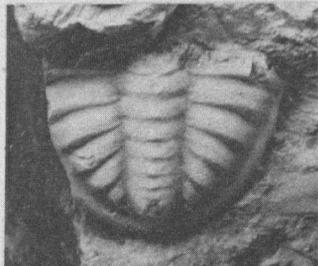
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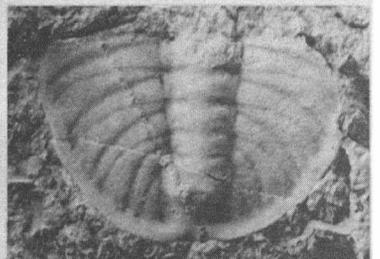
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PLATE 5

Fig.

1	<u>Ogygopsis</u> , new species (?) <u>B</u> , corner of pygid., X2, GSC 46430, 10	p. 117
2	<u>Helcionella</u> aff. <u>H. arguta</u> Resser, X2, GSC 46429, 13	151
3, 4	<u>Ogygopsis</u> , new species (?) <u>B</u> , pygidia, X1, GSC 46430, 4 and 22	117
5	<u>Pachyaspis isabella</u> Lochman, cranid., X4, GSC 46431, 3	131
6	<u>Ogygopsis</u> , new species (?) <u>B</u> , X1, GSC 46430, 24a and 24b	117
7	<u>Dictyonina pannula</u> (White), X4, GSC 46431, 3 .	141
8	? <u>Elrathina</u> sp., plasticine cast of cranid., X2, GSC 46430, 22	129
9	? <u>Elrathiella</u> sp., cranid., X2, GSC 46430, 13 .	130
10	<u>Pachyaspis isabella</u> Lochman, cranid., X4, GSC 46431, 7	131
11	<u>Pachyaspis typicalis</u> Resser, cranid., X2, GSC 46431, 2	130
12	<u>Bathyriscus</u> sp., pygid., X4, GSC 46431, 4 .	
13	Unknown pygidium, X4, GSC 46431, 10, from <u>Ton-</u> <u>kinella stephensis</u> subzone fauna; not described	
14, 15	<u>Paterina</u> sp., brach. valves, X2, GSC 46428, 18 and 37 respectively	143
16, 17	<u>Paterina</u> sp., ped. valves, X2, ventral view and right profile of same individual, GSC 46428, 13	143
18	Nisusiid brachiopod, X2, GSC 46432	144
19	Billingsellid brachiopod, X2, GSC 46432	144
20	<u>Ogygopsis</u> , new species (?) <u>A</u> , fragmentary pygidium, X1, GSC 46430, 11	116

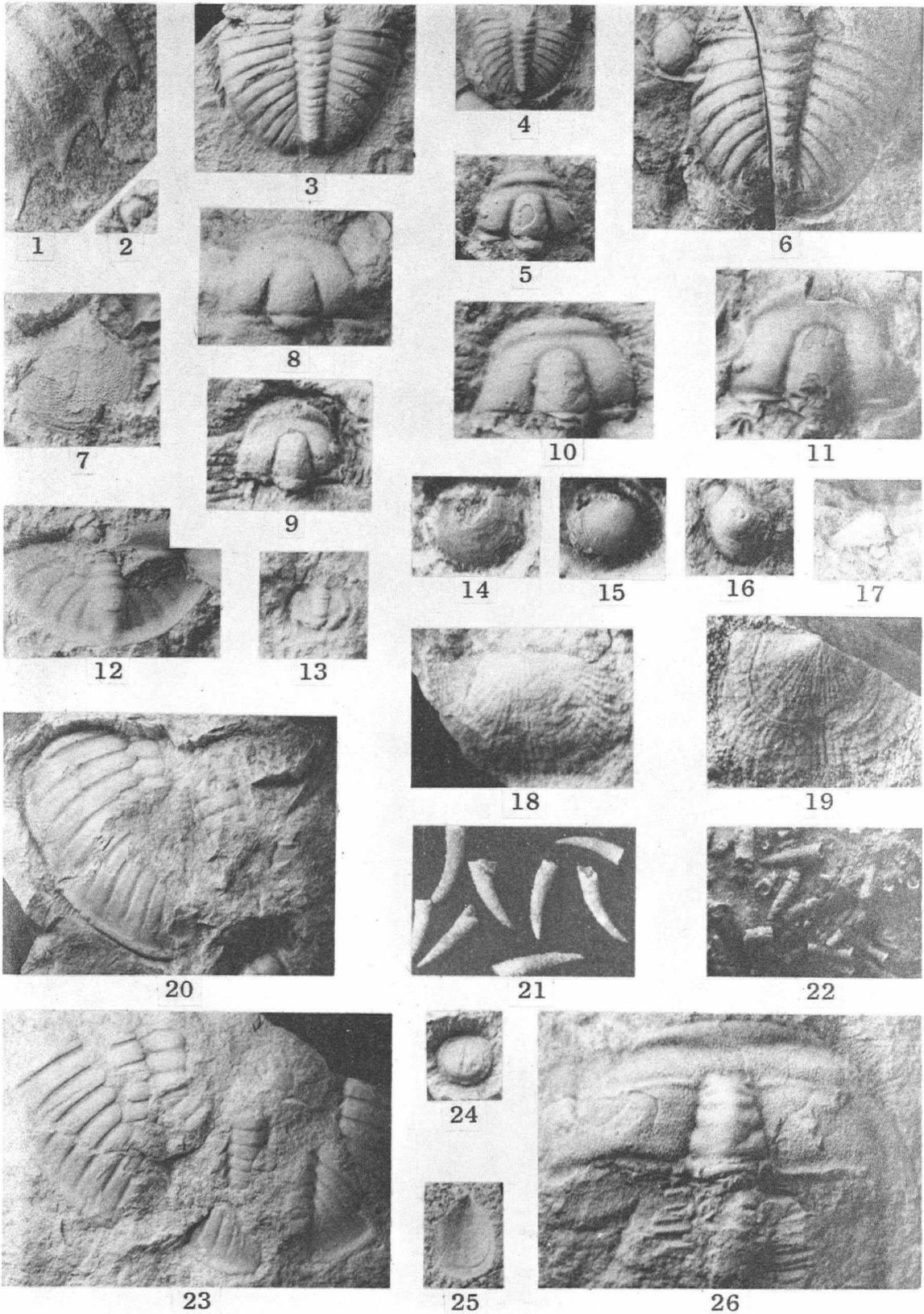


PLATE 5 (continued)

Fig.

21	<u>Salterella pulchella</u> Billings, silicified specimens, etched, dissolved from matrix, X2, GSC 46427 p. 147	
22	<u>S. pulchella</u> Billings, weathered into relief on surface of dolomite, X2, GSC 46427	147
23	<u>Ogygopsis</u> , new species (?) <u>A</u> , pygid., X1, GSC 46430, 23	116
24	? <u>Acrotreta</u> sp., internal cast of brach. valve, X2, GSC 46428, 26	140
25	Lingulid brachiopod, impression, X2, GSC 46430, 25	139
26	Unidentified alokistocarid (?) trilobite, cranid., X2, GSC 46430, 21	133

PLATE 6

Fig.

1	<u>Wilbernia</u> sp. A, cranid., X2, GSC 46420, 1 . . .	p. 170
2	Pygidium of <u>Lauzonella</u> sp.?, with cranid. of <u>Wilbernia</u> sp. A, X2, GSC 46420, 11 . . .	170
3	<u>Micragnostus</u> sp. cf. <u>Geragnostus</u> (<u>Micragnostus</u>) <u>bisectus</u> (Matthew) var. <u>typica</u> Shaw, pygid., X3, GSC 46419, 2	154
4	<u>Lauzonella</u> sp., cranid., X1½, GSC 46420, 12 . .	177
5	<u>Westonia linguloides</u> (Kobayashi), X2, GSC 46419, 1	182
6	<u>Wilbernia</u> sp. A, cranid., X1½, GSC 46420, 2 . .	170
7	<u>Wilbernia</u> sp. B, cranid., X1½, GSC 46409, 1 . .	171
8-10	<u>Saratogia</u> cf. <u>S. fria</u> Lochman and Hu, cranidia, X1, GSC 46408, 6, 5 and 3 respectively; illumi- nation from lower right	173
11, 12	<u>Pseudagnostus josepha</u> (Hall), cephalon and pygid., X2, GSC 46420, 5; illumination from lower right	158
13	<u>P. josepha</u> (Hall), pygid., X2, GSC 46409, 1 . .	158
14	<u>Loganellus logani</u> (Devine), cranid., X1½, GSC 46420, 5	180
15	<u>Saratogia</u> cf. <u>S. fria</u> Lochman and Hu, pygid., X1½, GSC 46408, 1	173
16	<u>Hystericurus</u> sp., cranid., X1½, GSC 46418, 1 . .	187
17	<u>Hystericurus</u> sp., cranid., X2, GSC 46418, 3; the two cranidia are illuminated from lower right	187
18	<u>Lloydia</u> (<u>Leiostegium</u>) <u>manitouensis</u> (Walcott), cranid., X2, GSC 46416, 11	194
19	<u>L.</u> (<u>Leiostegium</u>) <u>manitouensis</u> (Walcott) cranid., with <u>Nanorthis</u> sp., X2, GSC 46416, 5	194
20, 25	<u>Kainella flagricauda</u> (White), cranidia, X2, GSC 46416, 23 and 24	198

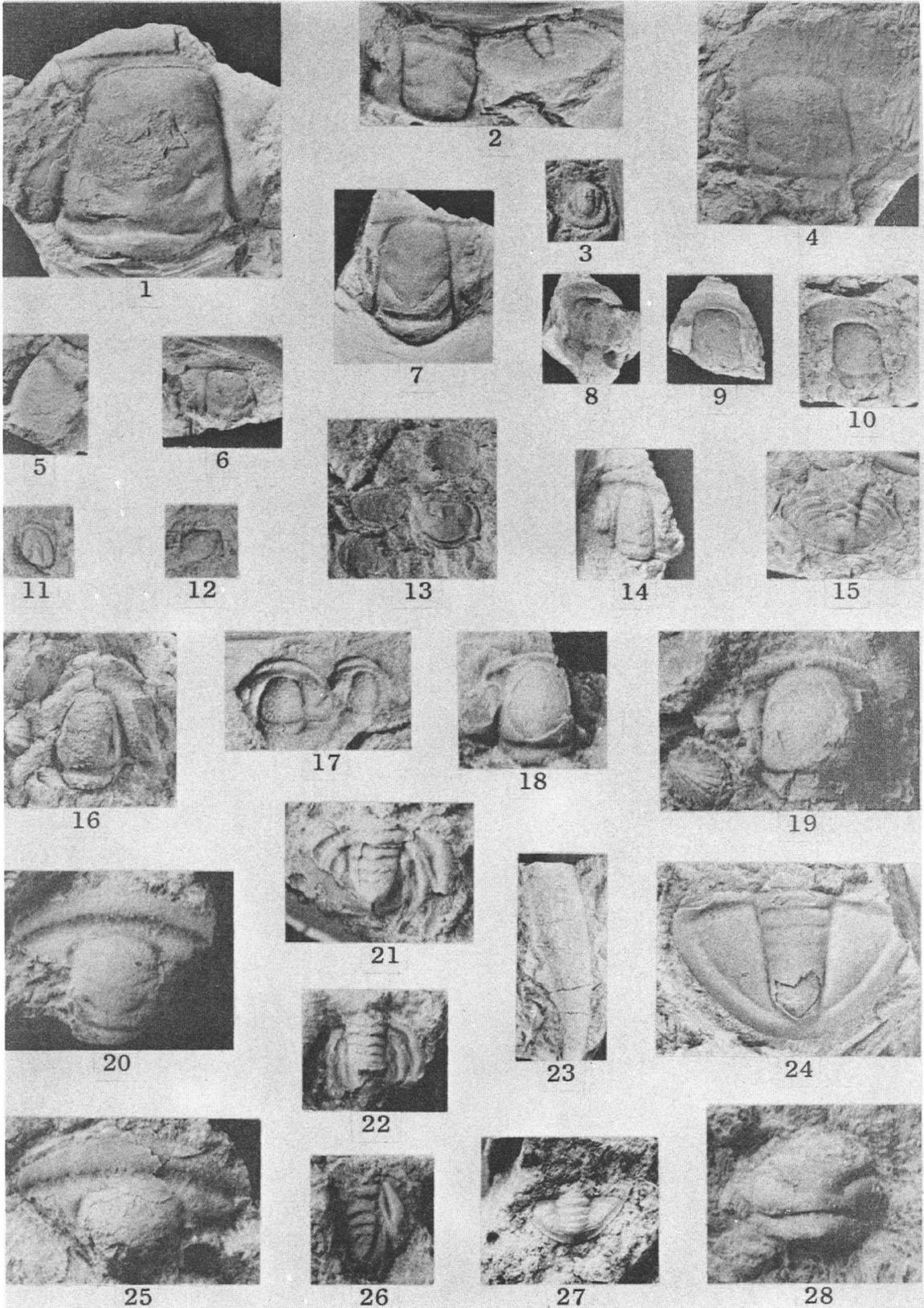


PLATE 6 (continued)

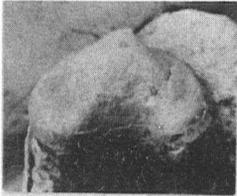
Fig.

21, 22	<u>Kainella</u> sp., pygidia, X2, GSC 46416, 20 and 21 respectively	p. 200
23	Unidentified genal spine, X2, GSC 46414, 5	212
24	<u>Lloydia (Leioptegium) manitouensis</u> (Walcott), pygidium, X2, GSC 46404,	194
26	<u>Kainella</u> sp., pygid., X2, GSC 46415, 1	200
27	Unidentified pygidium, X4, GSC 46417, 3	214
28	? <u>Pliomeroides</u> sp., fragment of glabella and occipital ring, X2, GSC 46404, 8	210

PLATE 7

Fig.

- 1-4 Clarkellid brachiopods, X2: 1, pedicle valve, ventral view, GSC 46418, 8a; 2, posterior view, same specimen; 3, brachial valve, posterior view, showing strong fold, GSC 46418, 8b; 4, pedicle valve, anterior view showing part of deep tongue, GSC 46418, 9 p. 224
- 5 Apheoorthis aff. A. vicina (Walcott), internal impressions of pedicle valves, X1 $\frac{1}{2}$, with Nanorthis sp., GSC 46418, 10 218
- 6 A. aff. A. vicina (Walcott), internal impressions of two pedicle valves, showing variation in depth of sulcus and prominence of growth lines, X2, GSC 46418, 1 218
- 7 A. aff. A. vicina (Walcott), pedicle valve, probably cast of external surface, X2, GSC 46418, 11 218
- 8, 10 Ophileta (Ozarkispira) leo Walcott, lower whorl surface, internal cast with some shell material, and side view of same specimen, lower whorl surface uppermost; X2, GSC 46415, 5 226
- 9 Nanorthis aff. N. hamburgensis (Walcott), X1 $\frac{1}{2}$, GSC 46418, 10 220
- 11 O. (Ozarkispira) leo Walcott, external impression of lower whorl surface, X2, GSC 46415, 4 226
- 12 Apheoorthis ocha (Walcott), brachial valve, X2, GSC 46407, 1 216
- 13, 14 Raphistomina sinclairensis Kobayashi, upper and lower whorl surfaces of same specimen, X2, GSC 46416, 7 228
- 15 R. sinclairensis Kobayashi, upper whorl surface, X2, GSC 46416, 14 228
- 16 Unidentified pygidium, X2, GSC 46402, 5 209
- 17 R. sinclairensis Kobayashi, whorl profile, same specimen as in fig. 15 above, X2, GSC 46416, 14 228
- 18 Unidentified hypostome, associated with Loganellus logani (Devine), X2, GSC 46420, 5 213



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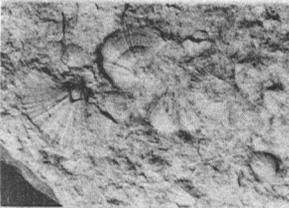
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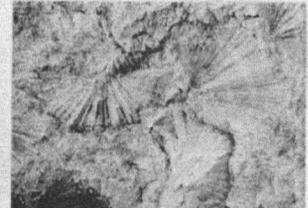
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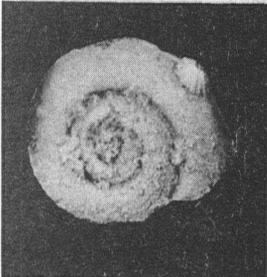
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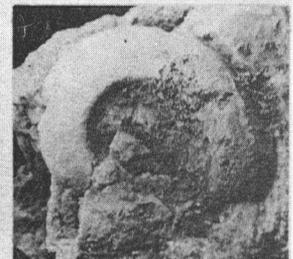
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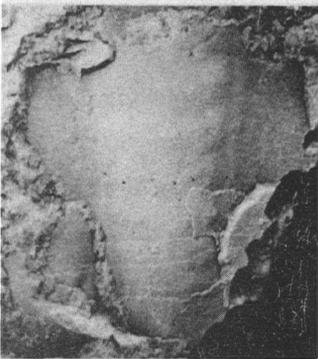
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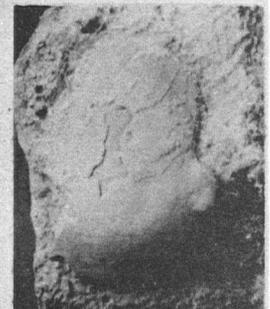
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PLATE 7 (continued)

Fig.

- 19 Schizambon ?discoidea (Walcott), impression of
brachial valve (?), X2, GSC 46418, 11 . . . p. 215
- 20 Symphysurina cf. S. spicata Ulrich, fragment
of cranium, X2, GSC 46417, 1 205

(Fig. 19 is illuminated from lower right).

Note: Beds from 7046' to 8165' on Mount Hunter are thinner-bedded than plotted section suggests.

LEGEND

F 399 etc.: GSC fossil locality numbers; first two digits omitted (46---).

-  Limestone
-  Dolomite
-  Siltstone, sandstone, quartzite
-  Shale, slate
-  Boudaries of Systems, Series
-  Lithologically equiv. horizons
-  Possible alternative lith. equiv.

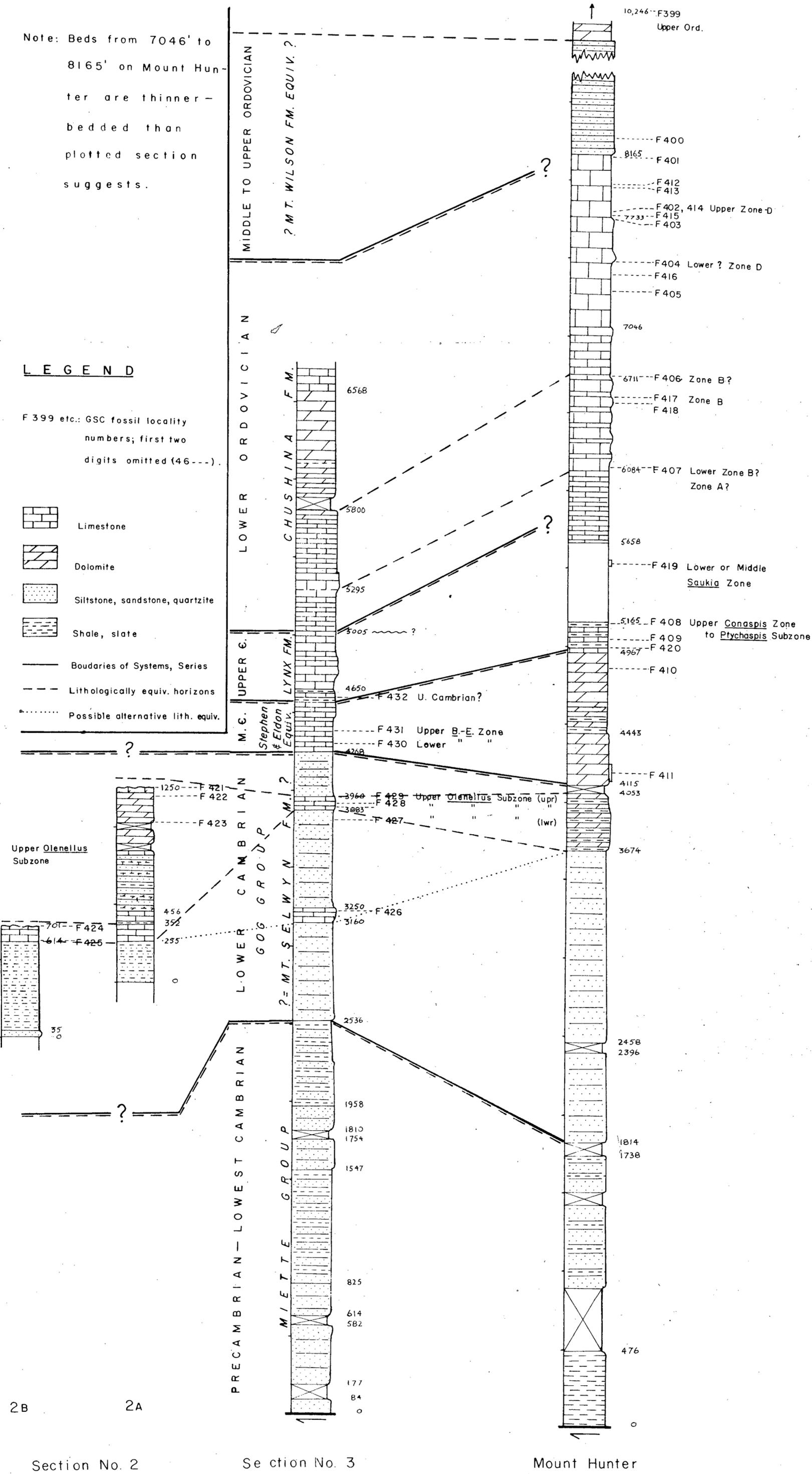


Fig. 4. CAMBRIAN-ORDOVICIAN SECTIONS, MURRAY RANGE, PINE PASS MAP-AREA, B. C.