GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 76-34

PRELIMINARY ACCOUNT OF THE TRILOBITE BIOSTRATIGRAPHY OF THE SURVEY PEAK AND OUTRAM FORMATIONS (LATE CAMBRIAN, EARLY ORDOVICIAN) AT WILCOX PASS, SOUTHERN CANADIAN ROCKY MOUNTAINS, ALBERTA

W.T. DEAN

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available by mail from

Printing and Publishing
Supply and Services Canada,
Hull, Québec, Canada K1A 0S9,

and

The Geological Survey of Canada
601 Booth St., Ottawa, K1A 0E8

or

Through your bookseller.

Catalogue No. M44-76/34
ISBN - 0-660-01511-0

Price: Canada: $2.50
Other Countries: $3.00

Price subject to change without notice

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Abstract

A section through the Survey Peak and Outram formations at Wilcox Pass, Alberta is more accessible than the type section at Mount Wilson and has facilitated the detailed collecting of shelly fossils, particularly trilobites, which often show marked affinities with those of Utah and Nevada. The basal silty member of the Survey Peak Formation yields evidence of the ***Saukia*** *Zone,* ***Corbinia apopsis*** *Subzone, followed by a group of beds containing* ***Apoplanias*** *and* ***Missisquoia****, and then Zone A with* ***Symphysurina****. The Survey Peak Formation ranges upwards probably almost to the top of Zone F, although evidence for the latter is inconclusive. The Outram Formation probably begins just below the base of Zone G and extends upwards into Zone J, to which zone the basal Skoki Formation also belongs. Stratigraphic ranges of principal trilobite genera are given, and evidence is presented to demonstrate the presence of Zones A, B, D, E, G and J. Evidence of Zone F is inconclusive, while Zones G, H and I are probably represented by strata without macrofossils.*

Résumé

Une coupe à travers les formations de Survey Peak et d'Outram, localisées à la passe Wilcox (Alberta), est davantage accessible que la section type au mont Wilson et a facilité la cueillette détaillée de fossiles coquilliers, plus particulièrement de trilobites, qui montrent souvent des affinités marquées avec ceux de l'Utah et du Nevada. Le niveau basal silteux de la formation de Peak Survey témoigne de la zone ***Saukia****, dont la sous-zone renferme des* ***Corbinia apopsis****, suivi d'un groupe de strates renfermant des* ***Apoplanias*** *et des* ***Missisquoia****, puis vient la zone A, caractérisée par la présence de* ***Symphysurina****. La formation de Peak Survey remonte probablement presque au-dessus de la zone F, bien que cette conclusion ne puisse être étayée. La formation d'Outram prend naissance probablement juste au-dessous de la zone G et remonte en pénétrant dans la zone J; à cette dernière se rattache la formation basale de Skoki. On présente ici les séries stratigraphiques des principaux trilobites, et des preuves sont apportées pour démontrer la présence des zones A, B, D, E, G et J. La présence de la zone F ne peut être affirmée, tandis que les zones G, H et I sont probablement représentées par des couches dénuées de macrofossiles.*

INTRODUCTION AND ACKNOWLEDGMENTS

The lithostratigraphic terms, Survey Peak Formation and Outram Formation were introduced by Aitken and Norford (1967) for strata of latest Cambrian (Trempealeauan) and early Ordovician (Canadian) age which succeed the Mistaya Formation (Upper Cambrian) and are widely distributed in the Main Ranges and Front Ranges of the Albertan Rocky Mountains. These and succeeding formations of Ordovician and Silurian age have since been reviewed by Norford (1969a) and one need only point out that the revised stratigraphic terminology was considered necessary in order to supersede a number of widely-quoted but unsatisfactorily founded names such as Mons and Sarbach formations.

Although the two formations were named for Survey Peak and Mount Outram respectively, the type section designated by Aitken and Norford for both is in the southern face of Mount Wilson, near North Saskatchewan River Crossing, directly in front of Mount Wilson (Fig. 1). The section at Mount Wilson is of considerable vertical extent (Aitken et al., 1972, Fig. 9) and the Survey Peak and Outram formations there are succeeded in turn by the Skoki Formation, Owen Creek Formation and Mount Wilson Quartzite (all Ordovician), the Beaverfoot Formation (Ordovician here, but Ordovician-Silurian elsewhere; see Norford, 1969, Fig. 16) followed unconformably by the Fairholme Group (Devonian) which oversteps the older rocks to both northwest and southeast. The Survey Peak Formation was subdivided into four successive informal members as follows: basal silty member, putty shale member, middle member and upper massive member; the Outram Formation has not yet been subdivided.

Numerous macrofossils from both formations were listed by Norford (in Aitken and Norford, 1967, p. 179-184) who also proposed a general scheme of correlation and pointed out the affinities of the faunas with those of Utah and eastern Nevada. A later paper by Derby et al. (1972) listed both macro- and micro-fossils (conodonts) from the basal silty member and putty shale member at Mount Wilson and made suggestions as to the interpretation of the Cambro-Ordovician boundary there. Apart from a paper by Norford (1969b) describing the trilobites **Jujuyaspis** and **Clelandia** from the basal silty member and putty shale member, no systematic account of the faunas has been published. The relative inaccessibility of parts of the Mount Wilson section makes detailed collecting there difficult and, following the suggestion of B.S. Norford who also introduced the writer to the area, the present work was undertaken at Wilcox Pass, almost 40 km to the northwest where a corresponding section is more accessible in the same west limb of the same syncline. Wilcox Pass lies at the southeastern end of Jasper National Park, between Wilcox Peak (or Mount Wilcox) to the west and Nigel Peak to the east, and about 2.5 km north of the Athabasca Glacier, a tongue-like extension from the Columbia Icefield (Figs. 1 and 2). Behind the Icefield information centre, sited beside the Banff-Jasper road at its junction with the road leading to the glacier, the ground rises steeply towards Wilcox Pass (some 600 m higher), the southern margin of which is formed by Upper Cambrian carbonate rocks of the Mistaya Formation.

A short distance north of the southern margin of the pass, a conspicuous gully (Fig. 2) trends west-northwest along the strike of the strata which constitute the topmost basal silty member and the lowest putty shale member. From a point just south of the gully a continuous section from the Survey Peak Formation to the Mount Wilson Quartzite may be followed north-northeastwards, ending at the unconformity at the base of the Devonian and younger rocks which form Nigel Peak.

The principal biostratigraphic subdivisions with which it is hoped eventually to correlate the present lithostratigraphic units are largely those introduced by Ross (1949; 1951), who

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Original Manuscript Received: 21 October 1976
Final Approved for Publication: 30 December 1976

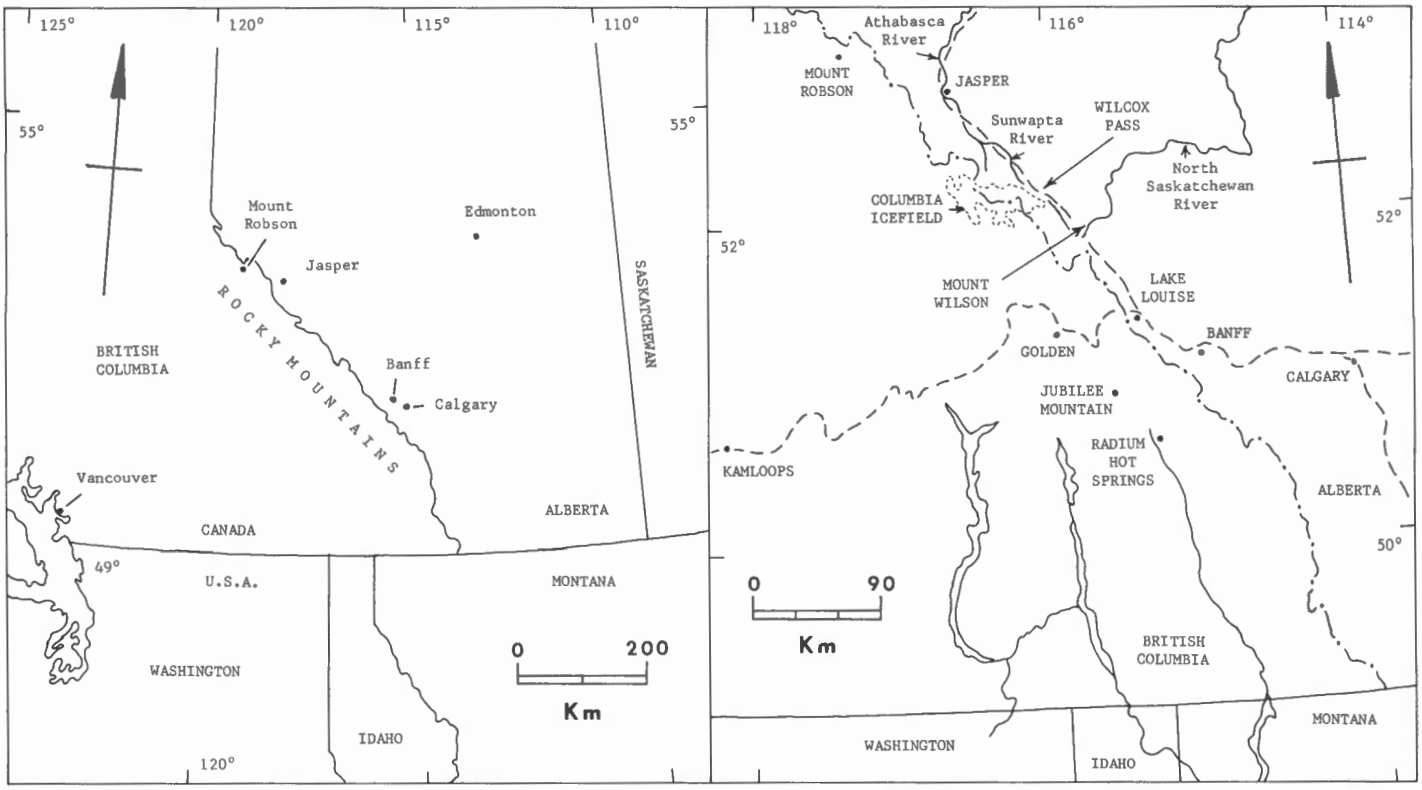

Figure 1. Outline map showing the position of Wilcox Pass in relation to other relevant areas of western Canada.

established a succession of lettered zones (A to M) of Early Ordovician age in northeastern Utah. Hintze (1953), working in adjacent areas of Utah and Nevada, added Zones N and O, and named all the zones after appropriate index fossils, mostly trilobites. Not all the index genera and species are common to these and other areas, however, and Ross's lettered zonation continues to be used by many workers. In the following pages both schemes may be referred to because in some cases no trace of the zonal index has been found, though the age is shown by means of other characteristic fossils. In the range chart (Fig. 3) emphasis is laid on genera rather than species in an attempt to produce a scheme readily usable in the field, but all the trilobites found will be described later.

Thanks to permits readily granted by the Director of the Western Region, Parks Canada, systematic collecting was carried out during summer visits in 1972, 1975 and 1976; the material collected is deposited in the national invertebrate fossil collection at the Geological Survey of Canada, Ottawa.

SURVEY PEAK FORMATION

The great variety of rock types constituting the formation have been described and discussed by Aitken and Norford (1967) and by Aitken (1966) who postulated a generally shallow-water environment of widely-distributed, offshore carbonate shoals. Limestones are common and varied, and, especially in the two lowest members, include domed masses of algal stromatolites. The latter rocks are almost invariably barren of macro-fossils, which have most often been found in subsidiary beds of calcarenite, generally impersistent and not more than 5 to 10 cm thick. Quartzose siltstones occur commonly in lenticular beds at almost any horizon and often display cross-lamination. They are almost always unfossiliferous but exceptions include: the local occurrence of orthid brachiopods in the basal silty member; some of the records of disarticulated agnostid trilobite remains higher in the same member and in the putty shale member; and most of the occurrences of the asaphid trilobite **Bellefontia** in the lowest sixth of the middle member.

Flat-pebble conglomerates, although found at almost any level, are particularly abundant in the two lowest members, and the condition of the contained pebbles has been judged to suggest some subaerial exposure and subsequent oxidation (Aitken and Norford, 1967, p. 172). Despite the often unpromising lithology, brachiopods, gastropods and fragmentary trilobites may be found in the matrix where it is sufficiently calcareous.

Shales are most conspicuously developed in the putty shale member, where their colour is self-evident and they form a conspicuous, distinct band in the local topography. Less fissile, often silty shales may be encountered in any of the remaining members. The shales of the Survey Peak Formation, of whatever sort, have proved virtually unfossiliferous, the only exception being a dendroid graptolite, ?**Dictyonema** sp., from the putty shale outcrop at Mount Wilson (Aitken and Norford, 1967, p. 196).

As might be expected for such shallow-water sediments, horizontal changes in detailed lithology are the rule rather than the exception, though larger lithostratigraphic units are often remarkably persistent. The predominance of such changes is the basic reason for the use of only informal members as subdivisions of the formation by Aitken and Norford, who emphasized the arbitrary nature of their defined boundaries. A case in point is the base of the Survey Peak Formation itself, which by definition (Aitken and Norford, 1967, p. 169) "is placed at the lowest occurrence of thin-bedded, recessive-weathering shales or calcareous siltstones" which succeed the "underlying, thick-bedded, massive cliff-forming limestones and dolomites of the Mistaya Formation...". At Wilcox Pass such a boundary is located only a short distance south of, and parallel to, the unnamed but well-defined hollow which runs from west to east along the strike of the rocks from the southern foot of Wilcox Peak and continues as a deep, stream-cut gully to the high, limestone cliffs above the Icefield campground, 5 km east-northeast of the Athabasca Glacier ("Camp" in Fig. 2). This line, which is conspicuous in distant view and visible in aerial photographs, is marked by a distinct step in the

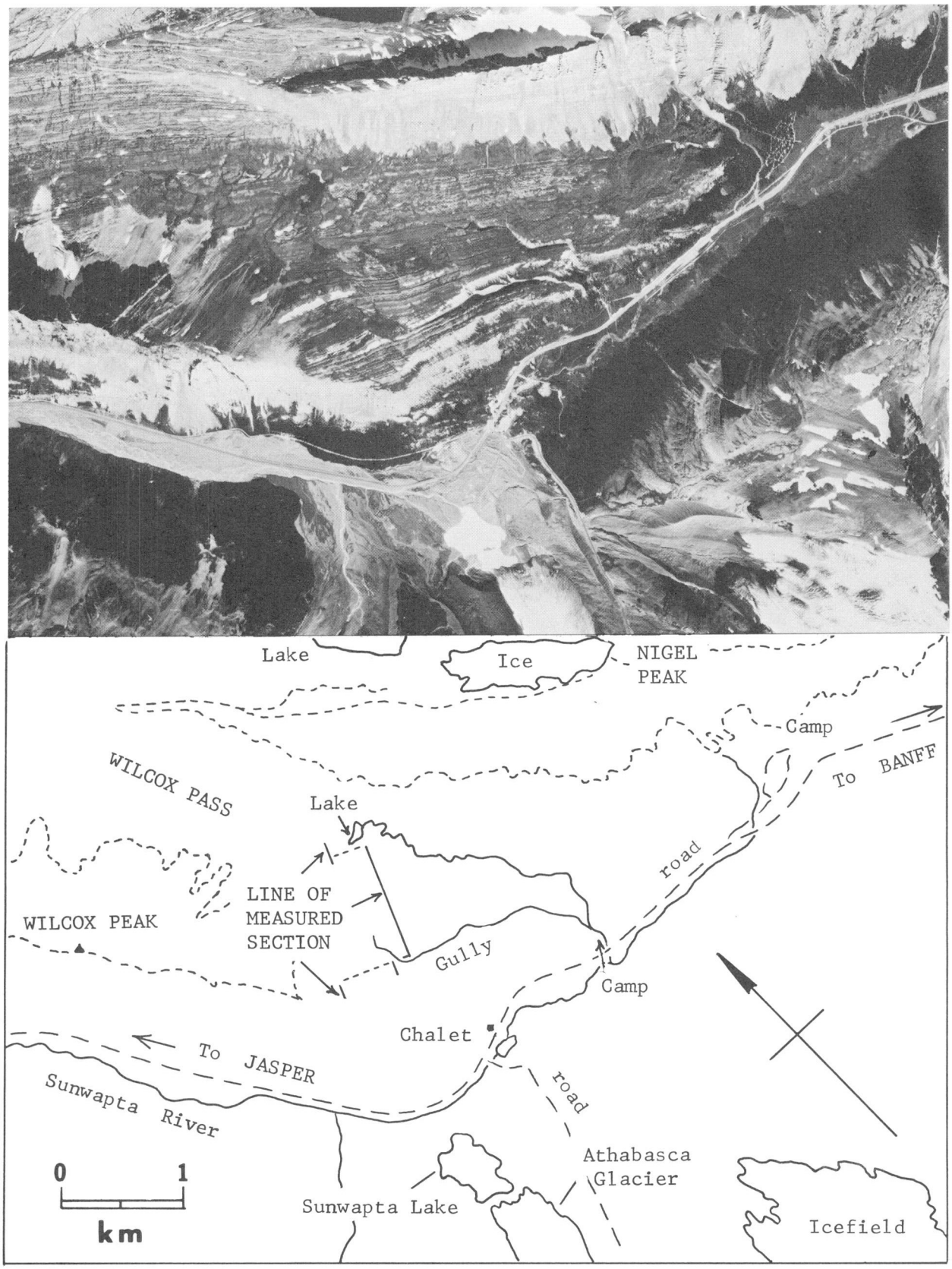

Figure 2. Aerial photograph of the Wilcox Pass area, and corresponding outline map showing some salient features.

topography and its southern margin coincides with the base of a recessively-weathering unit of shales almost 4 m thick. From Aitken and Norford's 1967 account (see also Derby et al., 1972) it appears that the Mistaya/Survey Peak boundary at Mount Wilson is slightly older than at Wilcox Pass, and that the lowest part of the type Survey Peak Formation is represented at Wilcox Pass by a unit of massive limestones and stromatolites which is here grouped with the Mistaya Formation.

As far as possible the line of section pursued during the present field-work follows the direction of dip and runs slightly east of north so as to intersect the summit of the low hill situated in the centre of the south end of Wilcox Pass. Because of snow cover or lack of exposures it was occasionally necessary to offset the traverse a short distance to east or west, a situation which particularly affects the upper half of the Outram Formation and the lower half of the basal silty member of the Survey Peak Formation. In the former case, parallel traverses were continued northwards by the eastern and western ends of the small lake in Wilcox Pass (Fig. 2); in the latter, the section was offset westwards to a point approximately midway between the southern foot of Wilcox Peak and the stream-cut gully noted earlier.

Basal silty member

As noted above, the lowest strata of the member comprise some 4 m of recessively-weathering brown, silty shales, only the topmost beds of which are exposed. No fossils were found but succeeding calcarenites associated with silty shales, conglomerates and stromatolites yielded **Corbinia** and **Apatokephaloides,** genera which Winston and Nicholls (1967) reported from central Texas in their **Corbinia apopsis** Subzone, the topmost of four subzones into which they subdivided the **Saukia** Zone of the Late Cambrian. A similar situation was reported from Oklahoma by Stitt (1971). At this point the strata with **Corbinia** are separated by about 1.5 m of barren rocks from a small thickness (about 1.8 m) of shales and calcarenites with poorly-preserved **Plethometopus** (s.l.), and 3.8 m higher comes a group of calcarenites and stromatolites in which **Apoplanias rejectus** Lochman (1964a, p. 57) is characteristic. **A. rejectus** was described first from boreholes in the Williston Basin of Montana and was regarded by its author as being of Late Cambrian age. Derby et al. (1972, p. 509), working at Mount Wilson, attempted to use the presence of **Apoplanias** as part of their evidence for the **Missisquoia** Zone, at present a contender for being considered the basal subdivision of the North American Ordovician, and they reported that "The basal few feet contain various species of **Missisquoia, Apoplanias rejectus** Lochman, **Nanorthis** and **Apheoorthis ovata** Ulrich and Cooper". However, their range table (loc. cit., Fig. 3) shows **Apoplanias** unaccompanied by any other trilobite genus, occurring 1.83 m (6 ft.) below the first appearance of **Missisquoia.** The evidence so far available from one section at Wilcox Pass suggests that **Apoplanias** appears, ranges through at least 0.7 m (questionably 4 m) and finally disappears before **Missisquoia** makes its debut, but the evidence at another section still under investigation is equivocal. Although Lochman did not report **Missisquoia** from the Montana subsurface rocks, she did find **Apoplanias** confined to 3.05 m (10 ft.) of core, so that the genus appears to have some potential as a zonal indicator, though its assignment to either Cambrian or Ordovician is as yet uncertain. At Wilcox Pass a unit 1.5 m thick of irregularly bedded stromatolites and shales occurs 2.0 m above the highest record of **Apoplanias;** associated calcarenites in this unit have yielded both **Missisquoia** (Shaw, 1951) and Symphysurina, the latter including species with both rounded and spinose pygidia. Material of the former genus has been described by Dean (1977) but the precise relationship of **Missisquoia** and **Symphysurina** at this section is still under investigation and the appearance of either may vary according to local conditions, though the two are recorded together from the Jasper area and from McKay Creek, British Columbia. **Symphysurina** has long been regarded as being of zonal significance in the early Ordovician of North America, but in recent years there has been disagreement and confusion regarding its rôle in stratigraphic nomenclature. The arguments were summarized by Norford (1969b, p. 2). More recently, at the Mount Wilson section, Derby et al. (1972) indicated three species of **Symphysurina, S. brevispicata** Hintze, **S. spicata** Ulrich and **S.** sp., as occurring in the **Symphysurina** Zone; they drew the base of the latter zone at the appearance of **S. brevispicata** and a short distance (1.52 m = 5 ft.) above their last record of **Missisquoia.** At Wilcox Pass **Symphysurina** has been found to range upwards through the remainder of the basal silty member and the whole of the putty shale member. Its appearance is closely followed by (or is approximately contemporaneous with – the evidence is not clear) that of **Highgatella cordilleri;** the latter was described first as **Euloma cordilleri** Lochman (1964b, p. 464) from the Williston Basin of Montana, but was later reassigned by Winston and Nicholls (1967, p. 73) to **Highgatella** Shaw, 1955 from northern Vermont. In Montana **H. cordilleri** was reported from two levels, 3.96 m (13 ft.) apart in rocks assigned to Zone A; at Mount Wilson, Derby et al. showed the species appearing at the same level as **Symphysurina** and ranging through the lower half of the **Symphysurina** Zone. **Highgatella** has so far been found in abundance only in the middle quarter, or less, of the basal silty member, that is to say within the lowest portion of the vertical range of **Symphysurina,** with which genus it has sometimes been found associated. Agnostid trilobites, referred here broadly to **Geragnostus,** are a rare and generally poorly preserved component of the Survey Peak Formation's fauna, but are found sporadically with **Highgatella** and/or **Symphysurina** in the upper half of the basal silty member. The uppermost third of the basal member is marked by the appearance of the diminutive genus **Clelandia** (regarded here as a senior subjective synonym of **Desmetia** Walcott, 1925 from Nevada) which then continues upwards to the top of the putty shale member. Corresponding material from Mount Wilson and elsewhere has been described by Norford (1969b) in a paper which also included an account of the olenid **Jujuyaspis.** Described originally by Kobayashi (1936) on the basis of material from Province Jujuy, Argentina, the latter genus is widely distributed in rocks of Tremadoc age. **J. borealis** Kobayashi (1955), founded on material from the McKay Group of British Columbia, was reported by Norford (1969b) from the Survey Peak Formation at Mount Wilson; at Wilcox Pass the species has been found in the highest 6 m of the basal silty member and the lowest 12 m of the putty shale member. For the sake of convenience, discussion of the age of the basal silty member is grouped with that of the putty shale member at the end of the next section.

Putty shale member

In their original account Aitken and Norford (1967, p. 168) pointed out that the change from basal silty member to putty shale member is gradational, and arbitrarily drew the base of the latter unit below "the lowest prominent interval (10 ft. or more)" of the putty coloured shales which are the member's most characteristic feature. Using this criterion, the member has a total thickness of just over 42 m at Wilcox Pass. Notwithstanding its name, the member also contains large numbers of thin (up to 20 cm), resistant beds of flat-pebble conglomerate and siltstone, while many of the shale intervals outside the restricted putty-coloured zone are silty and weather brown. The resistant beds sometimes include lenticular beds of calcarenite in which disarticulated trilobite fragments may be found. Although specimens may be locally abundant, the variety is small and almost confined to **Symphysurina, Clelandia** and **Jujuyaspis,** all of which range upwards from the basal silty member. **Jujuyaspis** is the most restricted vertically and extends through only about the

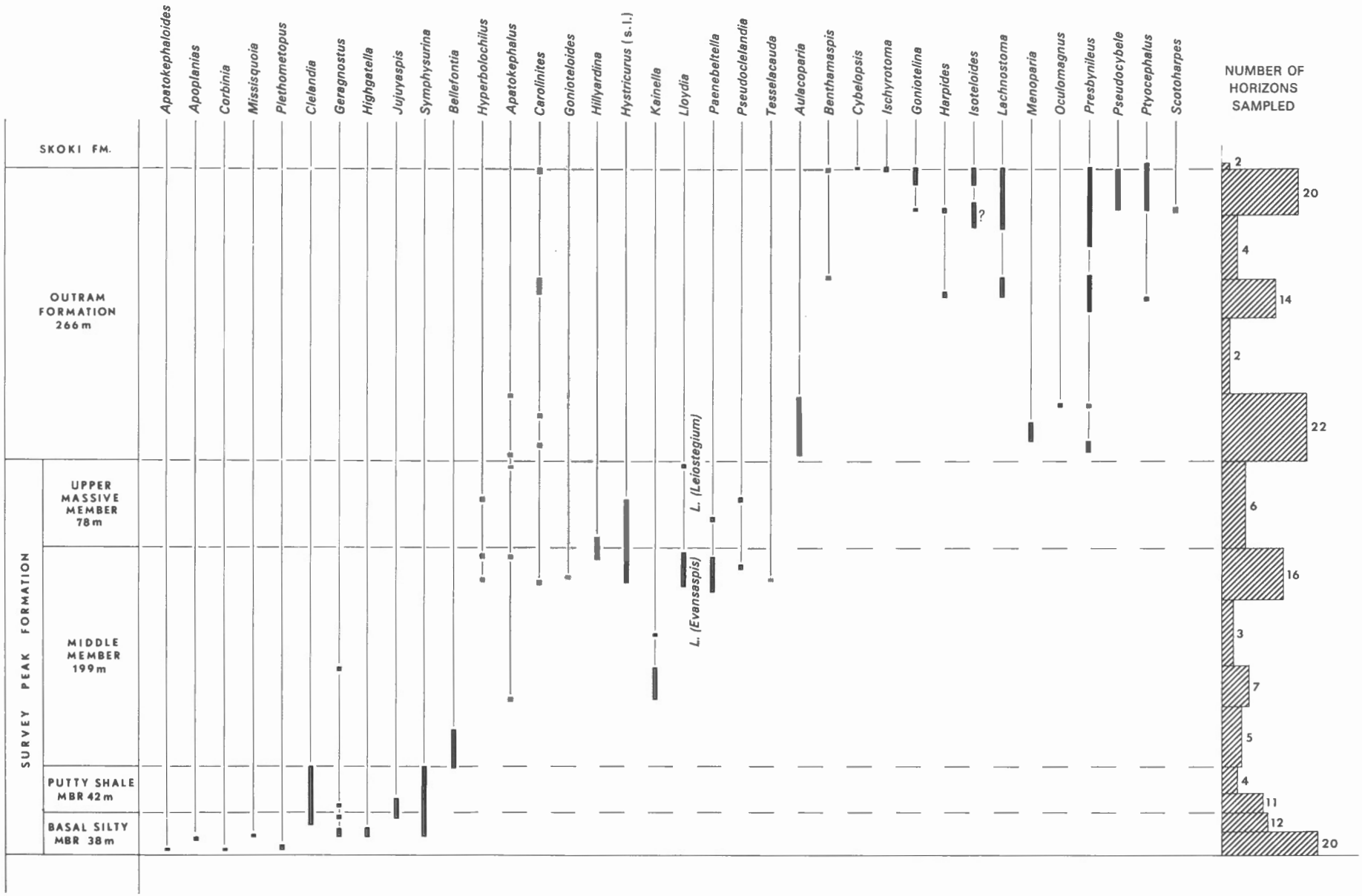

Figure 3. Chart showing present known vertical distribution of the principal trilobite genera in the Survey Peak, Outram and basal Skoki formations.

lowest 12 m, but the other two have been found as high as the upper boundary of the member. **Geragnostus** (s.l.) is a very minor constituent of the fauna, as was the case in the basal silty member. The asaphid **Bellefontia** appears uncommonly about 2 m below the top of the putty shale member; however, it is found essentially in the lowest 27 m of the middle member.

Ross's (1951) original sequence of lettered zones in the Ordovician of Utah began with the following: Zone A, containing, inter al., **Symphysurina, Hystricurus, Pseudohystricurus** and **Nanorthis;** Zone B, containing **Bellefontia, Clelandia, Xenostegium** and **Hystricurus;** Zone C, containing **Symphysurina, Hystricurus**?, **Nanorthis** and **Syntrophina**?. In western Utah and eastern Nevada Hintze (1953) failed to differentiate Ross's Zone A but appeared, in fact, to have the latter represented in what he interpreted as Zone B, as pointed out by Norford (1969b, p. 2). Norford also discussed the various usages of Zones A and B in western North America and showed that the bases are "essentially defined", respectively, by the appearance of **Symphysurina** and **Bellefontia.** He termed Zone A the **Symphysurina-Euloma** Zone (the **Euloma** is now interpreted as a **Highgatella**), and Zone B the **Bellefontia-Xenostegium** Zone. Using these criteria the upper half (approx.) of the basal silty member and all except the topmost 2 m of the putty shale member (in which **Bellefontia** appears) are assignable to Zone A. The lowest fossiliferous portion of the basal silty member at Wilcox Pass is assigned to the **Corbinia apopsis** Subzone, topmost subdivision of the **Saukia** Zone, and is followed by a group of strata broadly interpreted as belonging to the **Missisquoia** Zone. As already noted, the use of the last-named does not take into account the possible significance of **Apoplanias,** and there is a distinct possibility of stratigraphic overlap between the vertical ranges of **Missisquoia** and **Symphysurina,** in which case the appearance of the last-named would be interpreted as indicating the lower limit of Zone A.

Middle member

Although the distinctive colours of the putty shale member and thick thrombolitic limestones of the upper massive member are easily recognized in their typical development, there is between them a "grey area" which Aitken and Norford (1967, p. 169) termed the middle member, pointing out that its constituent rocks include all the various lithologies found throughout the Survey Peak Formation. Both lower and upper boundaries, particularly the former, are arbitrary; but as here interpreted the middle member is about 199 m thick and is considered to begin at the base of a 4.3 m unit of well-developed conglomerates with interbedded flaggy siltstones, limestones and limy shales. This unit overlies a 14.5 m interval of "putty shale" with minor beds of conglomerate. This boundary, which is just north of the western end of the stream-cut gully at the south end of Wilcox Pass, appears to conform best to Aitken and Norford's (1967, p. 168) requirement of a change "from dominant shale with subordinate limestone to dominant limestone with subordinate shale". Although this boundary at Wilcox Pass was chosen for lithostratigraphic reasons, it coincides almost exactly with the upper limit of the vertical range of both **Symphysurina** and **Clelandia.** It is only slightly above the lower limit of **Bellefontia,** a genus which has so far been found to range through about 33 m at this section, and is always indifferently preserved in grey, platy limestones occurring within a silty shale succession. By analogy with the succession in Utah, these strata are equated with Zone B, or **Bellefontia-Xenostegium** Zone. The lower limit of Zone B is correlated here with the appearance of **Bellefontia** rather than with the disappearance of **Symphysurina** and **Clelandia,** and in this interpretation, falls about 2 m below the base of the middle member.

Above the highest known level with **Bellefontia** lie grey shales, siltstones and conglomerates about 25 m thick in which no recognizable macrofossils have yet been found. As they are succeeded by strata with a Zone D fauna, these unfossiliferous beds are equated tentatively with Zone C, the **Paraplethopetis** Zone, of Utah. Judging from the faunal lists of Ross (1951) and Hintze (1953), the fauna of this thin zone is relatively small and unvaried, even in its type area, and appears less distinctive than that of neighbouring zones.

The trilobite fauna of the approximately middle portion of the middle member is almost confined to one genus, the remopleuridid **Kainella,** but the latter is of stratigraphic significance and is considered to be indicative of Zone D, named also the **Leiostegium-Kainella** Zone, in Utah (Hintze, 1953). At a few points **Kainella** is associated with the long-ranging **Geragnostus** (s.l.), and in the lowest 4 m of its vertical range is accompanied by a small species of another remopleuridid genus, **Apatokephalus;** this latter association recalls, and is perhaps analogous to, Walcott's (1884, p. 89, 90) description of **Kainella (Dicellocephalus) inexpectans** and **Apatokephalus (Dicellocephalus) finalis** from a supposedly single locality in the Eureka district of Nevada. **Kainella** does not appear in Ross's (1951) Zone D trilobite list, and the latter includes only **Leiostegium manitouense** Walcott, not yet found at Wilcox Pass but recorded by Mountjoy (in Aitken and Norford, 1967, p. 183) from the Chushina Formation farther north in the Canadian Rockies. It was from the type Chushina, near Mount Robson, that **Kainella billingsi** Walcott (1924, p. 37) was described, and its occurrence there probably corresponds to that of the genus in the middle member. Hintze's (1953) list for Zone D includes **Kainella** sp., **Apatokephalus finalis** and **Leiostegium manitouense.**

There is good evidence that **Kainella** ranges through at least 30 m of strata at Wilcox Pass, but the extension of this range through a further 30 m (Fig. 4) of unfossiliferous or unexposed shales and flat-pebble conglomerates is poorly documented. This dearth of macrofossils then becomes even more pronounced and there is an interval, some 36 m thick and represented by conglomerates and grey shales, which has so far proved barren. For present purposes the top of Zone D is drawn at the highest record of **Kainella,** and the succeeding barren interval is left unassigned (Fig. 4). The upper portion of the middle member is characterized by a varied trilobite fauna and the appearance of **Paenebeltella** is taken to indicate a correlation with the base of Zone E in Utah, by reference to the records of Ross and Hintze. The only species so far recognized is **P. convexa** Kobayashi (1955, p. 468), described first from the McKay Group of south-eastern British Columbia and since reported from Mount Wilson (Norford in Aitken and Norford, 1967, p. 181). It is closely followed in the succession by **Lloydia (Evansaspis) ceratopygoides** (Raymond, 1925), the distinctive spinose pygidia of which may be locally abundant. The writer agrees with Norford (in Aitken and Norford, 1967, p. 183) that this species is a senior subjective synonym of both **Leiostegium formosa** Hintze, 1953 and **Leiostegium (Evansaspis) glabrum** Kobayashi, 1955. In assigning the species to the genus **Lloydia** rather than to **Leiostegium,** and regarding both **Leiostegium** and **Evansaspis** as subgenera of **Lloydia,** the writer is following the course adopted by Lochman (1965, p. 477; 1966, p. 533). However, the matter is far from settled and Ross (1970, p. 73-74) preferred to restrict **Lloydia** virtually to the type species, and to use **Leiostegium** or its subgenera for species such as are listed here. Although reported from Zone E in Utah by Hintze (1953), **L. (E.) ceratopygoides** does not appear in Ross's (1951) lists from the Garden City Formation. At Wilcox Pass the species has so far been found to range through almost 32 m of strata, terminating below the top of the middle member. Zone E has also been termed **Tesselacauda** Zone in Utah by Hintze (1953) but at Wilcox Pass the eponymous genus has been found at only one locality, associated with **L. (E.) ceratopygoides** and represented by **T. flabella** Kobayashi (1955, p. 417). Also

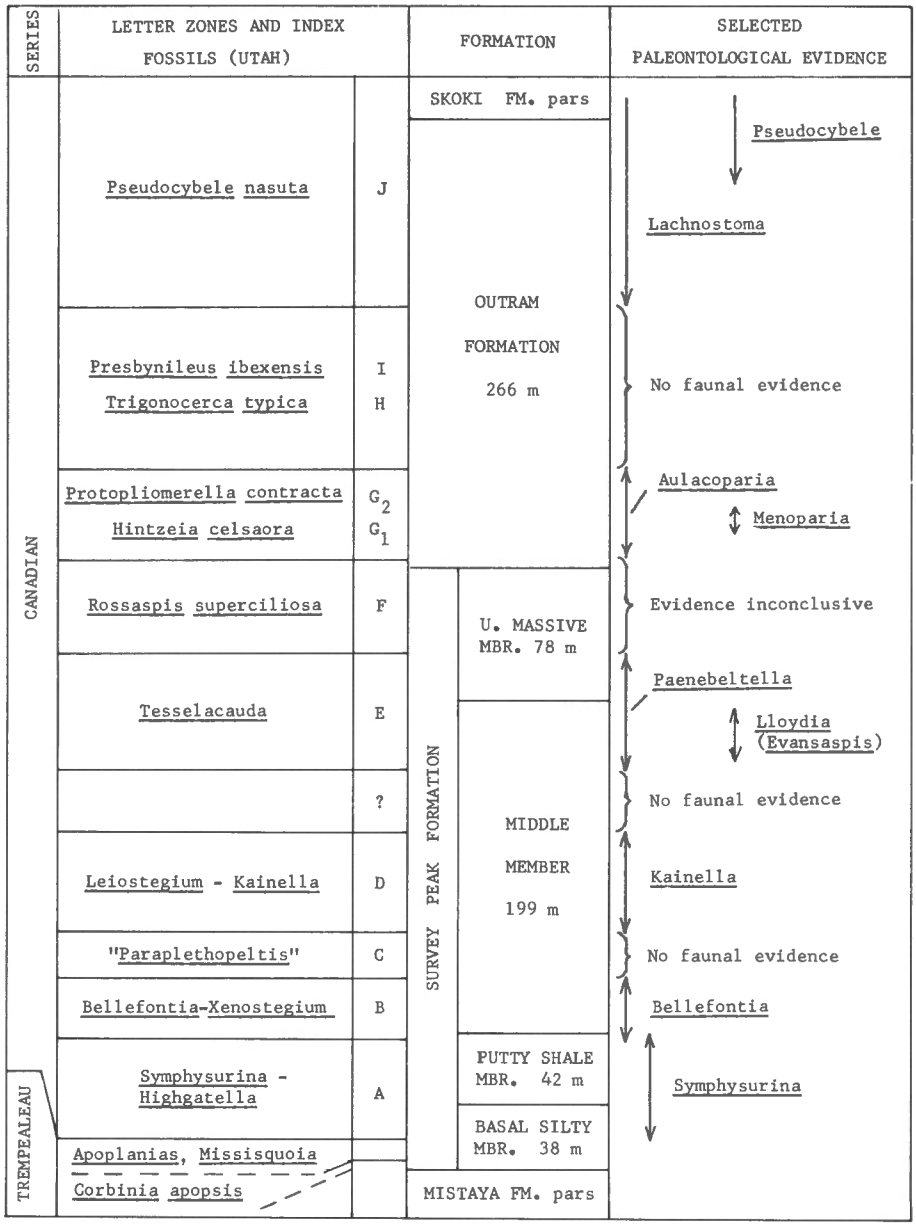

Figure 4. Provisional correlation table for the Survey Peak, Outram and basal Skoki formations showing selected trilobite evidence of particular stratigraphic value.

found at a single locality horizon in Wilcox Pass is the curious bathyurid **Gonioteloides monoceros** Kobayashi (1955, p. 447), yet another trilobite first described from the McKay Group of British Columbia. According to Kobayashi (1955, p. 365) this species occurs at two levels within the McKay Group, namely with **Jujuyaspis borealis** in his "**Symphysurina** Fauna" (= Zone B) and with **L. (E.) ceratopygoides** (= **glabrum**) in the "**Kainella-Evansaspis** Fauna" (= Zone E). Whether or not this is the case, and doubt has also been expressed by Norford (1969b, p. 4), the writer has so far found the species only in Zone E, at which horizon it is reported from Mount Wilson by Norford (in Aitken and Norford, 1967, p. 181) and from Colorado by Berg and Ross (1959, p. 117-118). A very rare component of the trilobite fauna at Wilcox Pass is **Pseudoclelandia** Ross (1951), which has been found there with **L. (E.) ceratopygoides. Pseudoclelandia** was at first recorded only from Zone E by Ross and Hintze, but its range has since been extended into Zone F and, in fact, a second locality, in the upper massive member, may be of that age. An unusual record from Zone E here is **Carolinites** Kobayashi, 1940, generally supposed to be found in Zones H, I and J in western North America and collected from several localities of Zones G and J age in the Outram Formation. Two levels in the upper part of the middle member have yielded evidence of **Hyperbolochilus** Ross (1951), first described from Zone F but here undoubtedly from Zone E, although the genus also occurs in the upper massive member at a higher level which may correspond to part of Zone F.

Upper massive member

The boundary between the middle member and the upper massive member was stated by Aitken and Norford (1967, p. 169) to be drawn "where thick thrombolitic beds become prominent upward; in all sections observed, the content of shale decreases markedly at the same level". As now interpreted, this boundary is situated a short distance north of the summit of the low, limestone hill at the south

end of Wilcox Pass, and at a level approximately 26 m higher than that of the rocks composing the summit. Massive, thrombolitic limestones are developed mostly in the lower half of the upper member; they form a second, lower "summit" on the north side of the hill and constitute a conspicuous topographic feature which can be easily traced eastwards along the strike. The thickness of the member is just over 78 m but fossiliferous horizons are few, confined to occasional thin beds of calcarenite which occur sparingly throughout. The trilobite fauna is relatively small in numbers, lacks variety, and the age assessment is correspondingly unsatisfactory.

The lowest 27 m are tentatively assigned to Zone E because this point marks the upper limit of **Paenebeltella**. The evidence of **Hillyardina** in the lowest 13 m is inconclusive because the genus is recorded from Zone F by Ross (1951) and from Zones E and F by Hintze (1953). In the upper half of the member, the presence of **Hyperbolochilus** could be interpreted as being indicative of Zone F by analogy with previous records from Utah, but the genus clearly has an extended vertical range at Wilcox Pass and occurs there also in the upper part of the middle member, in strata satisfactorily dated as Zone E. A single record of **Pseudoclelandia** from the upper half of the member again involves a genus known from both Zones E and F, while **Apatokephalus** at a point 6 m below the upper boundary is a genus which ranges at least from the middle member to the Outram Formation. Several fragments of hystricurid trilobites have been found in the lower half of the upper member and the highest part of the middle member, but have so far proved insufficiently well preserved for stratigraphic purposes.

OUTRAM FORMATION

The Survey Peak – Outram formational boundary (Aitken and Norford, 1967, p. 170) is again a gradational, arbitrary one and at the type section on Mount Wilson was defined as "The lowest occurrence of dark-coloured shales (even as partings between limestone beds)", or the point "where brown-weathering, slightly recessive strata appear above grey weathering, very massive and resistant rock". The dominant rock, as described by these authors, is a curious and characteristic form of nodular limestone in which small nodules of various limestone types are found in a brown-weathering shale matrix. The rock often weathers recessively to produce a talus of small limestone nodules. Except in occasional developments of larger nodules, this lithology yields few macrofossils but the latter may be locally abundant in thin, generally resistant beds of calcarenite which occur intermittently throughout the formation. Trilobite remains are invariably disarticulated and often broken. Calcareous siltstones and conglomerates are well represented but have generally proved unprofitable for macrofossil collecting. As interpreted here, the Outram Formation is about 266 m thick.

According to Aitken and Norford (1967, p. 177-179) the rocks of the Survey Peak Formation indicate deposition under very shallow or intermittently emergent conditions, whereas those of the Outram Formation indicate poorly aerated, moderately shallow (1 to 4 fathoms) conditions. The change in environment towards increasing depth of water is reflected also in the composition of the trilobite fauna, and members of the Asaphacea are particularly well represented in the dark grey limestones, both fine and coarse grained, of the Outram. Several genera known from Utah have been found, but the Pliomeridae, a family relatively abundant in the latter region and often used there as zonal indices, are scarce at Wilcox Pass. No fossils have been found in the lowest 4 m of the Outram Formation as here interpreted, but succeeding strata include several calcarenite beds and in these the asaphinid **Aulacoparia** Hintze and Jaanusson (1956) is not uncommon. The genus is known from Zones G_1 and G_2 in Utah, where it was documented first as **Asaphellus**? **venta** Hintze (1953) and as **Asaphellus**? **eudocia** Walcott by Ross (1951). Subdivision of Zone G has not yet proved practicable at Wilcox Pass and for the time being its lower and upper boundaries are interpreted as the limits of the vertical range of **Aulacoparia**. Also found in the lowest fossiliferous Outram is the isotelinid **P. (Presbynileus)** Hintze (1954), which extends upwards into the basal Skoki Formation and apparently ranges from Zone G at least into Zone J at Wilcox Pass. **Apatokephalus** at this level is of no obvious stratigraphic value, and **Carolinites** represents a cosmopolitan, probably pelagic genus with an impressively long vertical range. Spanning the lower middle portion (about 18 m) of the range of **Aulacoparia** is a set of dark, nodular limestones containing the remopleuridid genus **Menoparia** (Ross, 1951; 1953), a reliable indicator of Zone G (both G_1 and G_2) in Utah. The higher strata with **Aulacoparia** have yielded also the bathyurid **Oculomagnus**, founded by Lochman (1966, p. 541) on borehole specimens of Zone G age from the Williston Basin of Montana, together with material from Zone G_1 of Utah figured earlier by Ross (1951, pl. 29, figs. 20, 21, 24) as "Undetermined Genus and Species C". **Oculomagnus** has been found so far at only one locality in Wilcox Pass and its age there is probably Zone G_2 rather than G_1. The genus has been recorded from an approximately similar horizon at Mount Wilson by Norford (in Aitken and Norford, 1967, p. 181).

The published type section of both the survey Peak and Outram formations (Aitken and Norford, 1967, p. 180) contains five "barren" intervals, some of considerable thickness, in which no macrofossils were encountered. The more accessible section at Wilcox Pass has enabled the gaps to be greatly diminished but there remains within the Outram Formation a thickness of some 75 m of apparently unfossiliferous nodular limestones. These succeed the highest strata with **Aulacoparia**, assigned to Zone G (see earlier), and are followed by beds in which there is a reappearance of **P. (Presbynileus)**, a subgenus which continues upwards into the basal Skoki Formation, Zone J. Although recorded only from Zones H, I and J in Utah, **P. (Presbynileus)** has been found also in Zone G at Wilcox Pass and its presence, at least at subgeneric level, above the "barren" interval therefore has no precise zonal significance. The same may be said of **Ptyocephalus** Whittington (1948) (recorded in some earlier publications under the pre-occupied name of **Kirkella**), which extends through Zones H, I and J in Utah. At Wilcox Pass **Ptyocephalus** has been found within a restricted (3.5 m) interval some 9 m above the top of the "barren" beds but is then apparently absent until the top 37 m of the Outram Formation, where it re-appears and extends into the basal Skoki Formation.

The "barren" limestones plus 13 m of strata with **P. (Presbynileus)** and the earliest **Ptyocephalus** are thus, in default of positive evidence, assigned to Zones H and I (undifferentiated). Above this level the remainder of the Outram Formation, some 115 m of strata, and the lowest 6.5 m of the Skoki Formation are correlated with Zone J. The trilobite fauna shows some variety but most of the genera are known to extend through Zones H, I and J (or even higher) in Utah and Nevada; this is true, for example, of **Ischyrotoma** Raymond, 1925 (regarded by Whittington, 1963, p. 45 as a senior subjective synonym of **Dimeropygiella** Ross, 1951, p. 123), **Isoteloides** and **Pseudocybele**, as well as **P. (Presbynileus)** and **Ptyocephalus** already noted. For present purposes the base of Zone J is drawn at the appearance of the isotelinid **Lachnostoma** Ross (1951) which, according to published records, appears no earlier in Utah, and at Wilcox Pass is abundant and often well preserved. The bathyurid **Goniotelina** Whittington and Ross (in Whittington, 1953, p. 663) is confined to Zone J in Utah but has been found in only the highest 36 m of the Outram Formation and basal Skoki Formation during the present collecting. An interesting record in Norford's list (in Aitken and Norford, 1967, p. 179, 183) from the upper beds of the Outram Formation at Mount Wilson is the alleged komaspidid **Benthamaspis**. This genus

has now been found at two levels in the Wilcox Pass section, and two species are represented. The lower occurrence is in the middle part of the Outram Formation, within the lowest portion of what is interpreted here as Zone J, and the species is close to, if not identical with, the type species **Benthamaspis problematica** Poulsen (1946, p. 325) from the "Nunatami formation?" of Ellesmere Land. The higher occurrence of **Benthamaspis** is in the topmost Outram and basal Skoki formations, and in this instance the species is identified as **Benthamaspis** cf. **B. diminutiva** Hintze (1953, p. 142), described from Zone J of Utah. Well-preserved material of the isotelinid **Isoteloides** Raymond, 1910, also in the highest Outram and basal Skoki, indicates affinities with faunas in Utah (Hintze, 1953), northwest Greenland (Poulsen, 1927) and Vermont, while similar links (excluding Vermont) are shown by the pliomerid **Cybelopsis** Poulsen (1927), found here in the basal Skoki. Unusual records from Zone J at Wilcox Pass are **Harpides** and **Scotoharpes,** but the material is both rare and fragmentary.

Aitken and Norford's (1967, p. 175) original account of the Outram Formation emphasized the gradational nature of its upper boundary with the overlying Skoki and placed it arbitrarily "above the highest interval containing shales or nodules of limestone or dolomite in a matrix of dense, argillaceous carbonate rock". They pointed out that on this interpretation the highest Outram strata would necessarily encompass some beds of typical Skoki lithology and this has proved to be the case, though on a small scale, at Wilcox Pass. There the boundary was drawn above a 6.70 m interval composed of massive and thinly bedded limestones near both top and base, separated by nodular limestones of "Outram" type. Above this boundary, which is situated near the western end of the small lake on the north side of the hill at the south end of Wilcox Pass, the sequence passes upwards quickly into massive, almost unfossiliferous dolomites and dark nodular cherts of the Skoki Formation.

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