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A TRILOBITE ZONATION OF MIDDLE ORDOVICIAN ROCKS, SOUTHWESTERN DISTRICT OF MACKENZIE

Rolf Ludvigsen

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PREFACE

Precise paleontological zonation of the Middle Ordovician platform carbonate rocks of western and northern North America has been very difficult to accomplish because of the rarity of continuous stratigraphic sequences of fossiliferous rocks. This report presents a zonation for most of the Middle Ordovician, based on very detailed studies of exquisitely preserved silicified trilobites etched from samples that the author systematically collected from well exposed stratigraphic sections. This detailed study provides a benchmark for effective subdivision and correlation of Middle Ordovician rocks in North America. Such correlation is of particular importance to investigations of the distribution and manner of emplacement of metallic mineralization in the Ordovician rocks of the Yukon Territory and adjacent District of Mackenzie.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, February 1979

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Abstract

The upper Sunblood, Esbataottine, and lower Whittaker Formations in the southern Mackenzie Mountains, southwestern District of Mackenzie, have yielded many collections of well preserved silicifed trilobites of Middle Ordovician age (Chazyan to Shermanian/Edenian; late Llanvirnian to late Caradocian).

Based on occurrences of 41 species of bathyurid, cheirurid, and encrinurid trilobites and on presumed phyletic relationships among six species of *Bathyurus*, eight species of *Ceraurinella*, and eight species of *Ceraurus* (and *Whittakerites*), a sequence of nine assemblage zones is established. This is the first macrofaunal zonation of the Middle Ordovician interval in western North America. The zones and their ages are as follows: *Bathyurus nevadensis* Zone (early Chazyan, conodont Fauna 5), *Bathyurus granulosus* Zone (early or mid-Chazyan, conodont Fauna 5), *Ceraurinella nahanniensis* Zone (late Chazyan, conodont Fauna 6), *Bathyurus ulu* Zone (early Blackriveran, conodont Faunas 6 and 7), *Ceraurus gabrielsi* Zone (Blackriveran, conodont Fauna 7), *Ceraurinella longispina* Zone (Blackriveran/Rocklandian, conodont Faunas 7 and 8), *Ceraurinella necra* Zone (Rocklandian/Kirkfieldian, conodont Faunas 8 and 9), *Ceraurus mackenziensis* Zone (Kirkfieldian/Shermanian, conodont Fauna 9), and *Whittakerites planatus* Zone (Shermanian/Edenian, conodont Faunas 9 and ?10).

Twenty new species are described. These are distributed among *Bathyurus* (*B. ulu*, *B. esbataottinensis*, *B. granulosus*, *B. platyparius*), *Ceraurinella* (*C. seriata*, *C. arctica*, *C. longispina*, *C. media*, *C. necra*, *C. brevispina*), and *Ceraurus* (*C. gabrielsi*, *C. blussoni*, *C. hirsuitus*, *C. mackenziensis*, *C. maewestoides*), in addition to *Acanthoparypha? goniopyga*, *Holia anacantha*, *Sphaerexochus atacius*, *Cybeloides anna*, and *Cybellela? thor*.

Résumé

Les formations Sunblood (partie supérieure), Esbataottine et Whittaker (partie inférieure) de la partie sud des monts Mackenzie (sud-ouest du district de Mackenzie) ont fourni des collections de trilobites silicifiés, bien conservés, datant de l'Ordovicien moyen (du Chazyen au Shermanien/Edénien; du Llanvirnien supérieur au Caradocien supérieur).

Se basant sur la présence de 41 espèces de trilobites des familles des bathyuridés, des cheiruridés et des encrinuridés et sur les relations phylétiques supposées entre six espèces de *Bathyurus*, huits espèces de *Ceraurinella* et huit espèces de *Ceraurus* (et *Whittakerites*), l'auteur a établi une série de neuf groupements fauniques. Cette série constitue la première zonation par macrofaune de l'Ordovicien moyen dans la partie occidentale de l'Amérique du Nord. Voici la liste des différentes zones avec leur âge: zone à *Bathyurus nevadensis* (Chazyen inférieur, faune de conodontes n° 5), zone à *Bathyurus granulosus* (Chazyen inférieur ou moyen, faune de conodontes n° 5), zone à *Ceraurinella nahanniensis* (Chazyen supérieur, faune de conodontes n° 6), zone à *Bathyurus ulu* (Blackriverien inférieur, faunes de conodontes n° 6 et 7), zone à *Ceraurus gabrielsi* (Blackrivérien, faune de conodontes n° 7), zone à *Ceraurinella longispina* (Blackrivérien/Rocklandien, faunes de conodontes n° 7 et 8), zone à *Ceraurinella necra* (Rocklandien, Kirkfieldien, faunes de conodontes n° 8 et 9), zone à *Ceraurus mackenziensis* (Kirkfieldien/Shermanien, faune de conodontes n° 9), et zone à *Whittakerites planatus* (Shermanien/Edénien, faunes de conodontes n° 9 et ?10).

Vingt nouvelles espèces sont décrites. Elles sont réparties dans les taxons suivants: *Bathyurus* (*B. ulu*, *B. esbataottinensis*, *B. granulosus*, *B. platyparius*), *Ceraurinella* (*C. seriata*, *C. arctica*, *C. longispina*, *C. media*, *C. necra*, *C. brevispina*), *Ceraurus* (*C. gabrielsi*, *C. blussoni*, *C. hirsuitus*, *C. mackenziensis*, *C. maewestoides*), en plus de *Acanthoparypha? goniopyga*, *Holia anacantha*, *Sphaerexochus atacius*, *Cybeloides anna*, et *Cybellela? thor*.

A TRILOBITE ZONATION OF MIDDLE ORDOVICIAN ROCKS, SOUTHWESTERN DISTRICT OF MACKENZIE

INTRODUCTION

The well exposed character of the lower Paleozoic rocks in the southern Mackenzie Mountains and the pronounced colour differentiation and contrasting weathering styles of many of the Cambrian to Devonian carbonate units have permitted the compilation of a series of detailed and accurate geological maps for the 70 000 km^2 area bounded by Latitudes 61°00' and 64°00'N and Longitudes 124°00' and 128°00'W (Gabrielse et al., 1973; Douglas and Norris, 1974). The rapid advances in geologic mapping have greatly outpaced complementary lithostratigraphic and biostratigraphic studies of the lower Paleozoic rocks of this area. The paucity of biostratigraphic studies is unfortunate because the southern Mackenzie Mountains expose some of the most complete and continuously fossiliferous Cambrian to Devonian successions in North America. This paper concerns the biostratigraphy of some of the trilobites from the medial portion of the Ordovician sequence in the South Nahanni River area and provides the first zonal information on macrofossils for this interval in western North America.

A trilobite zonation of Lower Ordovician rocks that spans the interval from near the base of the Canadian to the late Whiterockian or early Chazyan was established by Ross (1951) and Hintze (1953) for stratigraphic successions in western and southwestern United States. This zonation has been widely and successfully used for North American Lower Ordovician rocks, but zonation of younger Ordovician rocks has not been possible in western United States and southwestern Canada because the biostratigraphic record terminates at the appearance of thick quartzitic sandstones and quartzites of the Eureka, Swan Peak, Kinnikinic, and Mount Wilson Formations (Ross, 1976; Norford, 1969). The sands probably were derived from erosion of Proterozoic and Cambrian sandstones from near the Peace River-Athabasca Arch in northern Alberta (Ketner, 1968). North of this area, the stratigraphic record largely escaped coarse clastic terrigenous sedimentation and in the study area near the South Nahanni River thick successions of well exposed and fossiliferous carbonate rocks are exposed which provide biostratigraphic information for the interval following that covered by the Ross/Hintze zonation.

The upper Sunblood, Esbataottine, and lower Whittaker Formations exposed in the southern Mackenzie Mountains (Figs. 1, 2) have yielded the silicified trilobites that are the basis for a sequence of nine assemblage zones covering the interval from near the base of the Chazyan to the Shermian/Edenian or late Llanvirnian to late Caradocian (Figs. 3, 4).

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This paper is a revision of part of a Ph.D. thesis completed at the University of Western Ontario under the supervision of A.C. Lenz to whom I express sincere appreciation. The field work during 1971, 1972, and 1973 was undertaken with the material and financial aid of V. Zay Smith Associates Ltd., Geological Survey of Canada, Department of Indian and Northern Affairs, and National Research Council (through a grant to A.C. Lenz). I thank a number of colleagues who aided the investigation in a variety of ways; notably S.L. Blusson, T.E. Bolton, B.D.E. Chatterton, J.F. Conrad, M.J. Copeland, D.B. Craig, W.T. Dean, C.E. Mitchell, B.S. Norford, D.G. Perry, J.R.P. Ross, P.M. Sheehan, R.S. Tipnis, H.B. Whittington, R.J.S. Wigington, and C.G. Winder. I also thank Brian Chatterton and Brian Norford for careful reviews of the manuscript. Finally, I express my deep gratitude and affection to my wife, Kathleen MacKinnon, who has been a part of this project from its inception.

PREVIOUS WORK

Kingston (1951) was the first to demonstrate the presence of Ordovician rocks in the South Nahanni River area and he defined the Sunblood Formation for exposures at Virginia Falls and Sunblood Mountain. Douglas and Norris (1960) demonstrated that the Sunblood is discontinuously exposed in the Virginia Falls and Root River map-areas (95F and 95K) and suggested that it is of Middle Ordovician age (Chazy and Wilderness). Douglas and Norris (1961) established the name Whittaker Formation for the Upper Ordovician to Lower Silurian succession overlying the Sunblood Formation in the Whittaker Range. Gabrielse et al. (1973) showed that the Sunblood and Whittaker Formations are widely exposed in the Flat River, Glacier Lake, and Wrigley Lake map-areas (95E, 95L, and 95M) and that the Road River Formation is the western fine clastic equivalent of these formations. Copeland (1974) described ostracode faunas from ten measured sections through the Middle Ordovician and recognized three broad biostratigraphic units of Whiterock, Porterfield, and Wilderness-Barneveld age (see summary in Copeland, 1977, p. 3). Ludvigsen (1975) revised the Sunblood and Whittaker Formations to accommodate an intervening unit, the Esbataottine Formation; proposed a number of preliminary trilobite and brachiopod faunal units of Early to Late Ordovician age; and suggested correlations with eastern North America and Britain. Chatterton and Ludvigsen (1976) described the rich late Chazyan trilobite faunas from the lower 50 m of the Esbataottine Formation in the Sunblood Range and demonstrated that environmental factors exert considerable influence over the distribution of trilobites in Chazyan and Blackriveran strata. Ludvigsen (1976) established two new cheirurid genera from the lower Whittaker Formation in the Funeral and Whittaker Ranges. Wigington (1977) described the orthid brachiopods and Mitchell (1978) the strophomenid brachiopods from the lower Whittaker Formation in the southern Mackenzie Mountains. Tipnis et al. (1978) recognized conodont Faunas 1 through 10 (Whiterockian to Edenian) of Sweet et al. (1971) in collections from the Sunblood, Esbataottine, and lower Whittaker Formations. Ludvigsen (1978c) analyzed the Chazyan to

Edenian trilobites from the South Nahanni River area by Q- and R-mode clustering techniques and according to species diversity and recognized three coeval carbonate platform trilobite biofacies (shallow to deep, Biofacies I to III) and one fine clastic slope trilobite biofacies (Biofacies IV). In hypothetical samples of 100 individuals, the composition of these biofacies consists of the following trilobites (for Chazyan and Blackriveran collections only):

Biofacies I: 1 to 6 species of *Bathyurus*, *Ceraurus* (*C. gabrielsi* n. sp.), *Isotelus*, *Calyptaulax*, *Ceraurinella*, *Amphilichas*, and *Nanillaenus*.

Biofacies II: 4 to 11 species of *Calyptaulax*, *Ceraurinella*, *Cybeloides*, *Isotelus*, *Nanillaenus*, *Bumastoides*, *Remopleurides*, *Sphaerexochus*, *Hemiarges*, *Amphilichas*, *Anataphrus*, *Ceraurus* (*C. hirsuitus* n. sp.) and *Bathyurus*.

Biofacies III: 9 to 19 species of *Calyptaulax*, *Ceraurinella*, *Dimeropyge*, *Sphaerexochus*, *Dolicholharpes*, *Remopleurides*, *Cybeloides*, *Nanillaenus*, *Acanthoparypha*, *Isotelus*, *Hemiarges*, *Carrickia*, *Bumastoides*, *Ceratocephala*, *Holia*, *Failleana*, *Apianurus*, *Amphilichas*, *Nahannia*, and *Encrinuroides*.

Biofacies IV: Few species of *Ampyx*? and *Triarthrus*.

STRATIGRAPHY

SUNBLOOD FORMATION

The Sunblood Formation, as mapped in the Sunblood Range, Whittaker Range, and Flood Creek area by Kingston (1951), Douglas and Norris (1960, 1961, 1974), and Gabrielse et al. (1973), was revised by Ludvigsen (1975, Fig. 2) to correspond largely to the interval

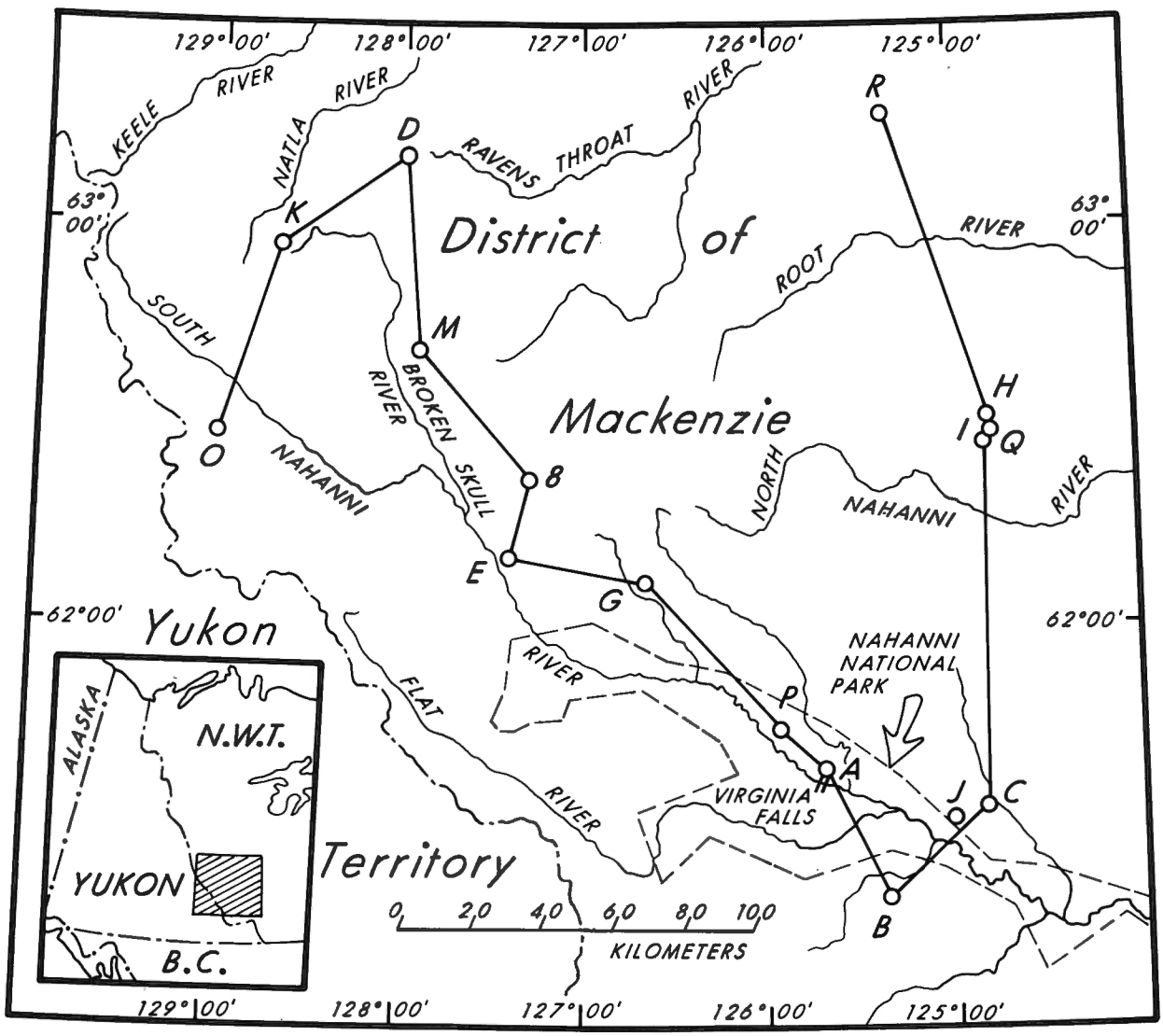

FIGURE 1. Locality map of southern Mackenzie Mountains showing measured sections and line of cross-section in Figure 2.

exposed at the type section on Sunblood Mountain (essentially from the base of Virginia Falls to the cairn on Sunblood Mountain) that exhibits weathering colours of vivid shades of red, orange, pink, and yellow. In the type area, the Sunblood comprises 1000 m or more of medium to dark grey, microcrystalline to finely crystalline limestones which are generally resistant. In a number of localities, the highest Sunblood is marked by an arenaceous interval. Northwest from the Sunblood Range, the limestones of the Sunblood Formation are replaced by unfossiliferous dolostones (Fig. 2) and, toward the west and southwest, the Sunblood passes into dark shales of the Road River Formation, but details of this facies change are unknown. In the northeast corner of the study area, at Section R, the Whittaker Formation rests unconformably on the Lower Ordovician Broken Skull Formation and the Sunblood Formation is absent (Fig. 2). The total age range of the Sunblood Formation is early Whiterockian (or older) to Kirkfieldian (or younger, Fig. 3).

ESBATAOTTINE FORMATION

A generally recessive interval of 80 to 200 m overlying the Sunblood Formation in the Sunblood and Whittaker Ranges (Sections P, A, H, I) and at Flood Creek (Section G) was named the Esbataottine Formation by Ludvigsen (1975). The type section is on Esbataottine Mountain, approximately 16 km northwest of Sunblood Mountain. The formation consists of medium to dark grey, microcrystalline to finely crystalline, thin- to medium-bedded, commonly argillaceous and silty limestones that weather banded grey and buff. Northwest of the Flood Creek area, the Esbataottine apparently passes into unfossiliferous dolostones of the Sunblood Formation and, southeast of the Sunblood Range, the Esbataottine cannot be recognized and the entire section at Mary Range (Section B) has been assigned to the Sunblood Formation (Fig. 2). North of the Whittaker Range, the Esbataottine is absent. The total age range of the Esbataottine Formation is late Chazyan to Rocklandian (Fig. 3).

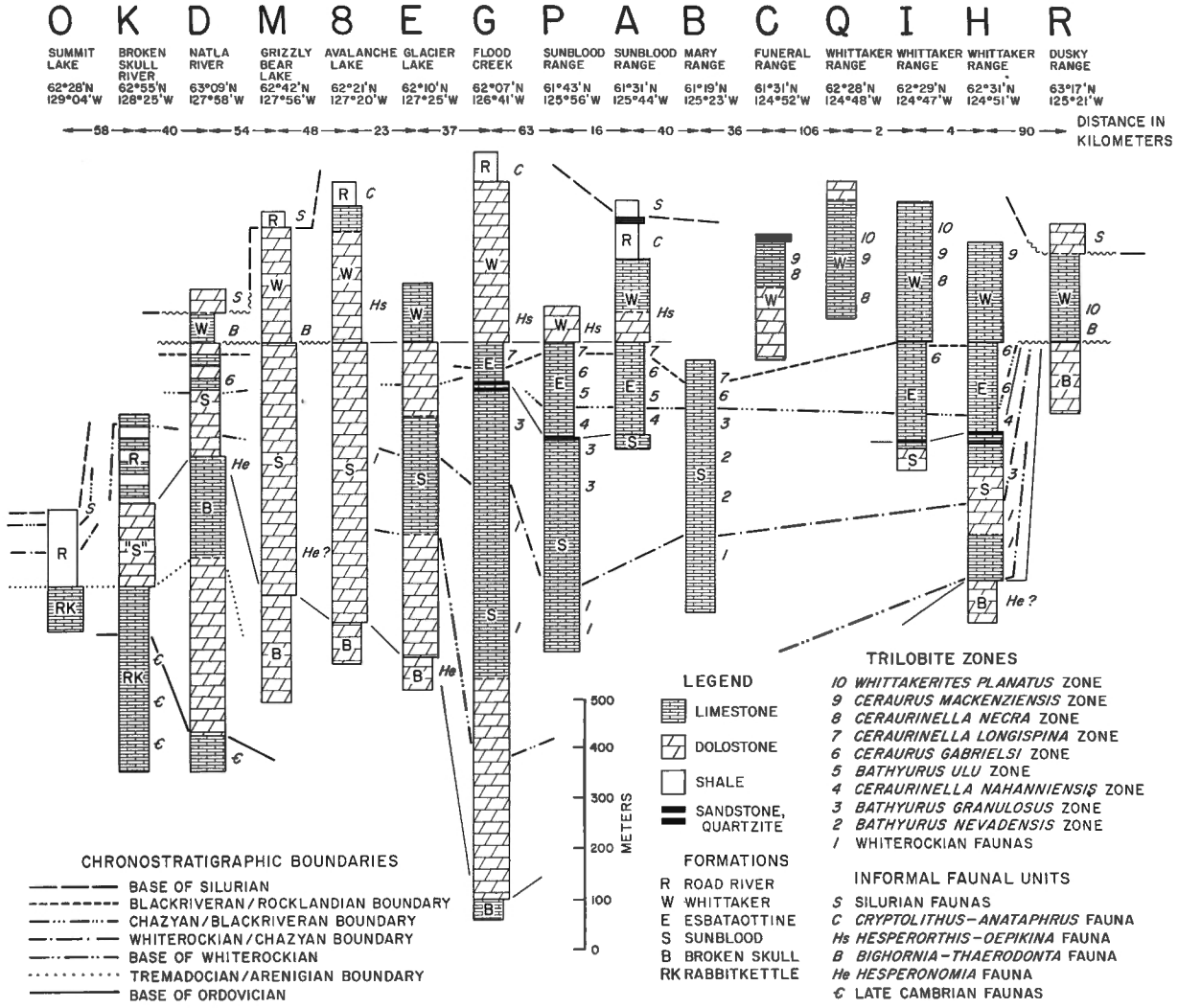

FIGURE 2. Cross-section of Ordovician rocks in the South Nahanni River area showing formational terminology, generalized lithology, and position of trilobite assemblage zones (2 to 10) as well as position of informal faunal units (Ludvigsen, 1975). Section 8 is from Gabrielse et al. (1973).

WHITTAKER FORMATION

In the type area in the Whittaker Range, the Whittaker Formation consists of about 1000 m of limestones, dolostones, and shales of late Middle Ordovician to Late Silurian age (O'Bertos and Jackson, 1963). Three lithofacies and biofacies associations comprise the lower part of the formation in the southern Mackenzie Mountains: (1) well bedded, medium grey dolostones overlying the Esbataottine Formation at Sections A, P, and G carrying the *Hesperorthis-Oepikina* fauna; (2) well bedded limestones above an unconformable lower contact of the Whittaker at Sections D, M, and R carrying the *Bighornia-Thaerodonta* fauna; and (3) thinly bedded, dark grey and argillaceous limestones within the axial portion of the Root Basin (Sections J, C, Q, I, H, and R) carrying the *Strophomena-Ceraurus* fauna (Ludvigsen, 1975). The Whittaker trilobites described in this paper are from the third association. In the area south and west of the Whittaker Range, the Whittaker conformably succeeds the Esbataottine Formation; in the northern area the Whittaker rests unconformably on strata as old as Helikian (Gabrielse et al., 1973). In Sections D and R, the Ordovician and Silurian portions of the Whittaker are separated by a disconformity. The total age range of the lower Whittaker Formation is Rocklandian to Edenian and younger (Fig. 3).

TRILOBITE ZONATION

The proposed zonation spans some 600 m of strata of the Sunblood, Esbataottine, and lower Whittaker Formations and extends from near the base of the Chazyan to the Shermanian/Edenian. This sequence of nine trilobite assemblage zones is based on occurrences of forty-one species of fifteen bathyurid, cheirurid, and encrinurid genera in some seventy collections from eleven measured sections in the southern Mackenzie Mountains (Figs. 2, 3, 4).

The reconnaissance nature of the field work and the necessary restriction to only three trilobite families caution that the zonation should be considered preliminary. Detailed sampling of the boundary intervals between zones will undoubtedly alter many of the species ranges and, possibly, require the addition of new zones. Further taxonomic work on the remaining trilobite groups, particularly the asaphids, pterygometopids, and lichids, plus description of the brachiopods and bryozoans promise increased zonal refinement.

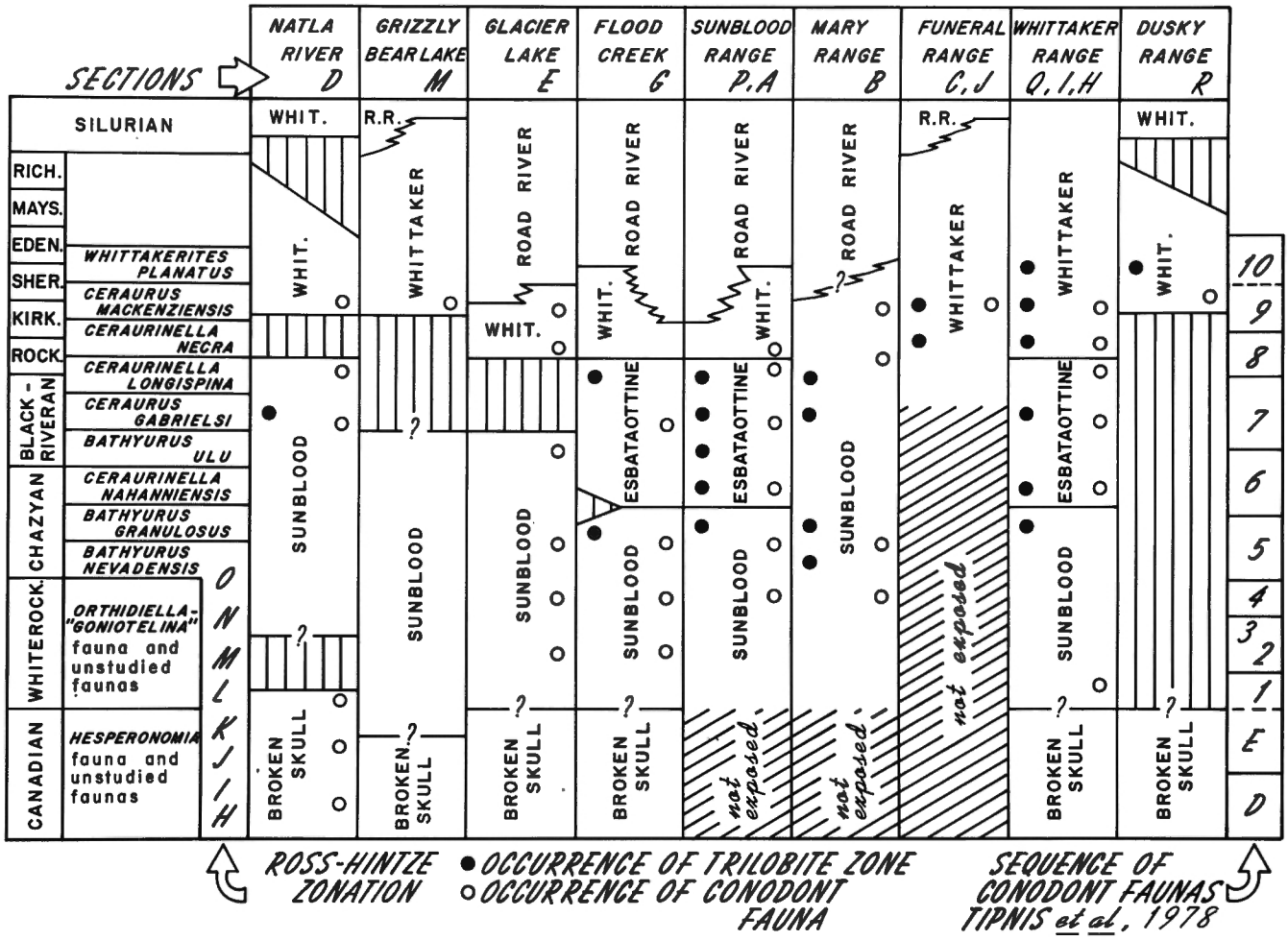

FIGURE 3. Correlation chart of Ordovician formations in the study area showing occurrences of trilobite assemblage zones and conodont faunas.

At least thirty-five genera of trilobites occur in the stratigraphic interval under consideration. From Figure 5 it is clear that generic occurrences are of little use in establishing precise age relationships because more than half of the genera range through five or more zones and even those genera restricted to one or more zones in the southern Mackenzie Mountains have demonstrably longer ranges in other parts of North America.

The trilobite zones are illustrated as though they provide time information for the entire Chazyan to Edenian interval (Fig. 4). The zones should more properly be shown to be separated by interzones because the zonal boundaries are drawn within unfossiliferous to poorly fossiliferous intervals between collections. These intervals are generally greater than 15 m in thickness and, occasionally, as thick as 60 m. The influence of environment on the distribution of trilobite genera within the Middle Ordovician of the study area has been taken into consideration but it is sometimes impossible to separate the effect of probable biofacies determinants (genera) from probably biochronologic determinants (species) in zonal definitions.

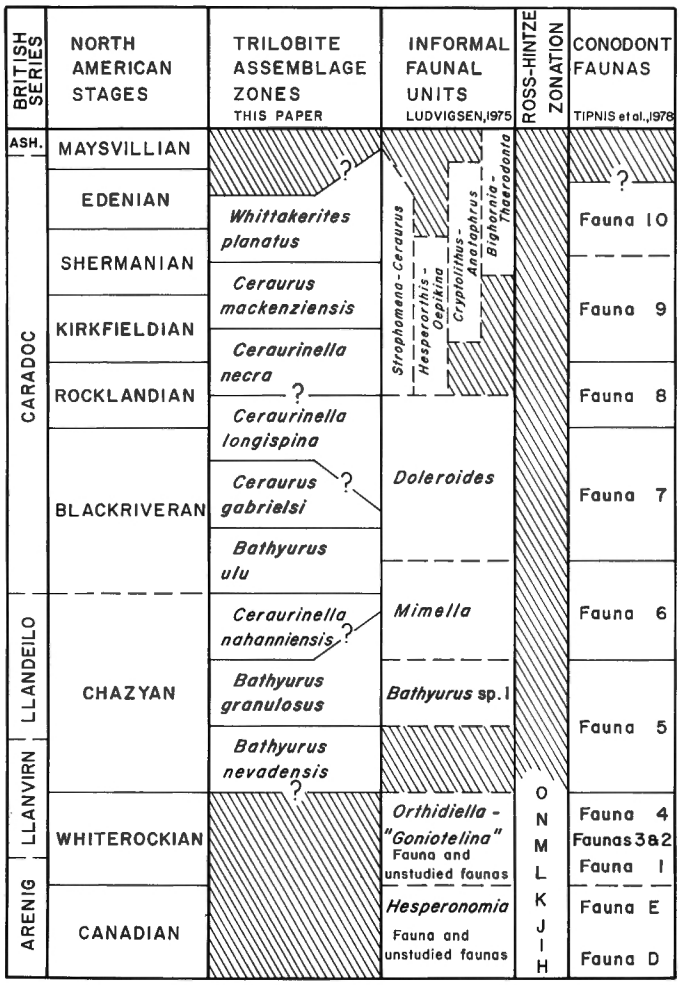

FIGURE 4. Sequence of trilobite assemblage zones related to sequence of condont faunas, Ross-Hintze zonation, various informal faunal units, and to North American stages and British series.

For example, both the *Ceraurinella nahanniensis* and *Ceraurinella longispina* Zones are defined largely on the presence of species of *Ceraurinella*, *Sphaerexochus*, and *Cybeloides* (Biofacies II and III taxa; Ludvigsen, 1978c) whereas the respective underlying zones, *Bathyurus granulosus* and *Ceraurus gabrielsi* Zones, are defined largely by species of *Bathyurus* and *Ceraurus* (Biofacies I taxa; Ludvigsen, 1978c). Therefore, it is possible that the *Bathyurus granulosus* and *Ceraurinella nahanniensis* Zones, on one hand, and the *Ceraurus gabrielsi* and *Ceraurinella longispina* Zones, on the other, are in part correlative and the boundaries between these zones are shown to be diachronous (Fig. 4).

In the following section, lists of identified taxa from each of the nine assemblage zones are included. The sources of the faunal information are as follows:

Trilobites: Ludvigsen (1975, 1976), Chatterton and Ludvigsen (1976), this paper.

Ostracodes: Copeland (1974, 1978).

Brachiopods: Ludvigsen (1975), Wigington (1977), Mitchell (1978).

Conodonts: Tipnis et al. (1978).

Bryozoans: J.R.P. Ross (pers. com., 1975).

WHITEROCKIAN FAUNAS

The megafauna of the Whiterockian interval of the Sunblood Formation remains undescribed. A few trilobites and brachiopods were illustrated by Ludvigsen (1975). The ostracodes were described by Copeland (1974). At the present time, the conodonts provide the only relatively complete biostratigraphic coverage of this interval (Tipnis et al., 1978).

Three species of trilobites are herein described from Whiterockian strata of the Sunblood Formation. Of these, *Heliomera* cf. *sol* (Billings) and *Kawina* sp. are well dated as late Whiterockian by conodonts. *Cybellela? thor* n. sp. is, in all likelihood, of similar age because it occurs with a species of *Calyptaulax* that is most similar to *C. incepta* Whittington from the lower Table Head Formation of Newfoundland.

Ross (1970) has convincingly demonstrated that the younger parts of the Whiterock Stage of Cooper (1956) (that is, upper *Anomalorthis* Zone) correlate with intervals above the base of the Chazyan or Marmorian in eastern North America. Ross (1970, p. 50) suggested that the *Anomalorthis* Zone extends as high as the Blackriveran, but the limited conodont information from the *Anomalorthis* Zone in Nevada and Utah (Sweet et al., 1971, p. 169; Hintze et al., 1972, p. 393; Ethington, 1977) does not suggest dates younger than Fauna 4 or 5. Bergström et al. (1973) concluded that the upper part of the type Whiterockian is equivalent to the Chazyan, but is entirely older than the type Porterfieldian. In this paper, the term Whiterockian is employed for those intervals yielding condonts of Faunas 1 through 4.

Bathyurus nevadensis ZONE (EARLY CHAZYAN)

The oldest zone of this study is the least satisfactory in terms of identification and the lowest in terms of trilobite diversity. The *Bathyurus nevadensis* Zone appears to represent the oldest post-Whiterockian trilobite-bearing interval in the study area. It occurs through nearly 100 m of strata in the Mary Range and its identification rests on only two species of *Bathyurus* - *B. angustus* Ross in the lower portion and *B. nevadensis* Ross in the upper. In Nevada, these species occur in the upper part of the Antelope Valley Limestone and in the Lehman Formation; *B. angustus* also occurs in the Kanosh Shale (Ross, 1967, p. D18; 1970, p. 86). These stratigraphic intervals have been assigned to the middle and upper *Anomalorthis* Zone (Ross, 1967, 1970) and were considered either Whiterockian or Chazyan in age (Ross, 1976, Textfig. 3). In the Mary Range, the collections assigned to the *B. nevadensis* Zone have yielded conodonts referable to Fauna 5 of Sweet et al. (1971) and dated as early Chazyan (Tipnis et al., 1978). This and the overlying zone provide unequivocal evidence that *Bathyurus* makes its first appearance in rocks considerably older than Blackriveran.

Assigned collections. Sunblood Formation, Mary Range (B 795, B 1005, B 1105). See Appendix 1 for explanation of locality code.

Trilobites.

Bathyurus angustus Ross
Bathyurus nevadensis Ross
Isoteloides sp.

Ostracodes.

Eokloedenella whittakerensis Copeland
Eoleperditia fabulites (Conrad)

Conodonts. Fauna 5 of Sweet et al. (1971) (Tipnis et al., 1978, Table 10).

Bathyurus granulosus ZONE (EARLY OR MID-CHAZYAN)

The higher parts of the Sunblood Formation at a number of localities in the study area contain low diversity assemblages of trilobites dominated by *Bathyurus granulosus* n. sp. and low diversity ostracode faunas. Only in a single collection do other trilobites occur. The trilobites and ostracodes are presently of little value for correlation, but the conodonts are assignable to Fauna 5 of Chazyan age (Tipnis et al., 1978). The maximum observed thickness of the *B. granulosus* Zone is 45 m in the Mary Range. The zone is recognized below the superjacent *Ceraurinella nahanniensis* Zone in only a single section in the Sunblood Range. In the Mary Range and at Flood Creek, the *B. granulosus* Zone is succeeded by Blackriveran zones. This may indicate the presence of unrecognized disconformities in this part of the section or, alternatively, suggest that the *B. granulosus* Zone is in part equivalent to the *C. nahanniensis* Zone is these areas.

Assigned collections. Upper Sunblood Formation at Mary Range (B 1165, B 1265, B 1295, B 1315), Whittaker Range (?H 410), Flood Creek (G 2795), and Sunblood Range (P 1090, P 1127, P 1130, P 1187).

Trilobites.

Bathyurus granulosus n. sp.
Bumastoides sp.
Calyptaulax sp.
Cybeloides anna n. sp.
Isotelus sp.
Pandaspinapyga cf. *stubblefieldi* (Bancroft)

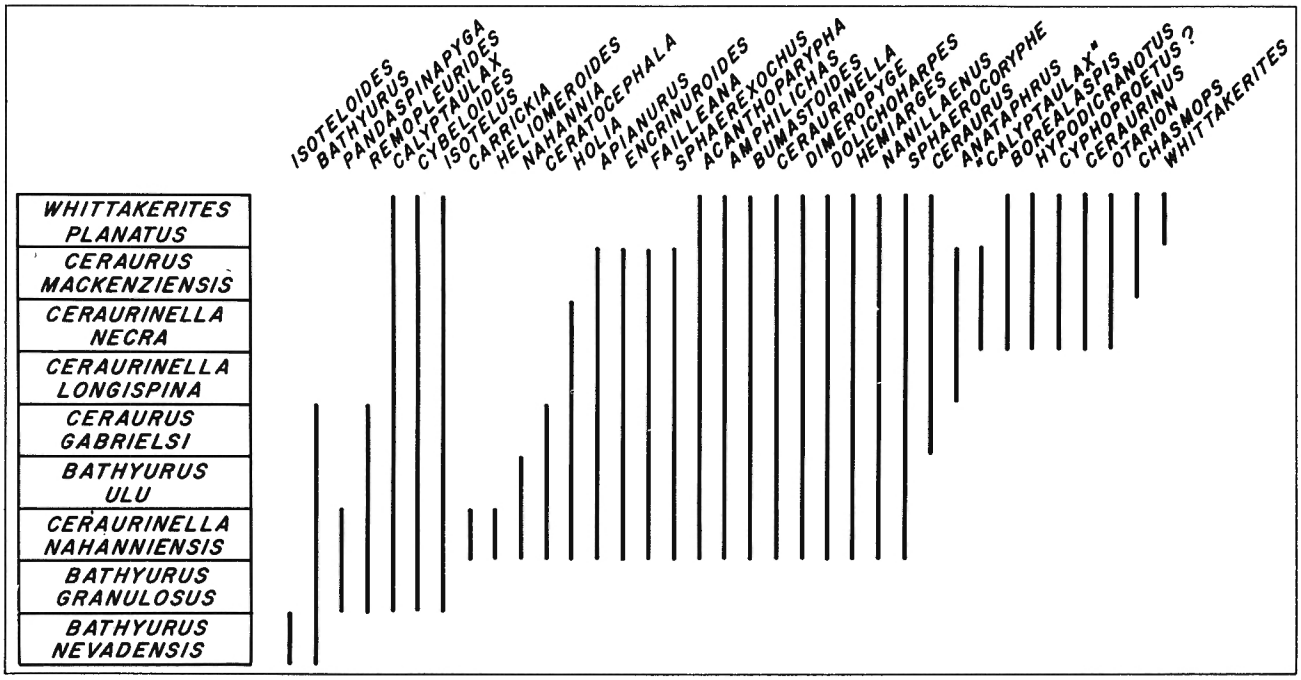

FIGURE 5. Composite range chart of thirty-five trilobite genera in the upper Sunblood, Esbataottine, and lower Whittaker Formations.

Ostracodes.

Krausella minuta? (Harris)
Leperditella cf. *germana* (Ulrich)
Schmidtella affinis Ulrich
Schmidtella cf. *subrotunda* Ulrich

Conodonts. Fauna 5 of Sweet et al. (1971) (Tipnis et al., 1978, Table 10).

Ceraurinella nahanniensis ZONE (LATE CHAZYAN)

Lower Chazyan strata of the study area are dominated by low diversity trilobite assemblages assignable to Biofacies I of Ludvigsen (1978c). In the late Chazyan, a pronounced transgressive event brought Biofacies II and III assemblages higher up on the platform, a biofacies shift that approximately coincided with the Sunblood/Esbataottine contact in the Sunblood and Whittaker Ranges. The diverse and abundant trilobite faunas of the lower Esbataottine Formation are assigned to the *Ceraurinella nahanniensis* Zone. The trilobites have recently been described and illustrated by Chatterton and Ludvigsen (1976) who also discussed their age significance. Trilobite-based correlations were suggested with the upper part of the Chazy Group in New York State and with the Lincolnshire Formation of Virginia. Tipnis et al. (1978) assessed the conodont faunas of this interval as belonging to Fauna 6 of Sweet et al. (1971). Copeland (1974) correlated the ostracode faunas of the lower Esbataottine Formation with those of the Lincolnshire and lower Edinburg Formations of Virginia. The brachiopods indicate an undifferentiated Chazyan-Blackriveran age (Ludvigsen, 1975). The maximum observed thickness of the *C. nahanniensis* Zone is 24 m in the Sunblood Range.

Assigned collections. Lower Esbataottine Formation, Sunblood Range (A 115, A 125, A 140, A 160, P 1440, P 1485, P 1497, P 1512, P 1520) and Whittaker Range (H 800-820).

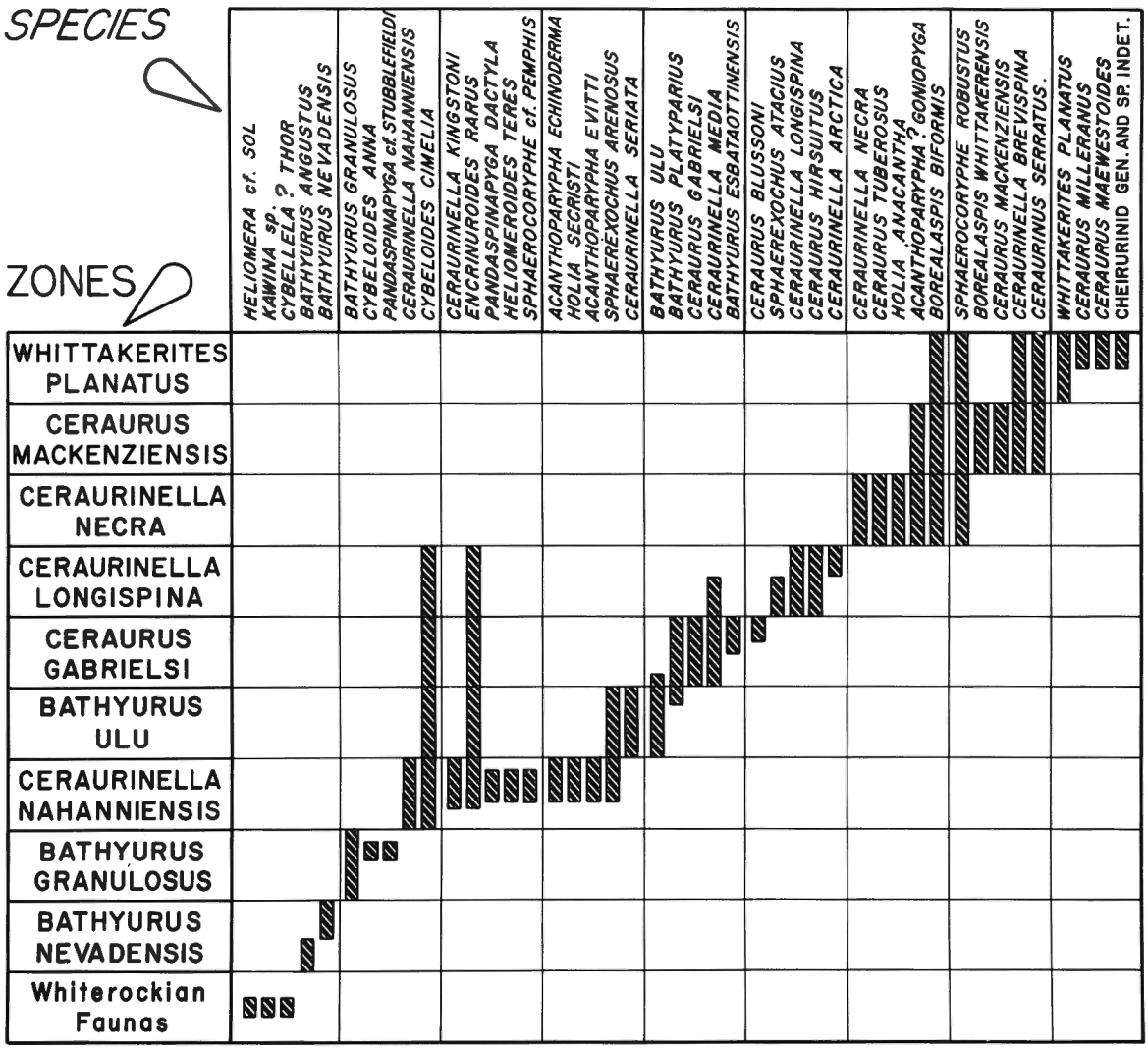

FIGURE 6. Composite range chart of forty-four species of bathyurid, cheirurid, and encrinurid genera.

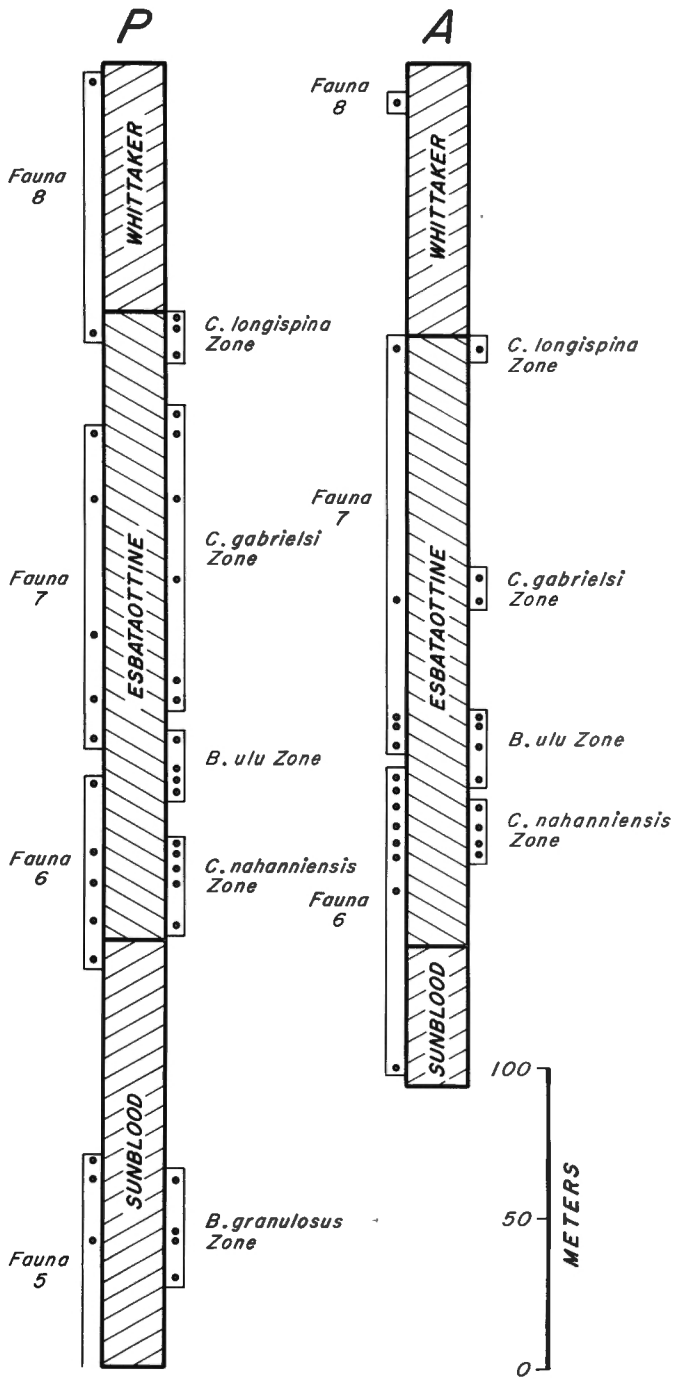

FIGURE 7. Comparison of trilobite and conodont biostratigraphy in two sections in the Sunblood Range. Conodont biostratigraphy from Tipnis et al. (1978).

Trilobites.

Acanthoparypha echinoderma Chatterton and Ludvigsen
Acanthoparypha evitti Chatterton and Ludvigsen
Amphilichas aff. *aspratilis* (Bradley)
Amphilichas conradi Chatterton and Ludvigsen
Apianurus parabarbatus Chatterton and Ludvigsen
Bumastoides lenzi Chatterton and Ludvigsen
Calyptaulax callirachis Cooper
Carrickia pinguimitra Chatterton and Ludvigsen
Ceratocephala triacantheis Whittington and Evitt
Ceraurinella kingstoni Chatterton and Ludvigsen
Ceraurinella nahanniensis Chatterton and Ludvigsen
Cybeloides cimelia Chatterton and Ludvigsen
Dimeropyge clintonensis Shaw
Dolichoharpes aff. *reticulata* Whittington
Encrinuroides rarus (Walcott)
Failleana calva Chatterton and Ludvigsen
Heliomeroides teres Evitt
Hemiarges turneri Chatterton and Ludvigsen
Holia secristi Whittington and Evitt
Isotelus parvirugosus Chatterton and Ludvigsen
Nahannia humilisulcata Chatterton and Ludvigsen
Nanillaenus mackenziensis Chatterton and Ludvigsen
Pandaspinapyga dactyla Chatterton and Ludvigsen
Remopleurides pattersoni Chatterton and Ludvigsen
Sphaerexochus arenosus Chatterton and Ludvigsen
Sphaerocoryphe cf. *pemphis* Lane

Brachiopods.

Chaulistomella cf. *nitens* Cooper
Glyptorthis cf. *costellata* Cooper
Macrocoelia? sp.
Mimella aff. *globosa* (Willard)
Onychoplesia sp.
Rostricellula sp.

Ostracodes.

"Aparchites" sp.
"Aparchites" fimbriatus (Ulrich)
Bairdiocypris cf. *granti* (Ulrich)
Bolbopisthia ludvigseni Copeland
Cryptophyllus oboloides (Ulrich and Bassler)
Echinoprimitia? n. sp.
Ectoprimitia? pustulosa Swain
Eohollina depressa (Kay)
Eoleperditia sp.
Euprimitia? krafti Copeland
Eurychilina sunbloodensis Copeland
Krausella minuta? (Harris)
Leperditella sp.
Leperditella mundula (Ulrich)
Ludvigsenites mackenziensis Copeland
Oecematobolbina varicata (Harris)
Piretia n. sp.
Platyrhomboides quadratus Harris
Schmidtella affinis Ulrich
Steusloffina borealis Copeland
Tetradella perplexa Copeland
Tetradellina n. sp.
Wincellatia n. sp.
New genus 1 n. sp. 1
New genus 1 n. sp. 2
New genus 3 n. sp. 1
New genus 4 n. sp. 1

Conodonts. Fauna 6 of Sweet et al. (1971) (Tipnis et al., 1978, Table 11).

Bryozoans.

Helopora spp.
Pachydictya sp.
Stictopora sp.
phylloporinids
trepostomes

Bathyurus ulu ZONE (EARLY BLACKRIVERAN)

Overlying the *Ceraurinella nahanniensis* Zone at Sections P and A is a thin (about 15 m) stratigraphic interval characterized by the association of *Bathyurus ulu* n. sp. and *Ceraurinella seriata* n. sp. This is defined as the *Bathyurus ulu* Zone. A period of regression resulting in the appearance of successively shallower biofacies (from Biofacies III to I; Ludvigsen, 1978c, Fig. 11) across the *C. nahanniensis*-*B. ulu* zonal boundary appears to be responsible for the restriction of the *B. ulu* Zone to the Sunblood Range. Sections P and A are located on the deeper parts of the shelf in a large embayment during the Chazyan and Blackriveran (Ludvigsen, 1975, Fig. 10-4). If Biofacies I predominates in the deeper parts of the shelf, then the interior parts would probably have been emergent. Some trilobites in the *B. ulu* Zone are identical to those of the underlying zone. Of the new elements, *Ceraurinella seriata* is a derivative of *C. nahanniensis* and *Bathyurus ulu* of *B. granulosus*. The conodonts of the lower part of the zone are assignable to Fauna 6 and those of the upper part to Fauna 7 (Tipnis et al., 1978). This suggests that the *B. ulu* Zone contains the Chazyan/Blackriveran boundary. The boundary is tentatively placed at the base of the zone.

Assigned collections. Lower Esbataottine Formation, Sunblood Range (A 190, A 220, A 247, P 1575, P 1585, P 1595, P 1625).

Trilobites.

Amphilichas sp.
Apianurus parabarbatus Chatterton and Ludvigsen
Bathyurus platyparius n. sp.
Bathyurus ulu n. sp.
Calyptaulax cf. *strasburgensis* (Ulrich and Delo)
Ceraurinella seriata n. sp.
Cybeloides cimelia Chatterton and Ludvigsen
Dolichoharpes aff. *reticulata* Whittington
Encrinuroides rarus (Walcott)
Isotelus parvirugosus Chatterton and Ludvigsen
Nahannia mediocrisulcata Chatterton and Ludvigsen
Nanillaenus mackenziensis Chatterton and Ludvigsen
Remopleurides pattersoni Chatterton and Ludvigsen
Sphaerexochus arenosus Chatterton and Ludvigsen

Brachiopods.

Mimella aff. *globosa* (Willard)
Strophomena inspeciosa Willard

Ostracodes.

Bairdiocypris sp.
Bolbopisthia ludvigseni Copeland
Eokloedenella whittakerensis Copeland
Eurychilina sunbloodensis Copeland
Krausella minuta? (Harris)
Leperditella mundula (Ulrich)
Oecematobolbina varicata (Harris)
Oepikella labrosa Copeland
Schmidtella affinis Ulrich
New genus 1 n. sp. 1
New genus 2 n. sp. 1

Conodonts. Faunas 6 and 7 of Sweet et al. (1971) (Tipnis et al., 1978, Tables 11, 12).

Bryozoans.

Dekayia sp.
Helopora sp.
Pachydictya sp.
Ptilodictya sp.
Stictopora sp.
Stictoporella? sp.
Ulrichostylus sp.

Ceraurus gabrielsi ZONE (BLACKRIVERAN)

The middle and upper parts of the Esbataottine Formation in the Sunblood and Whittaker Ranges and the upper part of the Sunblood Formation at Natla River and Mary Range contain distinct associations of trilobites dominated by *Ceraurus gabrielsi* n. sp., *Bathyurus esbataottinensis* n. sp., and *Bathyurus platyparius* n. sp. In contrast to the underlying zone, the *C. gabrielsi* Zone is thick (nearly 90 m in Section P and 120 m in Section H) and widely distributed along a 250 km belt from Natla River to Mary Range. Because the critical species are new and not known to occur outside of the southern Mackenzie Mountains, trilobite-based correlations are not possible. Copeland (1974) assigned a Wilderness age to the ostracode assemblages from this interval and Tipnis et al. (1978) considered the conodonts referable to Fauna 7 of Blackriveran age.

Assigned collections. Upper Sunblood Formation at Mary Range (B 1450) and Natla River (GSC loc. 69001, D 1342, D 1375). Esbataottine Formation at Sunblood Range (A 365, A 385, P 1665, P 1685, P 1785, P 1870, P 1931, P 1945-1955) and Whittaker Range (H 900, H 1020, H 1300, I 780).

Trilobites.

Amphilichas sp.
Bathyurus esbataottinensis n. sp.
Bathyurus platyparius n. sp.
Bathyurus cf. *ulu* n. sp.
Bumastoides sp.
Calyptaulax spp.
Ceraurinella media n. sp.
Ceraurus blussoni n. sp.
Ceraurus gabrielsi n. sp.
Cybeloides cimelia Chatterton and Ludvigsen
Encrinuroides rarus (Walcott)
Hemiarges sp.
Isotelus sp.
Nanillaenus sp.
Remopleurides sp.

Brachiopods.

Camerella cf. *obesa* Cooper
Doleroides sp.
Hesperorthis sp.
Rostricellula sp.
Oepikina sp.

Ostracodes.

Bairdiocypris sp.
Bolbopisthia lenzi Copeland
Bolbopisthia ludvigseni Copeland
Cryptophyllus oboloides (Ulrich and Bassler)
Dicranella macrocarinata Harris
Eokloedenella whittakerensis Copeland
Isochilina cf. *gregaria* (Whitfield)
Krausella inaequalis Ulrich
Krausella minuta? (Harris)
Leperditella mundula (Ulrich)
Oepikella? sp.
Schmidtella affinis Ulrich
Tetradella perplexa Copeland

Conodonts. Fauna 7 of Sweet et al. (1971) (Tipnis et al., 1978, Table 12).

Bryozoans.

Chasmatoporella sp.
Helopora? sp.
Ptilodictya sp.
Stictoporella sp.
Stictopora sp.
phylloporinid

Ceraurinella longispina ZONE (BLACKRIVERAN/ROCKLANDIAN)

The highest few metres of the Esbataottine Formation in the Sunblood Range contain a diverse and largely new trilobite fauna that is assigned herein to the *Ceraurinella longispina* Zone. The zone is only 12 m thick in Section P, but more than three times that in Section G. In the latter section, the *Ceraurus gabrielsi* Zone has not been recognized and it is possible that the *C. longispina* Zone at Flood Creek is, in part, correlative with the *C. gabrielsi* Zone in the Sunblood Range. Some of the trilobites and brachiopods of the *C. longispina* Zone are either conspecific or very similar to species occurring in the Platteville Group of the upper Mississippi Valley. These affinities are best seen among species of *Ceraurus*, *Encrinuroides*, *Cybeloides*, *Bumastoides*, *Dolichoharpes*, *Triplesia*, and *Skenidioides*. The *C. longispina* Zone is probably largely correlative with Fauna E of Ludvigsen (1978b) which occurs in the Leray and "Rockland" Formations of the Ottawa area, the lower Bobcaygeon Formation of southern Ontario, and the Mifflin and Grand Detour Formations of Illinois. The sparse conodont faunas available from the *C. longispina* Zone are assignable to both Faunas 7 and 8 (Tipnis et al., 1978). According to Copeland (1974), the ostracodes of the upper Esbataottine Formation belong to a cosmopolitan Wilderness-type fauna.

Assigned collections. Upper Esbataottine Formation, Sunblood Range (A 615, P 2010, P 2038, P 2050). Esbataottine Formation, Flood Creek (G 3195, G 3350). Upper Sunblood Formation, Mary Range (B 1510-1520).

Trilobites.

Anataphrus cf. *borraeus* Whittington
Bumastoides sp.
Calyptaulax sp.
Ceratocephala cf. *triacantheis* Whittington and Evitt
Ceraurinella arctica n. sp.
Ceraurinella longispina n. sp.
Ceraurinella media n. sp.
Ceraurus hirsuitus n. sp.
Cybeloides cimelia Chatterton and Ludvigsen
Dolichoharpes aff. *reticulata* Whittington
Encrinuroides rarus (Walcott)
Hemiarges sp.
Isotelus sp.
Sphaerexochus atacius n. sp.

Brachiopods.

Doleroides sp.
Hesperorthis sp.
Holtedahlina sp.
Oepikina sp.
Skenidioides cf. *anthonensis* (Sardeson)
Sowerbyella variabilis Cooper
Tetraphalerella planobesa? (Cooper)
Triplesia cf. *subcarinatina* Cooper
(strophomenids from Mitchell, 1978).

Ostrocodes.

"Aparchites" cf. *fimbriatus* (Ulrich)
Bairdiocypris cf. *granti* (Ulrich)
Bolbopisthia cf. *lenzi* Copeland
Eoleperditia sp.
Eurychilina prairiensis Copeland
Krausella inaequalis Ulrich
Oepikella cf. *labrosa* Copeland
Schmitdella affinis Ulrich

Conodonts. Faunas 7 and 8 of Sweet et al. (1971) (Tipnis et al., 1978, Tables 12, 13).

Bryozoans.

Calopora? sp.
Helopora? sp.
Oanduella? sp.
Ptilodictya sp.
Stictopora spp.
Stictoporella spp.
fistuliporid
two species of Arthrostylidae

Ceraurinella necra ZONE (ROCKLANDIAN/KIRKFIELDIAN)

This zone is based on three collections, one from each of three sections through the lower Whittaker Formation in the Funeral and Whittaker Ranges, and it signals the initiation of a new series of trilobite assemblages that continues into the next two zones. A number of trilobite genera appear in the zonal sequence for the first time in the *C. necra* Zone. These include *Borealaspis*, *"Calyptaulax"* (of the *lincolnensis* Branson type), *Ceraurinus*, *Cyphoproetus*, *Hypodicranotus*, and *Otarion*; genera that are components of a continent-wide faunal complex of "Trentonian" (Rocklandian to Edenian) age which extends from the high arctic (Cape Calhoun Formation, shaly beds at Silliman's Fossil Mount) to

the mid-continent (Decorah, Plattin, Kimmswick, Bobcaygeon, Verulam Formations) to south-central continent (Viola). The relationship of the *C. necra* Zone to the *C. longispina* Zone is equivocal. The *C. necra* Zone appears to be younger because it includes species of *Ceraurinella* and *Ceraurus* that are probable derivatives of species in the *C. longispina* Zone. The two zones have not been found in superpositional sequence. The sparse conodont faunas of the *C. necra* Zone appear to represent both Faunas 8 and 9.

Assigned collections. Lower Whittaker Formation, Whittaker Range (I 1275, Q 130) and Funeral Range (C 570-590).

Trilobites.

Acanthoparypha? goniopyga n. sp.
Borealaspis biformis Ludvigsen
Bumastoides sp.
Calyptaulax sp.
"Calyptaulax" lincolnensis (Branson)
Ceraurinella necra n. sp.
Ceraurinus sp. (with long paddle-shaped first spines; not described)
Ceraurus tuberosus Troedsson
Cyphoproetus sp.
Dolichoharpes sp.
Holia anacantha n. sp.
Hypodicranotus sp.
Hemiarges sp.
Isotelus sp.
Sphaerexochus sp.
Sphaerocoryphe robustus Walcott

Brachiopods.

Furcitella sp.
Glyptorthis sp.
Hesperorthis sp.
Holtedahlina sulcata (Verneuil)
Pionodema sp.
Sowerbyella aff. *rugosa* (Meek)
Strophomena fluctuosa Billings
Strophomena vetusta? (James)
Zygospira sp.
(orthids from Wigington, 1977; strophomenids from Mitchell, 1978).

Ostracodes.

"Aparchites" cf. *fimbriatus* (Ulrich)
Bolbopisthia lenzi Copeland
Bolbopisthia cf. *ludvigseni* Copeland
Eurychilina sp.
Diplopsis socialis Levinson
Krausella inaequalis Ulrich
Schmidtella affinis Ulrich

Conodonts. Faunas 8 and 9 of Sweet et al. (1971) (Tipnis et al, 1978, Tables 13, 14).

Bryozoans.

Escharopora sp.
two species of trepostomes

Ceraurus mackenziensis ZONE (KIRKFIELDIAN/SHERMANIAN)

The *Ceraurus mackenziensis* Zone overlies the *Ceraurinella necra* Zone in the Funeral and Whittaker Ranges and is closely linked to it. Many species continue from the *C. necra* Zone, but the independent character of the *C. mackenziensis* Zone is shown by relatively minor phylogenetic additions - *Ceraurus mackenziensis* n. sp. from *C. tuberosus*, *Ceraurinella brevispina* n. sp. from *C. necra*, and *Borealaspis whittakerensis* Ludvigsen from *B. biformis* Ludvigsen. The following trilobites indicate correlations of the *C. mackenziensis* Zone with the Verulam, Decorah, upper Bobcaygeon and equivalent formations of Kirkfieldian and Shermanian age in eastern North America (that is, with Faunas G and F of Ludvigsen, 1978b): *"Calyptaulax" lincolnensis* (Branson), *Hemiarges* cf. *paulianus* (Clarke), *Hemiarges* cf. *leviculus* Bradley, *Hypodicranotus* aff. *striatulus* (Walcott), *Cyphoproetus* sp., *Otarion* cf. *trentonensis* (Weller), and *Sphaerocoryphe robustus* Walcott (most of these species are illustrated in Ludvigsen, 1978c, Pls. 1-3). The *C. mackenziensis* Zone sees the full development of the "late Wilderness-early Barneveld" ostracode fauna with *Ceratopsis*, *Dicranella*, and *Tetradella?* that Copeland (1974) correlated with faunas from the shaly beds at Silliman's Fossil Mount of Baffin Island, Decorah Formation of Iowa and Minnesota, and the Bucke Formation at Lake Timiskaming. The conodonts of this zone belong to Fauna 9 (Tipnis et al., 1978). Fauna 9 conodonts also occur with the first representatives of the "Arctic Ordovician fauna" in the study area; that is, the *Bighornia-Thaerodonta* fauna at the base of the Whittaker Formation at Sections D and M. The maximum observed thickness of the *C. mackenziensis* Zone is 40 m at Section H.

Assigned collections. Lower Whittaker Formation, Funeral Range (C 640, C 655, J 220) and Whittaker Range (H 1850, H 1920, H 1975, I 1350-1380, I 1410, Q 430).

Trilobites.

Acanthoparypha? goniopyga n. sp.
Anataphrus sp.
Apianurus sp.
Borealaspis biformis Ludvigsen
Borealaspis whittakerensis Ludvigsen
Bumastoides sp.
Calyptaulax sp.
"Calyptaulax" lincolnensis (Branson)
Ceraurinella brevispina n. sp.
Ceraurinus serratus n. sp.
Ceraurus mackenziensis n. sp.
Chasmops n. sp.
Cybeloides sp.
Cyphoproetus sp.
Dimeropyge sp.
Dolichoharpes sp.
"Eomonorachus" sp.
Hemiarges cf. *leviculus* Bradley
Hemiarges cf. *paulianus* (Clarke)
Hypodicranotus aff. *striatulus* (Walcott)
Isotelus sp.
Otarion cf. *trentonensis* (Weller)
Sphaerocoryphe robustus Walcott

Brachiopods.

Ancistrorhyncha sp.
Boreadorthis sp.
Glyptorthis sp.
Hesperorthis sp.
Holtedahlina sulcata (Verneuil)
Lepidocyclus perlamelosus (Whitfield)
Megamyonia cf. *unicostata* (Meek and Worthen)
Oepikina aff. *pergibbosa* Foerste
Paucicrura? sp.
Plaesiomys? sp.
Platystrophia sp.
Rafinesquina cf. *sardesoni* Salmon
Rhynchotrema sp.
Sowerbyella sp.
Sowerbyella (Thaerodonta) recedens (Sardeson)
Strophomena sp.
Strophomena fluctuosa Billings
Strophomena planumbona (Hall)
Tetraphalerella sp.
Tetraphalerella cooperi Wang
Zygospira sp.
Zygospira modesta (Say)
Zygospira sulcata Howe
(orthids from Wigington, 1977; remainder from Mitchell, 1978).

Ostracodes.

"Aparchites" fimbriatus (Ulrich)
Bairdiocypris cylindrica (Hall)
Bolbopisthia sp.
Ceratopsis quadrifida (Jones)
Dicranella bicornis Ulrich
Diplopsis socialis Levinson
Eurychilina prairiensis Copeland
Krausella? cf. *acuta* (Teichert)
Krausella inaequalis Ulrich
Milleratia sp.
Oepikella labrosa Copeland
Oepikium sp.
Schmidtella affinis Ulrich
Tetradella? sp.

Conodonts. Fauna 9 of Sweet et al. (1971) (Tipnis et al., 1978, Table 14).

Bryozoans.

Escharopora sp.
Ptilodictya sp.
Stictopora sp.
nematoporid

Whittakerites planatus ZONE (SHERMANIAN/EDENIAN)

The youngest Ordovician trilobite zone available for study in the lower Whittaker Formation is named the *Whittakerites planatus* Zone. This zone occupies positions well below the top of the Ordovician succession in the study area. At Section Q, the *W. planatus* Zone is succeeded by about 300 m of Ordovician dolostones before the first Early Silurian graptolites appear at the base of the upper argillaceous division of the Whittaker Formation and, at Section R, the zone is followed by about 100 m of Ordovician limestones which are disconformably overlain by massive dolostones of Early Silurian age. The trilobites of the *W. planatus* Zone comprise hold-overs from the underlying zone (*Borealaspis biformis*, *Sphaerocoryphe robustus*, *Ceraurinella brevispina*, and *Ceraurinus serratus*), a phylogenetic addition (*Whittakerites planatus* Ludvigsen, derived from *C. mackenziensis*), and a few immigrant species whose affinities lie with Cincinnatian species of eastern North America (*Ceraurus milleranus* Miller and Gurley, *Ceraurus maewestoides* n. sp.). A Shermanian/Edenian age is suggested, with reservations, for the *W. planatus* Zone. Only a few diagnostic trilobites occur in the Cincinnatian of the type area and in Ontario (Ludvigsen, 1978b). The presence of *Ceraurus milleranus* in the *W. planatus* Zone is suggestive of a somewhat younger age than Edenian. In the Cincinnati area this species occurs in the Fairview and Grant Lake Formations (Maysvillian; Caster et al., 1955; Pope and Martin, 1977). The conodont faunas of the *W. planatus* Zone are sparse and merely suggestive of Faunas 9, 10, or younger (Tipnis et al., 1978).

Assigned collections. Lower Whittaker Formation at Whittaker Range (I 1590, Q 530) and Dusky Range (R 625, R 655).

Trilobites.

Borealaspis biformis Ludvigsen
Bumastoides sp.
calymenid
Ceraurinella brevispina n. sp.
Ceraurinus serratus n. sp.
Ceraurus maewestoides n. sp.
Ceraurus milleranus Miller and Gurley
cheirurinid gen. and sp. indet.
Cybeloides sp.
Cyphoproetus sp.
Dolichoharpes sp.
lichids
Otarion sp.
Sphaerocoryphe robustus Walcott
Whittakerites planatus Ludvigsen

Brachiopods.

Hesperorthis sp.
Megamyonia sp.
Rafinesquina cf. *sardesoni* Salmon
Sowerbyella sp.
Strophomena planumbona (Hall)
Strophomena vetusta (James)
Tetraphalerella sp.
Tetraphalerella? neglecta (James)
(from Mitchell, 1978).

Ostracodes.

Bairdiocypris cf. *cylindrica* (Hall)
Krausella inaequalis Ulrich
Krausella? cf. *acuta* (Teichert)
Leperditella sp.

Conodonts. Faunas 9 and 10(?) of Sweet et al. (1971) or younger (Tipnis et al., 1978, Table 14).

Bryozoans.

Sceptropora sp.
nematoporid
phylloporinid
trepostomes

SYSTEMATIC PALEONTOLOGY

The terminology and classification is basically that outlined in the Treatise on Invertebrate Paleontology (Moore, 1959).

Glabella includes the occipital ring.

Palpebral area is that area in bathyurids bounded by abaxial edge of palpebral lobe and the axial furrow.

Epsilon is that angle formed by facial suture at posterior end of palpebral lobe (Richter and Richter, 1949).

Gamma is that angle formed by facial suture at anterior end of palpebral lobe (Richter and Richter, 1949).

Number of individuals is the maximum number of either cranidia, pygidia, or hypostomes.

The illustrated specimens are kept at the Geological Survey of Canada (GSC prefix) and in the Department of Geology, University of Alberta (U.A. prefix).

Order PROETIDA Fortey and Owens, 1975

Discussion. The similarity of silicified specimens of *Bathyurus* (herein), on the one hand, and *Proetus*, *Otarion*, and *Warburgella* (Whittington and Campbell, 1967; Ormiston, 1971; Chatterton and Perry, 1977), on the other, lends support to Fortey and Owens' (1975) phylogenetic connections set out in their classification of the order Proetida.

Family BATHYURIDAE Walcott, 1886

Genus *Bathyurus* Billings, 1859

Type species. *Asaphus? extans* Hall, 1847 from the Lowville Formation, Mohawk Valley, New York State.

Diagnosis. A genus of Bathyuridae with inflated glabella that expands slightly forward and two pairs of faint to firm, obliquely disposed lateral glabellar furrows. Palpebral areas large. Genal spines long and tapering with flattened borders. Hypostome quadrate with narrow convex borders, firm border furrows, distinct maculae, and high anterior wings. Rostral plate thinly crescentic; strongly flexed (sag.) and markedly waisted by connective sutures. Pygidium semi-circular to sub-triangular with deep axial furrows, four (or rarely five) interpleural furrows, and flattened borders.

Discussion. Species of *Bathyurus* have previously been known largely from scattered occurrences in Ontario, Quebec, and New York State. The bulk of the species is represented by sparse and generally incompletely or indifferently preserved material from relatively few localities. The ventral morphology of any species of *Bathyurus* has not been made clear, although the rough outlines of the ventral sutures of a related genus, *Raymondites* Sinclair, has been sketched in by Whittington (1953), and the respective hypostomes remain incompletely known. The silicified material from the Mackenzie Mountains now provides information about the total morphology of *Bathyurus*.

Whittington (1953, p. 653) concluded that *Bathyurus* is restricted to rocks of Blackriveran age. The present work demonstrates that, in excellent stratigraphic sequences in the Mackenzie Mountains, *Bathyurus* first appears near the base of the Chazyan and persists to near the top of the Blackriveran; this range spans approximately 400 m of strata. This conclusion is, in itself, not new. Twenhofel (1938) described a species of *Bathyurus* from the Mingan Formation of Chazyan age from the Mingan Islands and *Bathyurus angelini* Billings, 1859 from Grenville, Argenteuil County, Quebec was collected from strata underlying the sandstone at the base of the Chazy Group (Raymond, 1913, p. 55). Therefore, the mere presence of *Bathyurus* can no longer be cited as evidence for a Blackriveran age assignment.

Whereas the temporal range of *Bathyurus* has been expanded, its ecologic range has now been restricted. *Bathyurus* is almost totally confined to the shoreward of three trilobite biofacies developed in platform carbonates in the Middle Ordovician of the southern Mackenzie Mountains (Ludvigsen, 1978c, Figs. 12, 13) and in other areas of North America (Ludvigsen, 1978a).

The ancestry of the genus *Bathyurus* has yet to be clarified, but presumably it lay with bathyurid species such as *"Bathyurus"* sp. or *"Goniotelina"* sp. (Ludvigsen, 1975, Pl. 1, figs. 11-13, 15-17) which occur in upper Whiterockian strata in the Mackenzie Mountains. Similar species occur in the same stratigraphic position in other areas of North America.

Of the six species of *Bathyurus* described herein from the upper Sunblood Formation and the Esbataottine Formation, four (that is, *Bathyurus angustus* Ross, *B. granulosus* n. sp., *B. ulu* n. sp., and *B. esbataottinensis* n. sp.) can be interpreted as a phylogenetic series (Fig. 8). Initially, this series sees the loss of the posterior pygidial spine and a reduction in size of the granulate micro-sculpture (from *B. angustus* to *B. granulosus*). The remaining series (from *B. granulosus* to *B. esbataottinensis*) shows a number of morphologic changes: the micro-sculpture changes from granulate to scaly; the palpebral areas move forward slightly; the palpebral furrows become effaced in mature specimens; gamma changes from an obtuse to an acute angle; the inflation of the glabella increases (especially the anterior part); and the glabellar furrows increase in size and depth, but are secondarily reduced in the terminal species.

The remaining species of *Bathyurus*, *B. nevadensis* and *B. platyparius*, share a few features (parallel-sided glabellae lacking glabellar furrows, effaced palpebral furrows, and hypostomes with stout spines at their posterolateral corners) and may be members of a second phylogenetic series. This series possibly includes *B. superbus* Raymond.

A third series is probably defined by *Bathyurus extans* (Hall), *B. acutus* Raymond and *B. angelini* Billings.

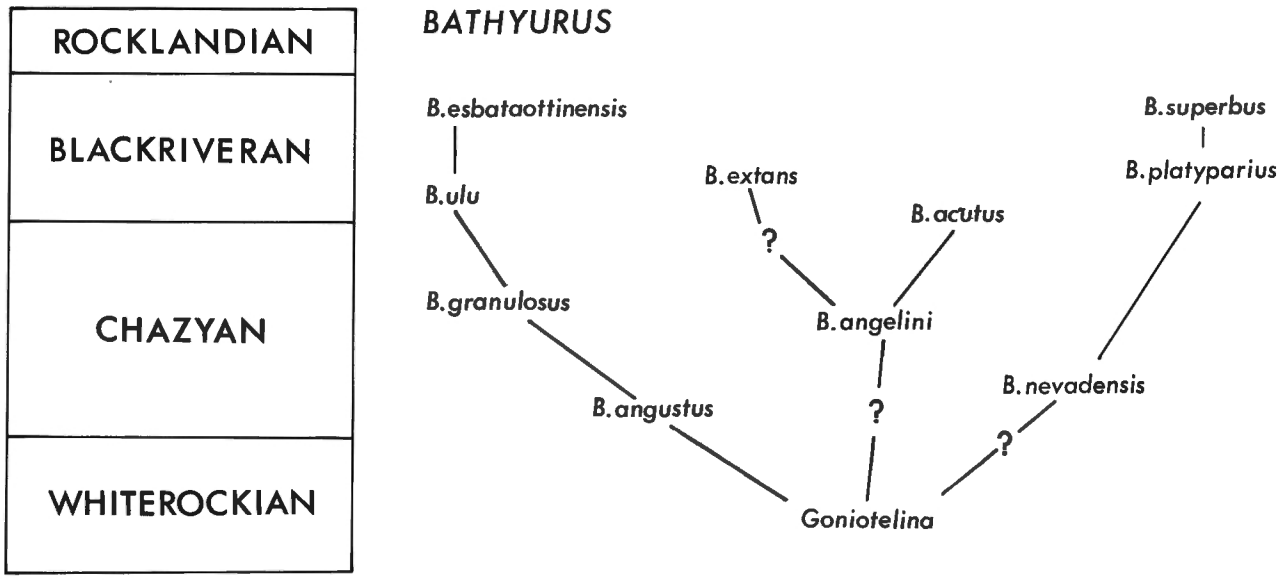

FIGURE 8. Inferred phylogeny of ten species of *Bathyurus* from North America.

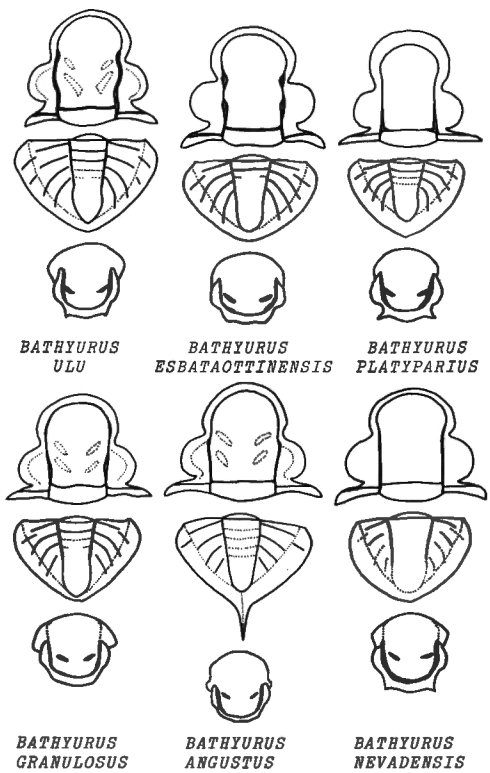

FIGURE 9. Outline drawings of cranidia, pygidia, and hypostomes of six species of *Bathyurus* from the upper Sunblood and Esbataottine Formations of the South Nahanni River area.

Bathyurus ulu n. sp.

Plate 4, figures 1-53, Figure 10C

Diagnosis. A *Bathyurus* with sub-parallel sided glabella modified by faint constrictions adaxially of posterior and anterior ends of palpebral area and possessing two pairs of oblique lateral glabellar furrows; posterior pair longest and deepest. Anterior border of cranidium moderately broad, slightly concave. Palpebral area sub-semicircular, includes faintly defined and crescentic palpebral lobe. Gamma slightly obtuse angle. A pair of small spines at posterolateral corners of hypostome. Pygidium triangular to semi-circular in outline, borders moderately broad and concave; 1-3 axial rings. Micro-sculpture of small, asymmetric, chevron-shaped scales.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 220, A 240, A 247, P 1595, ?P1665-1685). *Bathyurus ulu* Zone and (?)*Ceraurus gabrielsi* Zone.

Material. Nine hundred and twenty-five (925) individuals.

Holotype. A complete cranidium (GSC 43911) from A 220 illustrated on Plate 4, figures 1-3.

Paratypes. GSC 43912-43932 and GSC 43942-43946 from A 220, GSC 43933-43941 from P 1595.

Description. Glabella moderately vaulted posteriorly, strongly vaulted anteriorly where front edge descends vertically to anterior border. In longitudinal profile, glabellar flanks slope outwardly from a broad and rounded median keel. In lateral profile, crest of posterior two thirds of glabella slopes faintly backward (using upper edge of eye as horizontal datum). Glabella essentially parallel-sided, length (sag.) slightly less than one half width; anterior margin sub-circular. From occipital ring, moderately deep axial furrows converge slightly to minimum width of glabella just in front of epsilon; then shallow and diverge slightly to a second waisting which is located slightly in front of gamma. In front of this point, axial furrows curve slightly around anterior portion of glabella and then curve inwardly along sub-circular path to become preglabellar furrow. Anterior part of axial furrow defined by sharp slope change between forward-sloping portion of fixed cheek and glabella. Preglabellar field moderately broad, slightly concave medially. 1s furrow consists of elongate, straight flexure which extends inward and backward from point at an angle of about 40° to sagittal line. Furrow becomes slightly deeper and wider (tr.) posteriorly and terminates ahead of line joining epsilon, about one third way across glabella. 2s furrow sub-parallel with 1s, but shallower and slightly shorter (tr.); extends from axial furrow at second waisting of glabella one third way across glabella. Width across palpebral areas is slightly greater than sagittal length of cranidium. Palpebral area sub-semicircular in outline, length (exsag.) about one third glabellar length; includes crescentic palpebral lobe which extends from gamma to epsilon and is defined adaxially by faint palpebral furrow. Portion of palpebral area between palpebral furrow and axial furrow depressed slightly below level of palpebral lobe. In longitudinal profile, palpebral area stands below crest of glabella. Occipital furrow transverse; moderately deep with steep anterior and gentle posterior walls. Occipital ring rectangular to lenticular, four times as wide (tr.) as long (sag.); highly arched, but stands below level of highest portion of glabella (if upper edge of visual surface assumed horizontal). Posterior border furrow on cheek slightly deeper than occipital furrow, extends outward and downward with very gentle backward curvature from half-length (sag.) of occipital lobe and dies out in front of inside curvature of genal spine. Anterior branch of facial suture extends from gamma (which is slightly obtuse angle) forward in even curve along path parallel with glabellar margin. At a point in exsagittal line with axial furrows, suture obliquely crosses anterior margin in very faint curve to meet anterolaterally curving connective suture and then proceeds adaxially in straight path, just below anterior margin, as rostral suture. Posterior branch of facial suture proceeds outward and downward from epsilon in sigmoidal curve, crosses posterior border at low angle, and intersects posterior margin at a point halfway to lateral margin.

Visual surface of eye strongly curved in horizontal plane and slightly in vertical plane. Below eye, field slopes steeply to flat cephalic border which is broadest (tr.) anterolaterally. Cephalic border narrows somewhat posteriorly and becomes slightly concave, may be joined by nearly effaced extension of posterior border furrow; continues posteriorly to tip of long, gradually tapering genal spine. In lateral view, base of genal spine straight; directed obliquely backward at about 15-20° below horizontal.

On interior, occipital doublure extends about one third distance across occipital ring. Glabellar furrows expressed as relatively high ridges. Thin, narrow rim extends completely around lateral periphery of palpebral lobe. Genal spine encased by convex doublure as far forward as internal impress of posterior border furrow where it is notched by limiting device. Lateral parts of doublure convex, extend to inner edge of lateral border. Anteriorly, rostral plate forms part of this doublure.

Rostral plate may be described in two parts. A short (tr.), gently curved (tr. and sag.), cleaver-shaped anterior portion bounded by straight rostral suture and strongly anteriorly divergent branches of connective suture and a wide (tr.), strongly flexed (sag.), strongly curved (tr.), and thin crescent-shaped posterior portion bounded by posteriorly-divergent hypostomal suture. Considering both parts, rostral plate moderately curved (tr.) and strongly flexed (sag.) with pronounced waist formed by strongly laterally divergent connective sutures and attenuating distally to very fine, curved point. Two kinds of sutural contacts define rostral plate. The rostral and connective sutures are sharply-edged and plane surfaces set perpendicular to dorsal and ventral surfaces of exoskeleton. The hypostomal suture is a sagittally convex and posteriorly concave surface. The rostral and connective sutures are identical to the facial suture and their shape would not allow motion to take place across these planes. The hypostomal suture differs from the above in being a curved surface and possessing a form that suggests the possibility of motion taking place across this contact. The area on the hypostome that received the edge of the rostral plate is a forwardly convex and sagittally concave surface and it appears highly probable that the hypostome could be moved within a sagittal plane.

Hypostome sub-trapezoidal in outline; length (sag.) slightly less than maximum width across anterior wings. Central body slightly inflated; posterior two thirds bounded laterally by relatively narrow lateral border furrows which are parallel-sided or slightly convergent forwardly. Posterior border furrow follows even arc, shallowing somewhat medially; confluent with lateral border furrows. A pair of obliquely disposed maculae located on margin of central body, slightly farther than half the distance from anterior margin. Macula lenticular in outline, relatively deep with steep posterior edge and shallow anterior edge. Opposite maculae, lateral margins diverge slightly to define distinct shoulders which, in longitudinal profile, are narrow (tr.) and rounded ledges. From shoulder, lateral margin curves inward and backward to terminate at small and distinct anterolateral spine. Posterior margin faintly bowed toward rear and posterior border slightly wider (sag.) than lateral border at shoulder. In ventral view, anterior margin of hypostome defined by broad parabolic curve between high anterior wings and, on its edge, carries a smooth, concave groove which is widest (sag.) medially and fades out laterally. In anterior view, anterior margin broadly U-shaped. Anterior wings high, triangular in lateral profile, nearly vertical; forward portion curves directly from central body without interruption by furrow; rear portion defined basally by shoulder. Anterior wing divided by faint vertical furrow which runs from anterior part of shoulder to shallow pit near apex of wing. On interior, posterior doublure narrow (sag.) and convex medially; laterally it becomes wider (exsag.), higher, and concave. In front of posterolateral

corner, doublure flexed into faint fold and inner edge of doublure elevated into thorn-like posterior wing. Broad antennal notch bounded by shoulder ventrally and anterior wings anterodorsally. Notch directed forwardly and slightly outwardly. Except for impress of maculae, interior floor of hypostome completely smooth.

Axis of each thoracic segment high, vaulted; five times as wide (tr.) as long (sag.); width less than one third total width of segment. Articulating furrow moderately deep, nearly straight, but tending to bend slightly forward near axial furrow. Preannulus not present. Articulating half ring extends nearly to articulating furrow of preceding segment. Axial furrows narrow (tr.), deeply incised. Inner half of pleura horizontal; outer half declines gradually to a level 45-55° below horizontal. Pleural terminus bluntly pointed with a convex anterior edge and faintly curved posterior edge. Pleural furrow V-shaped (exsag.), deepest at mid-length; sub-parallel with posterior margin; extends to about mid-length of declined portion of pleurae. On interior, occipital doublure extends nearly to articulating half ring. Doublure encases slightly less than half of declined part of pleura. Dorsal edge of this doublure notched medially to form enrolment limiting device; in front of which, inner edge of doublure proceeds directly forward and is flexed upward slightly. This flexure extends slightly beyond anterior edge of pleura and is received by limiting device of preceding segment at maximum enrolment (Pl. 4, fig. 36). Posterior part of doublure extends inward from limiting device in gentle curve and attenuates toward outer part of horizontal portion of pleura. Aside from enrolment limiting device, articulating devices consist of small, forwardly facing, button-like axial furrow process and corresponding backwardly facing socket (best seen in *B. esbataottinensis*, Pl. 5, figs. 46, 48).

In fully extended state, anterolateral part of segment covered by posterior part of preceding segment (Pl. 4, figs. 34, 35). Upon enrolment, the axial furrow process and socket remain conjoined, as do the inner horizontal parts of adjoining segments as far laterally as adaxial tip of posterior doublure. The latter point serves as a fulcrum, but it is not expressed as a discrete structure on the margin of the segment. The relative rotation is taken up by the distal sloping part of the segment which slides underneath the segment in front until stopped by the panderian notch.

Pygidium sub-semicircular to sub-triangular in outline; width (tr.) about one and one half times length (sag.). Anterolateral corner modified into oblique facet. Axis high and vaulted, one quarter to rarely one third width of pygidium; crossed by single complete axial ring furrow and additional 1 or 2 faint furrows which are only evident on axial crest. Axial furrows deep, V-shaped; converging slightly backward for two thirds length of pygidium, then become parallel for short distance before fading out. In lateral profile; crest of axis declines gently; tip unbounded by furrows; defined by even sigmoidal decline to posterior border. Pleural field initially horizontal to faintly arched; outer part declines at about 50° below horizontal and flattens to form moderately broad, concave border. Pleural field crossed by four equally-spaced interpleural furrows which initially are nearly straight; first oriented at 75° and last at 40° to sagittal line. First pleural furrow very faint on pleural field, becomes deeper on border and extends to lateral margin. Second to fourth pleural furrows evident on border where they are broad depressions that extend nearly to margin. They cannot be recognized on pleural field. Second pleural furrow located only slightly behind distal end of second interpleural furrow. Third and fourth pleural furrows appear to be direct continuations of third and fourth interpleural furrows. Articulating devices on anterior edge of pygidium identical to those on thoracic segments. On interior, broad and flat doublure extends inward to a level halfway up declined portion of pleural field. Below axial dip doublure deflected into broad sulcus.

Micro-sculpture of *Bathyurus ulu* is basically the same as that of *B. esbataottinensis* and, because it is expressed better on that species, it will be described later.

Discussion. *Bathyurus ulu* n. sp. is most similar to *B. esbataottinensis* n. sp. Differences from this and other species from the Sunblood and Esbataottine Formations are recorded under the respective species. Of the remaining North American species, *B. ulu* is only comparable to *B. extans* (Hall) from the Lowville Formation of New York State (Whittington, 1953, Pl. 65, figs. 1-9, 11, 12) from which it differs in the following points. *Bathyurus ulu* possesses deeper and narrower ls glabellar furrows; a glabella that bulges slightly at mid-length; a narrower and higher axis on the cranidium, thoracic segments, and pygidium; a broader anterior cranidial border; micro-sculpture consisting largely of chevron-shaped scales; and pygidial pleural furrows that are considerably fainter than those of *B. extans*. The hypostomes are not compared because it seems probable that the two specimens assigned to *B. extans* by Whittington (1953, Pl. 65, figs. 13, 17) actually belong to *B. superbus* (see Ludvigsen, 1978a).

Bathyurus esbataottinensis n. sp.

Plate 1, figures 44-47, Plate 5, figures 1-48, Plate 6, figures 1-26, Figure 10D

1975 *Bathyurus* aff. *extans* (Hall), Ludvigsen, Pl. 4, figs. 20-33.

Diagnosis. A *Bathyurus* with glabella of clavate outline - parallel-sided posteriorly and sub-circular anteriorly. Glabella furrows shallow. Anterior margin moderately broad and flat. Palpebral areas large, semi-circular in outline; palpebral furrows absent (in large cranidia). Gamma an acute angle. Hypostome quadrate in outline; shoulders moderately small; posterolateral corners rounded. Pygidium sub-semicircular to sub-triangular in outline; border moderately broad to very broad in large specimens; axial rings number 2 or 3; ring furrows faint. Axial region of exoskeleton covered by small asymmetric chevron-shaped scales whose apices and steep sides point posteriorly. On glabella, scales arranged in irregular, forwardly curving rows.

Occurrences. Middle and upper Esbataottine Formation, Sunblood Range (P 1870, P 1931, P 1945-1955) and Whittaker Range (?H 900, H 1020, I 780); upper Sunblood Formation, Natla River (GSC loc. 69001, D 1342). *Ceraurus gabrielsi* Zone.

Material. One hundred and ninety-three (193) individuals.

Holotype. A nearly complete cranidium (GSC 40431) from P 1931 illustrated on Plate 5, figures 1-3 and Plate 6, figure 2.

Paratypes. GSC 57963-57966 from H 1020, GSC 43969-43975 from I 780, GSC 43976-43981 from P 1870, GSC 43947-43968, 40432-40434 from P 1931, GSC 43982, 43983 from P 1945-1955, GSC 43984, 43985 from GSC loc. 69001.

Discussion. *Bathyurus esbataottinensis* n. sp. is represented by abundant and well-preserved specimens from the middle and upper Esbataottine Formation at Section P where it occurs above, and was probably derived from, *B. ulu* n. sp. A comparison with *B. ulu* will serve to characterize the species.

The cranidium is parallel-sided between the palpebral areas and expands, in front of gamma, into a sub-circular anterior portion. The glabellar furrows are considerably shallower and shorter. In large cranidia they are evident as very shallow, obliquely disposed depressions that lack micro-sculpture. The furrows are very faint on the interior. Successively smaller cranidia possess more distinct glabellar furrows. Compare the progressively larger cranidia of the two species: *B. ulu* (Pl. 4, figs. 23, 22, 10, 2) and *B. esbataottinensis* (Pl. 5, figs. 17, 16, 12, 6, 1). The palpebral areas are larger and oriented at right angles to the sagittal line. In *B. esbataottinensis*, a line tangent to the curved anterior edge of the palpebral area is nearly transversely directed. The same line in *B. ulu* would be oriented at about 70-75° to the sagittal line. Palpebral furrows are absent in large cranidia, but may be seen in smaller cranidia. The palpebral areas attain the same height as the crest of the glabella (compare Pl. 5, figs. 2, 3 and Pl. 4, figs. 2, 3). In front of the palpebral areas the facial sutures diverge strongly and gamma is an acute angle. In *B. ulu*, it is obtuse (compare Pl. 5, fig. 1 and Pl. 4, fig. 1). The rostral suture is narrower (tr.)

Next to the cranidium, the hypostome is the most diagnostic element of *B. esbataottinensis*. It differs from that of *B. ulu* in possessing shoulders that do not extend as far anteriorly (compare Pl. 5, figs. 28, 33 and Pl. 4, fig. 24), lateral border furrows that are shallower and parallel maculae that are more transversely oriented and situated slightly farther posteriorly, and rounded posterolateral corners that lack spines. The uniquely preserved specimen of a hypostome and an attached rostral plate (Pl. 5, figs. 31-35, Pl. 6, fig. 3) indicates the position of the hypostome relative to the cephalon. If the rostral suture of the rostral plate is juxtaposed with the rostral suture of the cranidium, it is apparent that the ventral surface of the hypostome will be set at an angle of about 45° to the horizontal (that is, the upper and lower edges of the visual surface of the eye). If the free cheeks are then attached to the cranidium to complete the cephalon, the hypostome will project a considerable distance below the ventral edge of the genal spines. The hypostome, in this position, would seriously impede forward motion of the trilobite were it not for its ability to be moved in a sagittal plane.

The pygidia of *B. esbataottinensis* and *B. ulu* are very similar and can only be distinguished with difficulty. The only consistent difference appears to be the strength and width (tr.) of the axial ring furrows. In *B. ulu*, the anterior axial ring is convex (sag.) and outlined by deep and narrow articulating furrows and ring furrows; two additional rings are outlined by faint ring furrows, commonly only expressed medially (Pl. 4, figs. 4, 33). In *B. esbataottinensis*, the anterior ring is only convex (sag.) and is outlined by a narrow articulating furrow and a shallow first ring furrow; two additional rings may be faintly outlined by weak axial ring furrows that shallow medially (Pl. 6, figs. 19, 20). Larger pygidia of *B. esbataottinensis* are semi-circular in outline (Pl. 5, fig. 20, Pl. 6, fig. 22) and possess very broad and concave borders.

The dorsal surface of *Bathyurus esbataottinensis* is covered by distinct micro-sculpture whose orientation, shape, arrangement, and size change consistently away from the axis. The micro-sculpture on the ventral surface of the hypostome is uniformly distributed. The central part of the glabella and the axial lobe of the thoracic segments and pygidium of *B. esbataottinensis* are covered by densely distributed chevron-shaped scales

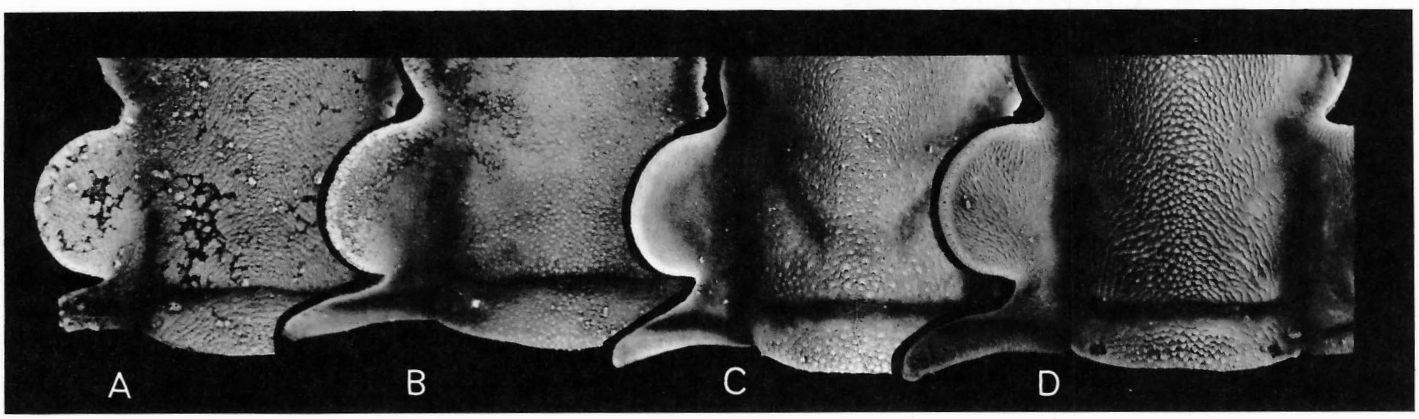

FIGURE 10. Comparison of palpebral areas and cranidial micro-sculpture of the holotypes of four new species of *Bathyurus*:
A. *B. platyparius* n. sp., GSC 57967, x7.6, from B 1450;
B. *B. granulosus* n. sp., GSC 40036, x7.8, from P 1090;
C. *B. ulu* n. sp., GSC 43911, x6.4, from A 220;
D. *B. esbataottinensis* n. sp., GSC 40431, x5.3, from P 1931.

whose apices point toward the rear (Pl. 6, figs. 1, 2, 20, 23, 24). In longitudinal profile, these scales are asymmetric, possessing steeper posterior slopes. On the glabella the scales are connected in long, anteriorly convex rows that, laterally, grade into long, sharp cuestas whose steep sides face posteromedially. The scale rows and cuestas follow the contours of the shell and are, largely, effaced within the lateral glabellar furrows and completely disappear adjacent to the axial furrows. The chevron-shaped scales are slightly finer on the axial lobe of the thoracic segments and the pygidium. An arrangement into forwardly convex rows is only apparent on the flanks of the thoracic axis where fine cuestas curve downward and backward. If the micro-sculpture is observed at high magnification with light of low obliquity, additional features become apparent (Pl. 6, fig. 23). The scales are seen to be sharp posterior deflections off a series of fine cuesta-like ridges that are convex forwardly and have steep inner edges. The scales of a single row overlap those of the rows immediately behind. Only the ridges are present adjacent to the axial, articulating, and ring furrows and on the articulating half ring. The pleurae carry irregular, subdued, and cuesta-like ridges. On the posterior part of the pygidium, these strike perpendicular to the axis and have their steep edges facing posteriorly and on the anterior part of the pygidium, the thoracic segments, and the posterior edge of the cephalon, they are curved forward so that their steep edges face posterolaterally. Similar ridges are found on the palpebral area and on the field below the visual surface of the eye. The cephalic borders and the thoracic spines are finely ridged parallel to the margins. The pygidial border contains fine ridges that are generally disposed perpendicular to the axis. The pygidial and cephalic doublure bears fine terrace lines parallelling the margin. The ventral surface of the hypostome is densely covered by fine chevron-shaped scales. These scales are similar to those covering the dorsal axis, but are much smaller and their apices and steep edges point toward the front.

Bathyurus granulosus n. sp.

Plate 3, figures 1-46, Figure 10B

1975 *Bathyurus* sp. 1, Ludvigsen, Pl. 1, figs. 20-23.

Diagnosis. A *Bathyurus* with lowly vaulted glabella that is essentially parallel-sided, but expands slightly between anterior parts of palpebral areas. Anterior portion of glabella slopes gradually and gently to relatively broad, concave anterior border. Two pairs of broad and faint glabellar furrows. Palpebral area arcuate to semi-circular in outline, includes faintly to well defined and crescentic palpebral lobe. Gamma a right angle or slightly obtuse angle. Hypostome rectangular in outline, lacks posterolateral spines. Pygidium triangular; axis high and long (sag.), crossed by two or three axial ring furrows, tends to expand very slightly posteriorly; border broad and concave anteriorly, narrows posteriorly. Surface of exoskeleton finely granulate.

Occurrence. Upper Sunblood Formation, Mary Range (B 1265, B 1295, B 1315), Sunblood Range (P 1090, P 1127, P 1187), Flood Creek (G 2795), and Whittaker Range (?H 410). *Bathyurus granulosus* Zone.

Material. Two hundred and sixteen (216) individuals.

Holotype. An incomplete cranidium (GSC 40336) from P 1090 illustrated on Plate 3, figures 1-3.

Paratypes. GSC 43887, 43888, 43899, 43901 from B 1265; GSC 40339, 43882, 43883, 43885, 43886, 43889, 43890, 43892, 43893, 43902, 43904, 43905, 43907, 43908 from B 1315; GSC 40337, 40338, 43880, 43881, 43884, 43891, 43895, 43896, 43900, 43906, 43909, 43910, from P 1090; GSC 43894, 43897, 43898, 43903, from P 1127.

Discussion. The following features distinguish *Bathyurus granulosus* n. sp. from *B. ulu* n. sp.

1. The glabella is less inflated, the axial furrows are not as deep, and the anterior portion of the glabella slopes gradually to the anterior border. This is best shown in lateral profile (compare Pl. 3, fig. 2 and Pl. 4, fig. 2).

2. The palpebral areas are situated farther to the rear. In *B. granulosus*, epsilon is located laterally to the occipital furrow (Pl. 3, figs. 1, 6, 9) and, in *B. ulu*, epsilon is located slightly ahead of the occipital furrow (Pl. 4, figs. 1, 21).

3. The glabellar furrows are much fainter, being broad and shallow depressions that are not evident on the interior (compare Pl. 3, figs. 1, 6, 9, 10, 13, 15 and Pl. 4, figs. 1, 6, 20, 37).

4. The hypostome is relatively longer (sag.) and lacks posterolateral spines.

5. The pygidium is triangular in outline and the lateral margin is only slightly curved. The lateral border and doublure narrows posteriorly. The axial furrows shallow abruptly behind fourth pleural furrow and, posterior to this, axis is expanded slightly.

6. The micro-sculpture consists of fine granules (compare Pl. 3, fig. 18 and Pl. 4, fig. 33).

Bathyurus nevadensis Ross, 1967

Plate 1, figures 1-32

1967 *Bathyurus nevadensis* Ross, p. D 17, Pl. 6, figs. 1-5.

Diagnosis. A *Bathyurus* lacking lateral glabellar furrows. Glabella parallel-sided, expands slightly in front of gamma. Palpebral furrows very faint. Axial lobe broad. Hypostome rectangular, border furrows deep, stout spines at posterolateral corners. Pygidium sub-circular in outline; axis wide, unfurrowed; four faint interpleural furrows; border moderately broad, concave. Micro-sculpture of relatively coarse granules.

Occurrences. Lehman Formation, about 30 m below base of Eureka Quartzite, southern Egan Range, Nevada. Antelope Valley Limestone, about 60 m below base of Copenhagen Formation, Hot Creek Canyon, Nevada. Upper *Anomalorthis* Zone (in Nevada). Sunblood Formation, Mary Range (B 1005, B 1100). *Bathyurus nevadensis* Zone (in Canada).

Material. About sixty (60) individuals.

Holotype. Nearly complete cranidium (USNM 145787) from the Lehman Formation, southern Egan Range, Nevada, illustrated by Ross (1967, Pl. 6, fig. 1).

Hypotypes. GSC 57940-57958 and U.A. 1716-1718 from B 1100.

Discussion. *Bathyurus nevadensis* Ross differs from *B. ulu* n. sp. in the following characteristics. The glabella, between the palpebral areas, is parallel-sided and lacks lateral glabellar furrows; the glabella is less convex; the entire axial lobe is relatively wider; epsilon is located farther toward the rear; the hypostome has larger posterolateral spines; all pygidial furrows are much fainter; and the micro-sculpture consists of coarse granules instead of scales.

Bathyurus nevadensis from the Mackenzie Mountains differs only slightly from the type material from Nevada. The genal spine of the Nevada form is shorter and the interpleural and axial ring furrows appear to be deeper. The latter feature is probably a result of the preservation as an internal mould (Ross, 1967, Pl. 6, fig. 4). In the material from the Mary Range, these furrows are more readily seen in ventral view (Pl. 1, figs. 15, 19).

Bathyurus platyparius n. sp.

Plate 2, figures 20-43, Figure 10A

Diagnosis. A *Bathyurus* with moderately convex glabella which expands slightly in front of gamma. Glabellar furrows very faint to indistinct. Palpebral areas semi-circular in outline, lack palpebral furrows. Anterior border and cephalic margins very broad and flat. Hypostome has prominent shoulders and strong posterolateral spines which are laterally deflected. Pygidium sub-triangular in outline with bowed sides; axis crossed by 3 faint axial ring furrows; border broad, concave, and of even width around periphery. Cranidium and axial region of pygidium densely covered by fine, irregular ridges.

Occurrences. Upper Sunblood Formation, Mary Range (B 1450); Esbataottine Formation, Whittaker Range (H 1300) and Sunblood Range (P 1625). *Bathyurus ulu* Zone and *Ceraurus gabrielsi* Zone.

Material. Thirty-seven (37) individuals.

Holotype. An incomplete cranidium (GSC 57967) from B 1450 illustrated on Plate 2, figures 20, 21.

Paratypes. GSC 57970-57972, 57974-57976, 57978, 57981, 57986 from B 1450; GSC 57983, 57984 from H 1300; GSC 57968, 57969, 57973, 57977, 57979, 57980, 57982, 57985 from P 1625.

Discussion. *Bathyurus platyparius* n. sp. differs from most species of *Bathyurus* in lacking distinct glabellar furrows and palpebral furrows (except in small cranidia) and in possessing very broad and flat cephalic and pygidial borders. The cephalic and pygidial doublures are also very wide and, consequently, the anterior portion of the rostral plate is considerably longer (sag.) than the corresponding portion of the plate of *B. ulu* or *B. esbataottinensis.*

The broad cephalic borders of *Bathyurus platyparius* and the absence of glabellar furrows and palpebral furrows indicate affinity with *B. superbus* Raymond. This affinity becomes pronounced when the free cheeks, hypostomes, and pygidia are taken into consideration. The broad cephalic border of *B. platyparius* extends to the apex of the genal spine resulting in a gradually tapering and stubby spine; very similar to that of *B. superbus* (compare Pl. 2, fig. 33 and Whittington, 1953, Pl. 69, fig. 28). The pygidium of *B. superbus* (Wilson, 1947, Pl. 2, fig. 10; Whittington, 1953, Pl. 69, fig. 28) shows a wide border crossed by very faint pleural furrows and an axis crossed by only a single ring furrow. The pygidium of *B. platyparius* differs slightly in being sub-triangular, rather than sub-circular, in outline and in having more, but fainter, axial ring furrows. The hypostome of *B. superbus* (Ludvigsen, 1978a, Fig. 4A, G) is similar to that of *B. platyparius* in having a pair of prominent, rounded, sill-like shoulders. The latter species has shoulders that extend farther anteriorly and is distinguished by possessing a pair of laterally deflected posterolateral spines. A few additional features set the Nahanni species apart from the eastern species. *Bathyurus platyparius* has a relatively longer glabella that is covered by fine, irregular, and discontinuous ridges; gamma is a right angle; and the palpebral areas stand as high as the highest part of the glabella. The glabella of *B. superbus* is largely smooth, but very faint ridges occur on the anterior portion; gamma is an obtuse angle; and the palpebral areas stand below the crest of the glabella.

Bathyurus angustus Ross, 1970

Plate 2, figures 1-19

1970 *Bathyurus acutus angustus* Ross, p. 86, Pl. 16, figs. 6-12.

Diagnosis. A *Bathyurus* with a parallel-sided lowly vaulted glabella bearing two pairs of shallow and curving lateral furrows. Palpebral areas with pronounced palpebral furrows. Gamma an obtuse angle. Hypostome sub-trapezoidal in outline, lacks posterolateral spines. Pygidium triangular with long slender terminal spine; well defined axis with 3-4 faint axial rings. Micro-sculpture of coarse granules.

Occurrences. Lehman Formation, Egan Range, Nevada, about 50 m below base of Eureka Quartzite. Kanosh Shale, Egan Range, about 125 m below base of Eureka Quartzite. Antelope Valley Limestone, Hot Creek Canyon and Pahranagat Range, Nevada. Middle and upper *Anomalorthis* Zone (in Nevada). Upper Sunblood Formation, Mary Range (B 795). *Bathyurus nevadensis* Zone (in Canada).

Material. About forty (40) individuals.

Holotype. Incomplete cranidium (USNM 169877) from the Lehman Formation, Egan Range, Nevada illustrated by Ross (1970, Pl. 16, figs. 9-11).

Hypotypes. U.A. 1701-1715 from B 795.

Discussion. *Bathyurus angustus* Ross is readily distinguished by the presence of a long slender terminal spine on the pygidium and by the coarse granulate micro-sculpture. The only other species of *Bathyurus* with a terminal pygidial spine is *B. acutus* Raymond from the Pamelia Formation (Blackriveran) of Ontario, but that species (notwithstanding the views of Ross,

1970, p. 86) differs considerably from *B. angustus* in many other features. *Bathyurus acutus* has an inflated glabella demarcated by deep axial and preglabellar furrows, a wide (tr.) fixed cheek in front of the eye, and a glabellar micro-sculpture of very fine and irregular wrinkles (rather similar to that of *B. platyparius*; Fig. 10A). The pygidium of *B. acutus* differs from that of *B. angustus* in possessing deeper axial and interpleural furrows and a single deep axial ring furrow. In addition, it bears a distinct fifth set of interpleural furrows.

Order PHACOPIDA Salter, 1864

Suborder CHEIRURINA Harrington and Leanza, 1957

Family CHEIRURIDAE Hawle and Corda, 1847

Subfamily CHEIRURINAE Hawle and Corda, 1847

Genus *Ceraurinella* Cooper, 1953

Type species. *Ceraurinella typa* Cooper, 1953 from the Edinburg Formation, Virginia.

Diagnosis. See Chatterton and Ludvigsen, 1976, p. 51.

Discussion. Lane (1971), Chatterton and Ludvigsen (1976), and Ludvigsen (1977a) have recently reviewed the species assigned to this typically Middle Ordovician and North American genus. Chatterton and Ludvigsen (1976) assigned 14 species to *Ceraurinella*, ranging in age from Whiterockian to, probably, Edenian and this study adds another six new species. It is now possible to suggest phylogenetic relationships among these species (Fig. 11).

The oldest species from North America, *Ceraurinella polydorus* (Billings), from the Whiterockian of Newfoundland displays certain features not seen in later species (barrel-shaped glabella, short anterior glabellar lobes, markedly curved and deep lateral glabellar furrows, deep and long palpebral furrows, erect and widely divergent first pygidial spines, and widely separated third spines). The pygidial similarities between this species and *C. kingstoni* Chatterton and Ludvigsen from the Nahanni area are informative (Fig. 12) and are the bases for a postulated ancestor-descendant relationship of the two species. The cranidia of these species are rather different, but this difference is one of degree and does not negate the presumed phylogenetic connection.

Ceraurinella kingstoni, *C. chondra* Whittington and Evitt from Virginia, and *C. magnilobata* Tripp from Scotland belong in a species group of Chazyan age characterized by highly vaulted cephala and glabellae, isolated 1p lobes, small palpebral lobes, stout and divergent first pygidial spines followed by two pairs of short and blunt spines. *Ceraurinella typa* Cooper from Virginia and *C. media* n. sp. from the Nahanni area are of Blackriveran age and appear to have been derived from the Chazyan species group. *Ceraurinella*

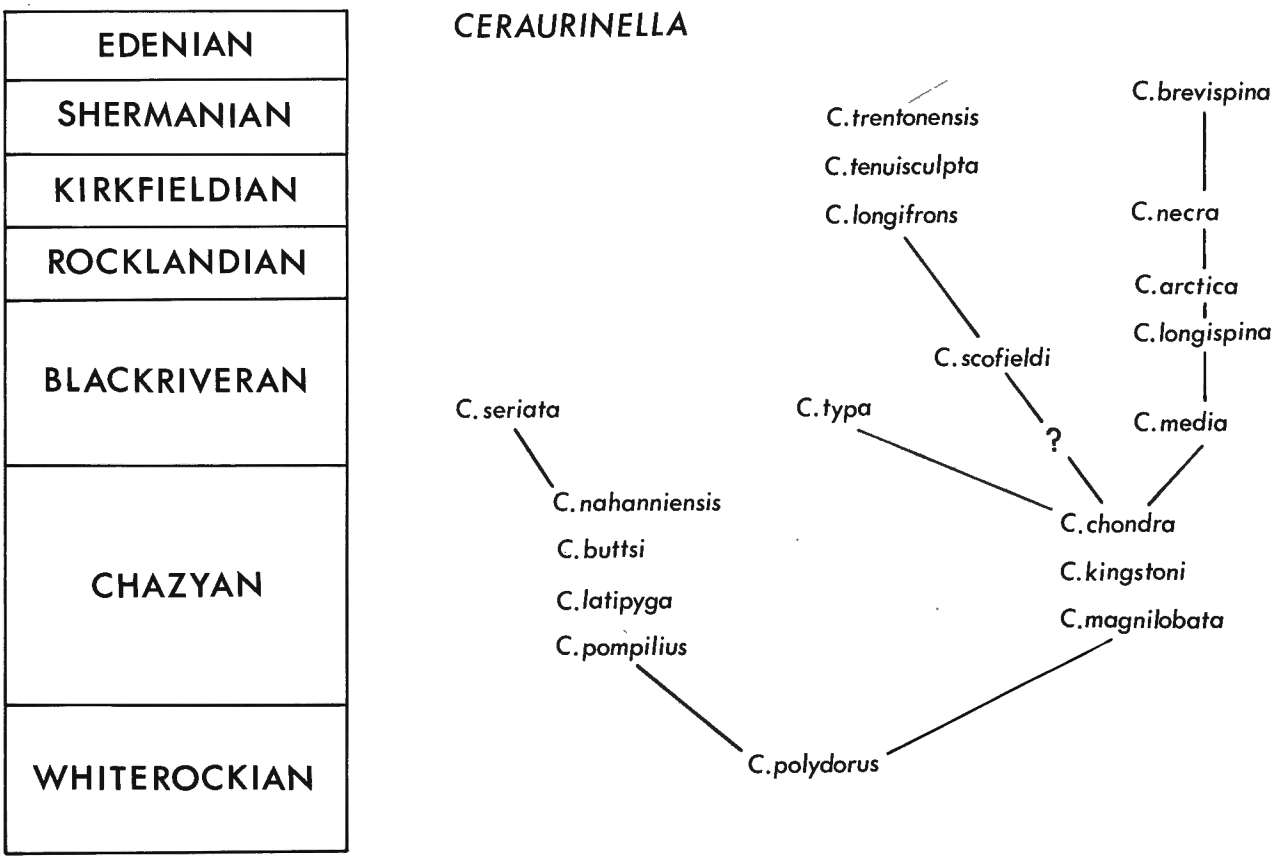

FIGURE 11. Inferred phylogeny of nineteen species of *Ceraurinella* from North America.

typa differs by its tuberculate ornament and larger palpebral lobes and *C. media* by its slightly larger palpebral lobes, less vaulted cephalon, non-isolated 1p lobes, and in possessing only five pygidial spines (the posterior pair having merged into a single median spine).

A second species group of Chazyan age includes *C. nahanniensis* Chatterton and Ludvigsen from the Nahanni area and three species from the Appalachians - *C. latipyga* Shaw, *C. pompilius* (Billings) and *C. buttsi* Cooper. Also included in this group is a single species, *C. seriata* n. sp., from the Blackriveran of the Nahanni area. These species are united by their gently arched cephala, rather faintly incised glabellar furrows, flattened genal spines, and first pygidial spines that are long, curved, gradually tapering and, basally, aligned in the same plane as the posterior spine pairs.

The youngest group recognized in the Nahanni area consists of four successive species, *Ceraurinella longispina* n. sp., *C. arctica* n. sp., *C. necra* n. sp., and *C. brevispina* n. sp., of Blackriveran to Edenian age. This group may be related to the Chazyan group of *C. kingstoni* by a morphological and temporal intermediate, *C. media*. The younger group is united by rather flat glabellae and gently arched cephala, expanded anterior cranidial borders caused by the forward and downward migration of the rostral sutures, and pygidia with five marginal spines that are flattened in cross-section. This group may, in turn, be divided into an older group (*C. longispina* and *C. arctica*) possessing essentially parallel-sided glabellae, preglabellar furrows that are straight medially, large palpebral lobes, broad cheeks, and pygidia with long first spines that diverge and are markedly upturned; and a younger group (*C. necra* and *C. brevispina*) possessing slightly forwardly expanding glabellae, inflated 1p lobes, evenly curved preglabellar furrows, small palpebral lobes, narrower cheeks, and pygidia with short first spines that diverge only slightly and are only faintly upturned. These four species possess pygidia that show a gradual decrease in the length of the first spine and a gradual co-alignment of the first spines with the posterior three spines. The earlier species have long first spines that are oriented obliquely upward and outward and the later species possess short first spines that are directed nearly straight backward. At the same time, the posterior spine of each successive species becomes narrower until, in the Edenian interval (Pl. 10, figs. 41, 43), it is the same size as the second spines. The gradualism of

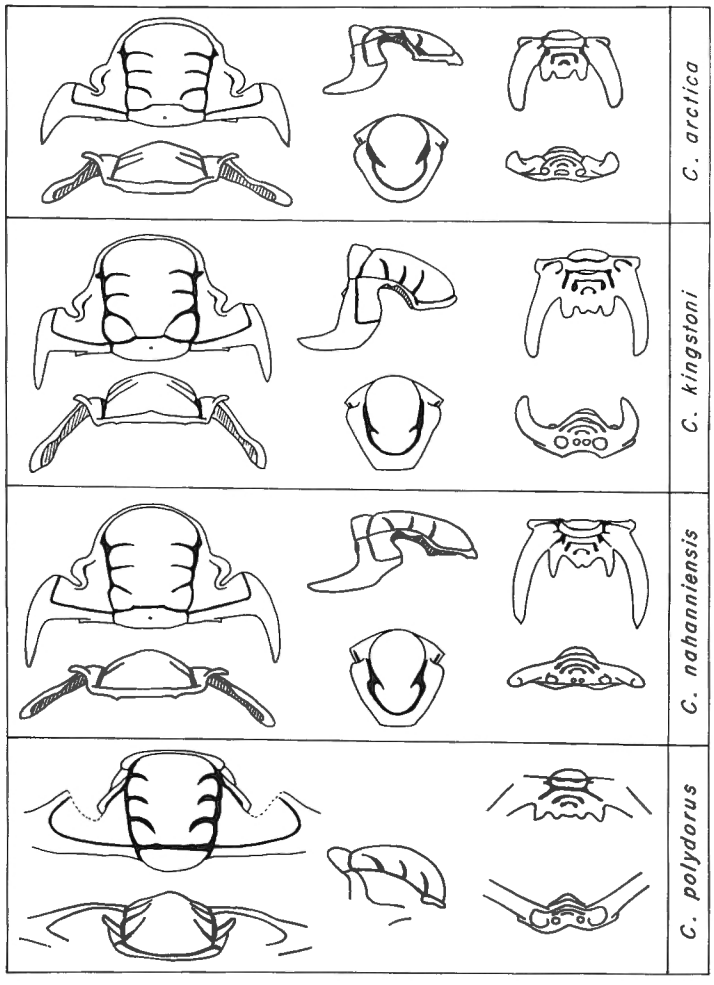

FIGURE 12. Outline drawings of cranidia, pygidia, and hypostomes of four species of *Ceraurinella*: *C. polydorus* (Billings), *C. nahanniensis* Chatterton and Ludvigsen, *C. kingstoni* Chatterton and Ludvigsen, and *C. arctica* n. sp. Not to scale.

pygidial morphology is well seen in Figure 14. This diagram is based on the principle of co-ordinate transformation (Thompson, 1917) and, briefly, shows that a rectangle superimposed on the *C. longispina* pygidium becomes deformed into a semi-ellipse on the *C. brevispina* pygidium. The decrease in areas of the superimposed figures indicates progressively more compact pygidia; changes that are duplicated on the cephalon and shown by the narrower cheeks and shorter genal spines of the two younger species.

The species group of *Ceraurinella* demarcated by *C. longispina* and *C. brevispina* is difficult to relate to a contemporaneous species group from eastern North America which includes *C. scofieldi* (Clarke) of Blackriveran age and *C. trentonensis* (Barton), *C. tenuisculpta* (Bradley), and *C. longifrons* (Troedsson) of Kirkfieldian to Edenian age. These species possess parallel-sided glabellae, deep and oblique 1s furrows, faint 2s and 3s furrows, inflated 1p lobes, and small palpebral lobes. Only the pygidium of *C. scofieldi* is known. This has a pair of long and curving first spines followed by two(?) pairs of smaller spines. These species do not recall those of the *C. longispina-C. brevispina* lineage, but instead appear similar to earlier Chazyan species (*C. kingstoni* and *C. magnilobata*) and may have been derived from this group.

Lane (1971, p. 71-81) has succinctly treated the phylogeny of most of the known cheirurid genera. His conclusions about the phylogeny of *Ceraurinella*, however, demand revision in light of the discovery of the *C. longispina-C. brevispina* lineage in northern Canada. He stated (p. 77) that *Ceraurinella* shows "a progressive incorporation of the anterior border and border furrow into the frontal lobe of the glabella ... and a gradual reduction and final loss of the posterior two pairs of pygidial spines". The delimitation of these trends appears to be based on Lane's choice of end members; that is, *Ceraurinella polydorus* (Billings) from the late Arenigian and Llanvirnian and *Ceraurinella intermedia* (Kielan) from the Ashgillian; and not on an evaluation of the intermediate species from the Middle Ordovician. The present investigation concludes that the expansion of the frontal lobe of the glabella was completed early in the history of *Ceraurinella* (between the Whiterockian and Chazyan) and that further cranidial modification (between Chazyan and Edenian) includes a secondary expansion of the anterior border due to forward and downward migration of the rostral suture. The acceptance of *"Ceraurus" intermedius* Kielan as a species of *Ceraurinella* by Lane essentially demanded that he describe the change in pygidial morphology as a reduction and loss of the posterior two pairs of spines. Reasons for the exclusion of *"C." intermedius* from *Ceraurinella* were given by Chatterton and Ludvigsen (1976) and need not be repeated. The younger species of *Ceraurinella* dealt with in this paper do not approach the morphology of *"C." intermedius* and, although this does not bear directly on the generic identity of the Ashgillian species, it does suggest that it was not a terminus of the relatively long phylogenetic lineage of species of *Ceraurinella* identified in northern Canada.

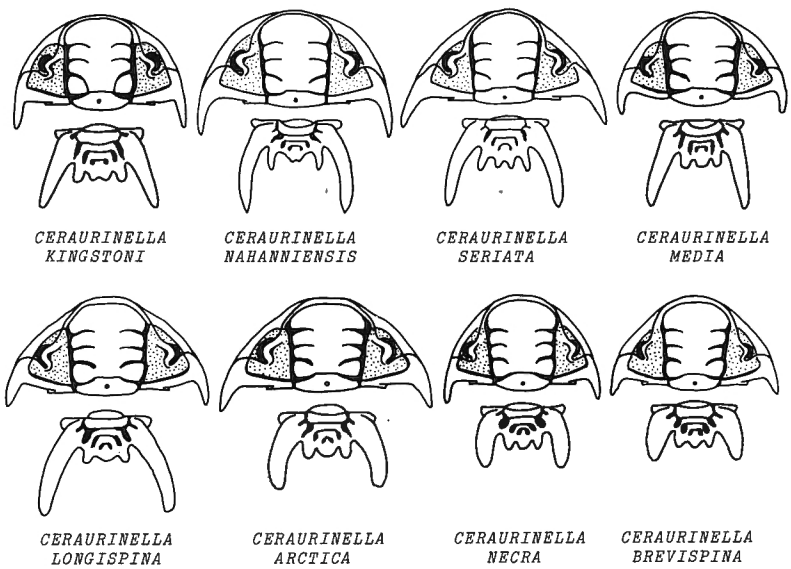

FIGURE 13. Outline drawings of cephala and pygidia of eight species of *Ceraurinella* from the Esbataottine and lower Whittaker Formations of the South Nahanni River area. Not to scale.

Ceraurinella nahanniensis
Chatterton and Ludvigsen, 1976

Plate 7, figures 1-21

1975 *Ceraurinella* n. sp. 2, Ludvigsen, Pl. 3, figs. 16, 17.

1976 *Ceraurinella nahaniennsis* Chatterton and Ludvigsen, p. 55, Pl. 9, figs. 1-35.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 110, A 125, A 140, A 160, P 1440, P 1485, P 1497, P 1512, P 1520) and Whittaker Range (H 800-820). *Ceraurinella nahanniensis* Zone.

Material. One thousand one hundred and twenty-four (1124) individuals.

Hypotypes. GSC 43986-43995 from P 1440.

Discussion. This species has been fully described by Chatterton and Ludvigsen (1976). The additional material illustrated herein came from the lowest part of the Esbataottine Formation and serves to demonstrate the abundant occurrence of this species through the *Ceraurinella nahanniensis* Zone.

Ceraurinella kingstoni
Chatterton and Ludvigsen, 1976

1975 *Ceraurinella* n. sp. 3, Ludvigsen, Pl. 2, figs. 37, 38.

1976 *Ceraurinella kingstoni* Chatterton and Ludvigsen, p. 52, Pl. 8, figs. 1-40.

1977a *Ceraurinella kingstoni*, Ludvigsen, Text-fig. 3.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 110, A 125, A 140, A 160, P 1485). *Ceraurinella nahanniensis* Zone.

Material. One hundred and forty-seven (147) individuals.

Ceraurinella seriata n. sp.

Plate 7, figures 22-42

1977b *Ceraurinella* n. sp. 4, Ludvigsen, Fig. 1A-C.

Diagnosis. A *Ceraurinella* with a glabella that expands slightly forward; deep 1s furrow, shallow 2s and 3s furrows; large palpebral lobe opposite 2p lobe. Pygidium

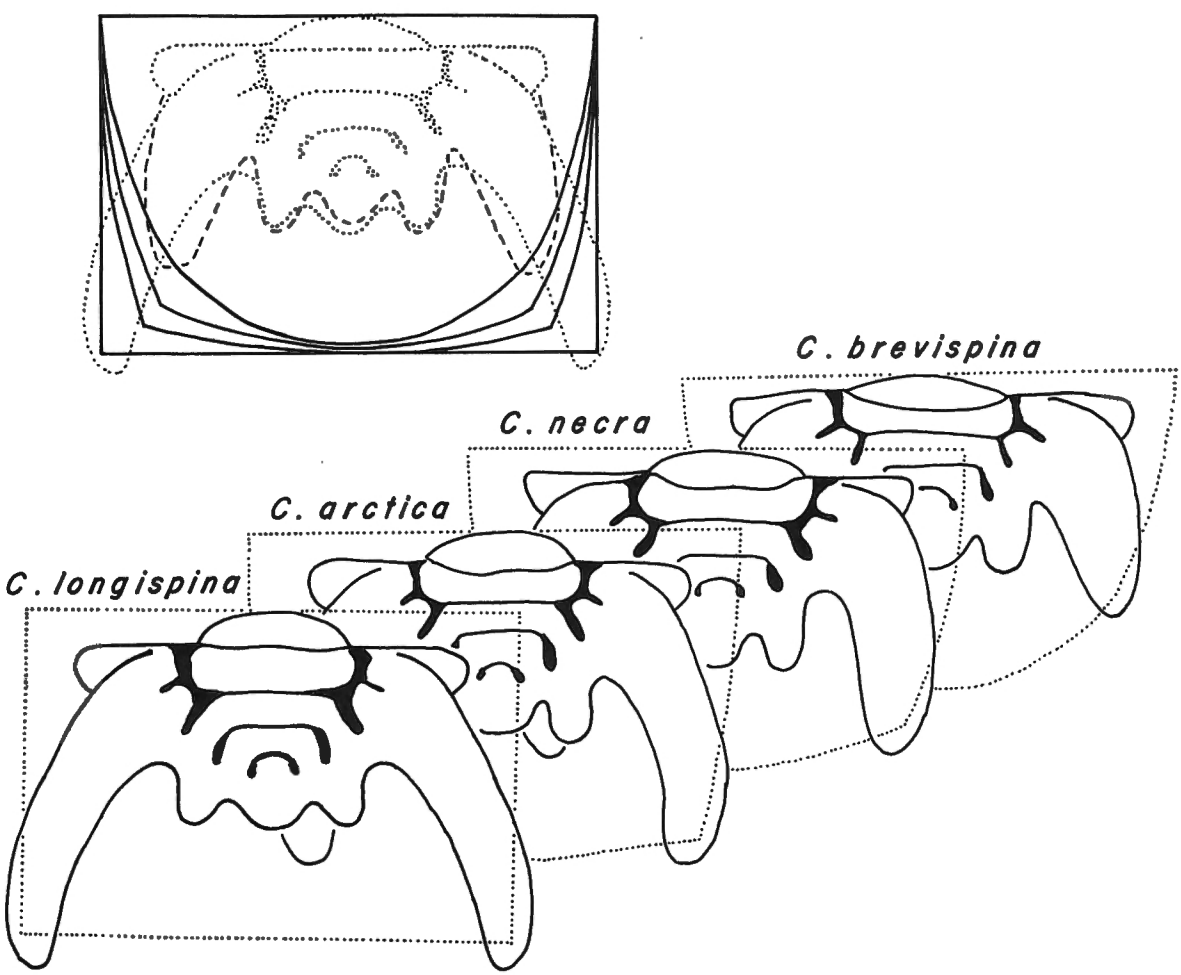

FIGURE 14. Co-ordinate deformation of pygidia of *Ceraurinella longispina-C. brevispina* lineage.

has 3 spine pairs; first long, slender, and outwardly and backwardly curving; second much shorter, subparallel to slightly diverging; third slightly shorter than second set, closely aligned and discrete for nearly their total length. Pygidial spines directed slightly upward in same plane.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 220, A 240, A 247, P 1575, P 1625). *Bathyurus ulu* Zone.

Material. Eighty (80) individuals.

Holotype. An incomplete pygidium (GSC 43999) from P 1625 illustrated on Plate 7, figures 28, 29.

Paratypes. GSC 43996-43998, 44000-44008 from P 1625.

Discussion. *Ceraurinella seriata* n. sp. differs in a few minor, but persistent features from the slightly older *C. nahanniensis* Chatterton and Ludvigsen. The most obvious of these is the aspect of the third set of pygidial spines. In *C. nahanniensis*, these spines are nearly conjoined in a single, broad, flat, and triangular spine whose dual composition is revealed by a small median notch (Chatterton and Ludvigsen, 1976, Pl. 9, figs. 11, 13, 17, 19; this paper, Pl. 7, figs. 8, 12). In *C. seriata*, these spines are closely aligned, but discrete and separated for nearly their total length (Pl. 7, figs. 28, 37). The cephala of the two species are very similar, but *C. seriata* has a less vaulted cranidium and a glabella that is not so inflated (compare Chatterton and Ludvigsen, 1976, Pl. 9, fig. 3 and this paper, Pl. 7, fig. 23). In addition, the palpebral lobes of *C. seriata* are slightly larger, the anterior cephalic border narrower, and the second and third glabellar furrows are shorter (exsag.) and sharply incised (compare Chatterton and Ludvigsen, Pl. 9, fig. 33 and this paper, Pl. 7, fig. 42).

Ceraurinella arctica n. sp.

Plate 9, figures 1-34

1975 *Ceraurinella* n. sp. 7, Ludvigsen, Pl. 4, fig. 7.

1977b *Ceraurinella* n. sp. 7, Ludvigsen, Fig. 1D.

Diagnosis. A *Ceraurinella* with a weakly convex glabella that expands slightly forward. 1s furrow is deep and backwardly curving, does not reach occipital furrow. 2s and 3s furrows slightly curved, sub-parallel. Palpebral lobe is large. Hypostome has evenly rounded posterolateral corners. Pygidium has five spines; first long (ratio of length of spine to width of pygidium across anterior margin is 0.90), flatly oval in cross-section, directed backward with slight outward and upward curvature; second much shorter, blunt, directed backward; broad, tongue-shaped spine occupies median position.

Occurrence. Esbataottine Formation, Flood Creek (G 3195); Upper Esbataottine Formation, Sunblood Range (P 2038, P 2050); and upper Sunblood Formation, Mary Range (B 1510-1520). *Ceraurinella longispina* Zone.

Material. One hundred and forty-five (145) individuals.

Holotype. A complete cephalon (GSC 44033) from P 2050 illustrated on Plate 9, figures 1-5, 31-34.

Paratypes. GSC 40419, 44020, 44034, 44036, 44037, 44039-44043 from P 2050; GSC 44035, 44038 from B 1510-1520.

Description. Cephalon semi-circular in outline; transversely gently convex. Glabella only slightly inflated. Minimum width across occipital ring is five sixths of maximum width across anterior lobe. Axial furrows deep, straight, slightly diverging as far forward as anterior pit where they are abruptly bowed slightly outwardly before turning inwardly to become preglabellar furrow. Three pairs of narrow, sharply incised glabellar furrows extend about one third way across glabella. 1s deep, curved inward and slightly backward with marked backward deflection along its inner portion, which does not, however, reach occipital furrow. 2s and 3s furrows subparallel, slightly curved, directed inward and very slightly backward. Lateral glabellar lobes with slight independent convexity, most pronounced in 1p lobe. Occipital furrow deep behind 1p lobe, swings gently forward and becomes narrower and shallower along median part. Deep anterior pit located just forward of juncture of 3s furrow and axial furrow. Preglabellar furrow narrow, sharp; in anterior view it rises faintly toward midline of glabella. Anterior border moderately wide (sag.), convex; in dorsal view, its width is constant around periphery of frontal lobe; in anterior view, it is markedly broadened in its central portion due to ventral migration of rostral suture (Pl. 9, fig. 7). Rostral suture is straight, slightly narrower (tr.) than width of glabella across occipital furrow. Cheek triangular, eye located centrally on highest point from which cheek slopes away in all directions. Palpebral lobe located opposite 2p lobe and 1s furrow; moderately large, length (exsag.) one quarter that of glabella. Palpebral lobe delimited abaxially by short crescentic palpebral furrow; continuous anteriorly with faintly outlined palpebral ridge which curves forward to meet axial furrow at anterior pit. Visual surface curved moderately in a vertical plane and markedly (through 160°) in a horizontal plane. Anterior part of facial suture curves forward from palpebral ridge to a point opposite mid-length of anterior lobe, then turns forward inward in a straight path to cross anterior border and curves downward to meet rostral suture on ventral side of anterior margin. Connective suture short, straight. Rostral, hypostomal, and connective sutures (Pl. 9, fig. 33) isolate wide (tr.) and narrow (sag.) rostral plate, narrowest at mid-line, gently convex (sag.), area adjacent to hypostomal suture smooth. Posterior part of facial suture follows an evenly curved outward and downward course. Lateral border furrow broad, moderately shallow; interrupted by posterior facial suture (Pl. 9, fig. 34). Genal spine triangular, short, transversely oval in cross-section, directed obliquely backward.

On inner surface, occipital doublure curves forward to occipital furrow. Outer part of occipital furrow carries downwardly and inwardly directed tongue-shaped appendifer. 1s extended as high, thin, blade-like appendifer. 2s and 3s appear as thin ridges. Anterior and lateral doublure gently convex, of constant width. Posterior portion much narrower, continues adaxially to distal end of articulating flange halfway between genal spine and axial furrow. Inner edge of anterior portion of doublure turned slightly upward to receive anterior margin of hypostome. The fit is perfect. Deep pits on external side of cheek inside lateral border furrow, appear on interior as slightly raised nodes of very thin shell material. Glabellar interior smooth.

Hypostome sub-triangular to sub-trapezoidal in outline, length (sag.) slightly less than maximum width across anterior wings. Central body moderately convex, divided into sub-oval anterior lobe with maximum convexity just forward of line joining anterior wings and narrow, crescentic posterior lobe with slight independent convexity. Lateral, and posterior border furrows confluent, shallow and broad; anterior border furrow sharply incised, convex forwardly. Bald middle furrow initiated adaxially of shoulder, continues obliquely inward and backward to bound anterior side of small oval macula. Lateral border flatly convex, inwardly sloping, continuous with flatly convex posterior border; anteriorly it is deflected slightly outwardly and abruptly constricted at base of anterior wing. Anterior margin approximately described by 80° arc of circle with axis at mid-point of posterior border. Anterior border attenuates medially. Posterior margin evenly curved, its mid-point marked by minute dorsally deflected notch. Posterior part of doublure narrow, its inner edge with distinct upward deflection. Doublure widens and rises toward rectangular, obliquely oriented posterior wing. Shoulder prominent, evident as flexure of doublure which rises to base of posterior wing. Anterior wing high, carries small node-like wing process at the apex of its dorsal side. Between anterior and posterior wings, doublure depressed into U-shaped, posterolaterally disposed antennal notch.

Thorax of eleven segments. Entire width (tr.) of first segment four fifths and width of eleventh segment two fifths that of cranidium across tip of genal spines. Axis narrows gradually backward, width (tr.) at eleventh segment two thirds that at first. Axis convex, one third width that of entire segment. Inner portion of each pleura inflated, crossed by short, backwardly and outwardly directed pleural furrow. Articulating flange extends along edge of pleura from axial furrow to base of spines, defined by narrow flange furrow. Outer part of pleura extended into long, gradually tapering, slightly backwardly directed spines. On inner surface, outer part of articulating furrow rises to form tongue-shaped, obliquely disposed appendifer. Pleural doublure extends forward to articulating furrow and is covered by articulating half-ring of following segment.

Pygidium (without spines) sub-triangular in outline, width (tr.) twice length (sag.). Axis moderately convex at anterior margin, width (tr.) slightly less than one half total width, consists of three narrow axial rings separated by axial ring furrows. Articulating furrow descends laterally into deep appendiferal pit. First axial ring convex (sag.), terminates laterally against moderately deep, narrow axial furrow. Second and third rings moderately convex, bounded laterally by very faint axial furrows. First axial ring furrow straight between axial furrows, extended posterolaterally as deep, elongate pit (representing inter-pleural furrow). Second axial ring furrow straight, connected laterally to pair of deep, oval, posteriorly directed pits. Third axial ring furrow small, crescent shaped. First pleural furrow short, diagonal, divides narrow inflated pleura. First segment bears long, slightly curved spine which gradually tapers to blunt point. Spine transversely oval in cross-section (about twice as wide as high). In dorsal view, it is directed backward and outward for two thirds length, then backward for last one third. In lateral view, directed gently upward with gradual increase in curvature along length of spine. Spine on second segment much shorter, blunt, directed backward. Single, short, broad-based spine occupies central position. Width (tr.) of central spine twice that of second spine, length about the same. Doublure narrow, sharply flexed, distinct posterior U-shaped sulcus at posterior termination. Articulating and first axial ring furrows carry appendifers similar to, but smaller than, those on thorax. Dense, even granulation covers entire exoskeleton with following exceptions which are smooth: undersurface of genal spines and adjacent doublure; inner portion of doublure of cephalon; doublure of hypostome; and under and outer surface of thoracic spines. Posterolateral part of cephalon, just in front of spine on first thoracic segment, has scattered granules. In addition to fine granulation, cheek inside border furrows (excepting palpebral lobe and palpebral ridge) finely pitted.

Discussion. Descriptions of *Ceraurinella longispina* n. sp., *C. necra* n. sp., and *C. brevispina* n. sp. take the form of comparisons with *C. arctica* n. sp. These species are defined chiefly by the length and direction of the first pygidial spines and this information is summarized on Figure 14. Each of the species listed above possesses five pygidial spines and this feature renders them unique among the species of *Ceraurinella*. Indeed, only few cheirurid genera possess an uneven number of pygidial spines. *Paraceraurus* Mannill and *Cyrtometopus* Angelin have seven and *Osekaspis* Prantl and Přibyl has five. Of the Silurian and Devonian genera, *Cheirurus* Beyrich and *Crotolocephalina* Přibyl and Vaněk possess three pairs of pygidial spines and a short terminal mucronation which, in *Chizoon* Lane, is developed into a spine of similar size to the other pygidial spines. The uneven spine number seen in the species of *Ceraurinella* originated in a different manner than the uneven number displayed by the other genera. That is, by progressive coalescence of the third spine pair.

Ceraurinella longispina n. sp.

Plate 8, figures 1-31

1975 *Ceraurinella* n. sp. 6, Ludvigsen, Pl. 4, figs. 1, 2.

Diagnosis. A *Ceraurinella* with a parallel-sided and nearly flat glabella. Pygidium has five spines; first long (ratio of length of spine to width of pygidium across anterior margin is 1.03), strongly divergent, generally with marked upward curvature; second short, blunt, backwardly directed; median spine short, broad.

Occurrence. Upper Esbataottine Formation, Sunblood Range (A 615, P 2010, P 2038). *Ceraurinella longispina* Zone.

Material. Two hundred and fifty-six (256) individuals.

Holotype. A complete cranidium (GSC 44018) from P 2038 illustrated on Plate 8, figures 1-4, 31.

Paratypes. GSC 40413, 40414, 44019, 44025, from A 615; GSC 44021-44024, 44026-44032 from P 2038.

Discussion. The parallel-sided and nearly flat glabella and the pygidium with five spines, of which the first pair is long, divergent, and upwardly curving, readily distinguish *C. longispina* n. sp. from other species.

It is most similar to *C. arctica* n. sp. which possesses a glabella that expands slightly forward and shorter first pygidial spines. The granulate ornament on the pygidium is coarser than in *C. arctica* and is more sparsely distributed. On some specimens of *C. longispina*, the central three spines are nearly bald and the granules are confined to the tips, while other pygidia from the same sample are entirely covered by fine granules. *Ceraurinella kingstoni* Chatterton and Ludvigsen and *C. media* n. sp. from lower in the Esbataottine Formation have pygidia on which the granular ornamentation is sparsely distributed near the base of the first spines and on the central spines. *Ceraurinella arctica* from the highest Esbataottine Formation has pygidia that are completely covered by fine granules. The intermediate distributional pattern of ornamentation seen in *C. longispina* appears to reflect its derivation from *C. kingstoni* (via *C. media*) and its ancestral relationship to *C. arctica* and younger species. *Ceraurinella media* possesses a more inflated glabella that is slightly indented anteromedially, slightly smaller palpebral lobes that are located closer to the glabella, and a pygidium with straight and less divergent first spines.

The anterior cranidial border of *C. longispina* is slightly expanded medially resulting in an angulate anteromedian cranidial margin. This effect is caused by a forward migration of the rostral suture. The same feature is evident in later species of the *C. longispina-C. brevispina* lineage, but in this species the sutural shift has proceeded forward and downward across the anterior edge of the cephalon.

Ceraurinella media n. sp.

Plate 7, figures 42-53, Plate 8, figures 32-37

Diagnosis. A *Ceraurinella* with an approximately parallel-sided glabella that is moderately inflated and slightly indented anteromedially. lp lobes are moderately inflated, not isolated. Palpebral lobes are moderately small. Pygidium has five spines; first pair long, straight, directed obliquely upward and slightly outward; posterior three spines short, blunt, approximately equal in size.

Occurrences. Middle to upper Esbataottine Formation, Sunblood Range (A 385, P 1785, P 2038); Esbataottine Formation, Whittaker Range (Q 130). *Ceraurus gabrielsi* Zone and *Ceraurinella longispina* Zone.

Material. Forty-six (46) individuals.

Holotype. An incomplete cranidium (GSC 44009) from A 385 illustrated on Plate 7, figures 43-45.

Paratypes. GSC 44010-44014, 44014a, 44014b from A 385; GSC 44015-44017 from P 2038.

Discussion. Ceraurinella media n. sp. displays characters which suggest an intermediate position between *C. longispina* n. sp. and *C. kingstoni* Chatterton and Ludvigsen. Its cranidium differs in a few points from that of *C. longispina* in possessing smaller palpebral lobes that are located slightly closer to a more inflated glabella. The anterior cranidial margin of *C. media* is curved and not angular as in *C. longispina* (although it may be slightly indented medially) and the first pygidial spines are straight. The cranidium of *C. media* is less inflated than that of *C. kingstoni*, the first glabellar furrow does not reach the occipital furrow, and the palpebral lobes are slightly larger. A point of similarity is the faint V-shaped deflection of the preglabellar furrow. The pygidium of *C. media* differs from that of *C. kingstoni* in possessing less erect first spines; other features are identical. The hypostomes of *C. media* and *C. longispina* are identical and share the faint curved furrow that joins the maculae and separates the posterior from the anterior lobe. In *C. kingstoni*, the posterior and anterior lobes are continuous between the maculae.

Ceraurinella necra n. sp.

Plate 10, figures 1-30

Diagnosis. A *Ceraurinella* with a weakly inflated glabella that expands slightly forward; faintly inflated basal glabellar lobes that are nearly isolated; and relatively narrow (tr.) cheeks. Palpebral lobe is small. Pygidium has five spines; first pair longest (ratio of length of spine to width of pygidium across anterior margin is 0.70), oval in cross-section, directed backward with slight outward and upward curvature; posterior three spines short, blunt.

Occurrence. Lower Whittaker Formation, Funeral Range (C 570-590) and Whittaker Range (I 1275). *Ceraurinella necra* Zone.

Material. More than thirty (30) individuals.

Holotype. A complete pygidium (GSC 44044) from C 570-590 illustrated on Plate 10, figures 11-13.

Paratypes. GSC 44045, 44046, 44048, 44051-44055, 44057, 44058 from C 570-590; GSC 44047, 44049, 44050, 44056 from I 1275.

Discussion. Ceraurinella necra n. sp. is chiefly characterized by the length and direction of the first pygidial spine which is intermediate in size and orientation between that of *C. arctica* n. sp. and *C. brevispina* n. sp. Further differences with *A. arctica* can be summarized as follows:

1. The cheeks are narrower (tr.) and the palpebral lobes smaller.
2. The glabella is slightly narrower (tr.) and the anterior glabellar lobe is longer.
3. The ornament of granules is not as densely distributed.
4. The hypostome has narrower lateral and posterior borders.
5. The glabella is perforated by minute pits which are arranged in four irregular exsagittal rows - one pair bisecting the lateral glabellar lobes and one pair located just adaxial of inner tips of the lateral glabellar furrows - and scattered on the glabella, especially evident on the anterior lobe (Pl. 10, fig. 30).

The latter feature is one newly introduced to the *C. longispina-C. brevispina* lineage. It is definitely not a character of the two earlier species, but it appears to be present in *C. brevispina*. The function of these pits is unknown. It is unlikely

that they were the loci of sensory hairs. The arrangement of at least the larger pits in four exsagittal rows suggests that this organization may be related to the placement of the longitudinal muscles.

Ceraurinella brevispina n. sp.

Plate 10, figures 31-57

1975 *Ceraurinella* n. sp. 9, Ludvigsen, Pl. 5, figs. 14, 15.

Diagnosis. A *Ceraurinella* with a glabella that expands in front of moderately inflated basal glabellar lobes. Palpebral lobe is small, located close to glabella. Pygidium has five spines; first pair longest (ratio of length of spine to width of pygidium across anterior margin is 0.57), directed backward with faint outward and upward curvature; median three spines blunt to pointed.

Occurrence. Lower Whittaker Formation, Whittaker Range (H 1850, H 1920, H 1975, I 1350-1380, I 1410, I 1590, Q 430, Q 530); Funeral Range (C 655, ?J 220); and Dusky Range (?R 625, R 655). *Ceraurus mackenziensis* Zone and *Whittakerites planatus* Zone.

Material. About fifty (50) individuals.

Holotype. A pygidium (GSC 44059) from I 1590 illustrated on Plate 10, figures 40, 41.

Paratypes. GSC 40453, 40454, 44060, 44061, 44065, 44066, 44069, 44071 from C 655; GSC 44070, 44072, 44073 from H 1920; GSC 44062, 44067 from I 1410; GSC 44063, 44068 from I 1590; GSC 44064 from Q 530.

Discussion. Aside from the shorter first pygidial spines, *Ceraurinella brevispina* n. sp. differs from *C. necra* n. sp. by having more inflated basal glabellar lobes and slightly smaller palpebral lobes. The glabellar pitting is evident as faint "rosettes" in, for example, Plate 10, figure 52.

An interesting comparison can be made between the pygidium of *C. brevispina* and that of *Ktenoura retrospinosa* Lane (1971, Pl. 6, figs. 1-3, 5-2, 14, 15) from Wenlockian of Dudley, Worcestershire. The Ordovician species has five pygidial spines and the Silurian species has six; otherwise these pygidia are very similar and, if Lane's (1971, p. 77) suggestion about the derivation of *Ktenoura* is correct, these taxa are the respective products of parallel phylogenetic trends - *Ktenoura* from an early Silurian species of *Hadromeros* by shortening of the first pygidial spines and *Ceraurinella brevispina* from *C. longispina* by the same process.

Genus *Ceraurus* Green, 1832

Type species. *Ceraurus pleurexanthemus* Green, 1832 from the Trenton Group of New York State.

Diagnosis. A genus of Cheirurinae with forwardly expanding glabella, three pairs of generally narrow (tr.) glabellar furrows, and long genal spines. Glabellar ornament of coarse granules or tubercles, commonly paired. Hypostome triangular in outline with inflated central body, posteriorly placed maculae, and narrow convex borders. Pygidium with long curving first spines; second and third spines are either very short or completely missing.

Discussion. Species of *Ceraurus* abound in almost every trilobite fauna of Blackriveran to Richmondian age in North America. By contrast, the genus is very rare in Europe. The only definite extra-North American species is *Ceraurus proicens* Tripp, 1967 from Scotland. Other species assigned to *Ceraurus* have probably been misidentified. *Ceraurus latifrons* Warburg, 1925 from

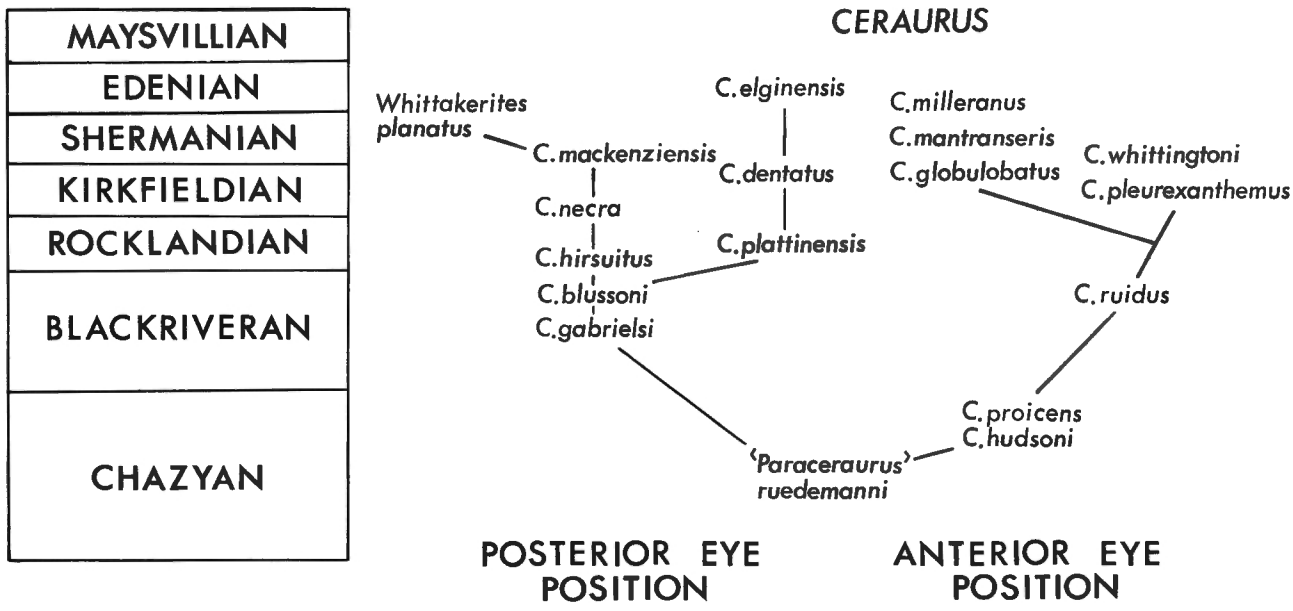

FIGURE 15. Inferred phylogeny of seventeen species of *Ceraurus* and *Whittakerites* from North America.

Balto-Scandia may belong to *Paraceraurus*. *Ceraurus kassini* Chugaeva, 1958 from Kazakhstan probably belongs to *Hadromeros*.

Ceraurus appears to have been derived from Balto-Scandian species of early Viruan age or older that have been assigned to *Paraceraurus* (Neben and Krueger, 1971); that is, *P. exsul* (Beyrich) and *P. neglectus* (Kummerow). The assignment of these species to *Paraceraurus* may be questioned because of the singularity of the type species, *P. aculeatus* (Eichwald). The older species of *Ceraurinella*, that is, *C. polydorus* (Billings) and *C.? ingrica* (Schmidt), are very similar to these species of *Paraceraurus*, suggesting that *Ceraurus*, *Ceraurinella*, and *Paraceraurus* (and possibly *Ceraurinus* and *Xylabion*, Ludvigsen, 1977a) shared a common ancestor in Arenigian or Llanvirnian strata of Balto-Scandia.

Shaw (1968), p. 72) pointed out that *Paraceraurus ruedemanni* (Raymond) from the Chazy Group differs in a few critical features from the type species, *Paraceraurus aculeatus*. Lane (1971, p. 41) assigned *P. ruedemanni*, with query, to *Xylabion*. This species, however, is considerably closer to the *Paraceraurus* and *Ceraurus* group than to the *Xylabion* and *Ceraurinus* group and is assigned herein to *"Paraceraurus"*.

Figure 15 is an attempt at relating many of the species of *Ceraurus* of Chazyan to early Late Ordovician age in North America. The figure was constructed on the assumption that a single feature, that of eye position, would remain relatively stable in descendant species. A literature search has indicated that this assumption is at least reasonable.

In the Nahanni area, the first appearance of *Ceraurus* within the zonal scheme is at the base of the *Ceraurus gabrielsi* Zone (Blackriveran). The pioneer species, *C. gabrielsi*, differs considerably from the type species, *C. pleurexanthemus* Green, in possessing pervasive ornament of spike-like tubercles, a faintly vaulted glabella, wide (tr.) lateral glabellar furrows, short (exsag.) palpebral lobes located opposite or slightly behind 2s furrows, and a wide pygidium with short and backwardly directed first spines. High in the *C. gabrielsi* Zone occurs a derivative species, *C. blussoni*, in which the tubercles on the cephalic border and pygidium are supplanted by fine granules and the genal and pygidial spines are longer and more divergent. Still higher in the succession occurs *C. hirsutus* in which the granules on the cephalic borders and pygidium are replaced by fine hair-like spines and the genal and pygidial spines are very long, stout, and curving. These three species occur in the Blackriveran to Rocklandian interval in the Nahanni area and constitute a graded series. The eyes of these species are opposite or slightly behind the 2s furrow, the glabellae are sub-rectangular in outline, and the lateral glabellar furrows are broad (tr.). The replacement of coarse ornament by fine ornament on the borders of these species and the gradual lengthening

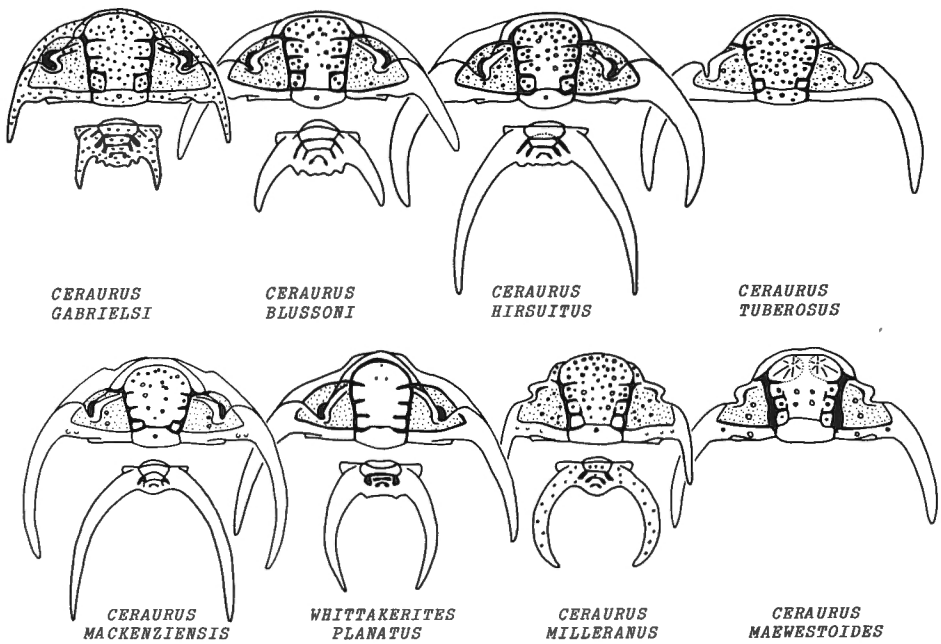

FIGURE 16. Outline drawings of cephala and pygidia of seven species of *Ceraurus* and one species of *Whittakerites* from the Esbataottine and lower Whittaker Formations of the South Nahanni River area. Not to scale.

of the genal and first pygidial spines is significant because it coincides with a habitat shift of the species from the shallow Biofacies I (*C. gabrielsi* and *C. blussoni* = *Ceraurus* I in Ludvigsen, 1978c) to the deeper Biofacies II and III (*C. hirsuitus* and all later species = *Ceraurus* II in Ludvigsen, 1978c).

Ceraurus hirsuitus is followed by two species in succession, *C. tuberosus* Troedsson and *C. mackenziensis*, of Rocklandian to Shermanian age. These species maintain the gross morphology of the parent species with a few modifications; the glabellae become strongly forwardly expanding, the glabellar furrows narrower (tr.), the palpebral lobes longer (exsag.), and the tuberculate ornament sparser. In the final species of the lineage, *Whittakerites planatus*, of Shermanian or Edenian age, the tuberculate ornament has completely disappeared, the glabella is gently vaulted and expands only slightly forward, the glabellar furrows wider (tr.), and the eyes are shifted posteriorly to opposite 1s furrow.

The five species of *Ceraurus* and the single of *Whittakerites* from the Nahanni area are considered a graded morphologic and phylogenetic series. This series sees a lengthening of genal and first pygidial spines, a shortening and complete disappearance of the posterior pygidial spine pairs, and changes in ornament from spike-like tubercles to sparser and subdued tubercles to a total effacement of tubercles. Throughout this series, the eye remains in a position opposite or posterior to 2s furrow.

If the eastern North American species of *Ceraurus* are considered, a slightly different picture emerges. *Ceraurus* makes its appearance considerably earlier here than in the Nahanni area. Already by the Chazyan, two "kinds" are present: *"Paraceraurus" ruedemanni* (Raymond) and *Ceraurus hudsoni* Raymond, both occurring in the Chazy Group. The provenance of these species within the Chazy Group is important because it provides additional evidence about a possible correlation between morphology and habitat preference. According to Shaw (1968, p. 72), *"P." ruedemanni* and *C. hudsoni* have not been collected at the same localities. The former is restricted to reef limestones of the Valcour Formation and the latter to off-reef silty limestones and calcarenites of the Crown Point and Valcour Formations. *"Paraceraurus" ruedemanni* is similar to the slightly younger *C. gabrielsi* from which it differs by its longitudinal glabellar furrows and its unique pygidium with elongate second spines. Both species appear to be restricted to shallow habitats. By contrast, *C. hudsoni* possesses very long genal spines (the pygidium of this species has not yet been found, but the first pygidial spines are presumably of similar length as the genal spines, in view of the close size correspondense in other species of *Ceraurus*) and is similar to both the younger *C. hirsuitus* and subsequent species from the Nahanni area and to the younger *C. ruidus* Cooper and subsequent species from eastern North America. These species appear to be components of deeper platform biofacies than those occupied by *"P." ruedemanni* and *C. gabrielsi*.

In the Nahanni area, the morphological shift evident in the *C. gabrielse* to *C. hirsuitus* lineage corresponds to a biofacies shift of these species from Biofacies I to Biofacies II during the late Blackriveran to Rocklandian. An analogous morphology and habitat shift, predating those from the Nahanni area, probably occurred in eastern North America during the Chazyan.

Ceraurus ruidus Cooper, *C. whittingtoni* Evitt, and *C. pleurexanthemus* Green appear in Blackriveran to Shermanian strata of eastern North America. These species are similar to each other and to *C. hudsoni*, and also to the contemporary lineage of *C. hirsuitus* to *C. mackenziensis* of the Nahanni area. The eastern species group differs from the Nahanni species group principally in having the eyes located in front of 2s furrow and in possessing small palpebral lobes.

Another eastern group of "Trentonian" age, consisting of *Ceraurus globulobatus* Bradley and *C. mantranseris* Sinclair, and characterized by markedly expanding glabellae of moderate convexity, probably shared a common ancestry with *C. pleurexanthemus* and, indeed, can only be distinguished from this species with difficulty. The Edenian and younger species, *C. milleranus* Miller and Gurley, show particular affinity with *C. mantranseris*. These species maintain the eye position opposite 3p lobe or, occasionally, opposite 3s furrow.

In conclusion, the bulk of Rocklandian to Edenian species of *Ceraurus* (and *Whittakerites*) from the Nahanni area and from eastern North America are generally similar in most features, but differ consistently in the position of the eye - the northern species group has eyes opposite or behind 2s furrow while the eastern group has eyes opposite or in front of 3p lobe. The occurrence of "out of place" species in either area can be explained by a breakdown of isolation following the extensive "Trentonian" transgression. An example is the presence, in the Trenton Group, of *Ceraurus dentatus* Raymond and Barton whose eye position and other features indicate a derivation from *C. hirsuitus* or an allied species of the northern group. Other examples are the occurrences of *C. milleranus* and *C. maewestoides* in the Edenian of the Nahanni area. The history of these two species lies with species of the eastern group.

The difference between the northern and the eastern species groups reflects either a separate post-Chazyan evolutionary history of these two groups or the existence of single evolving species complex of *Ceraurus* during the Middle Ordovician, the extremities of which (northern Canada and eastern North America) may have been reproductively isolated from each other even though they were connected by a chain of interbreeding populations.

Ceraurus gabrielsi n. sp.

Plate 11, figures 1-44, Plate 12, figures 1-49, Plate 13, figures 1-8

1975 *Ceraurus* n. sp. 1, Ludvigsen, Pl. 4, figs. 13, 14.

1975 *Ceraurus* n. sp. 2, Ludvigsen, Pl. 4, figs. 24, 25.

Diagnosis. A *Ceraurus* with a lowly vaulted cephalon and short genal spines. Glabellar furrows wide (tr.), 1p lobe isolated. Palpebral lobe small, located opposite or just behind 2s furrow. Pygidium wide, bears three marginal spine pairs; anterior spine pair longest, diverges very slightly; posterior spine pairs very short. Ornament of scattered large thorn-like tubercles and coarse granules.

Occurrences. Middle and upper Esbataottine Formation, Sunblood Range (A 365, P 1665-1685, P 1785, P 1870, P 1931, P 1945-1955) and Whittaker Range (H 900, H 1020). Upper Sunblood Formation, Natla River (D 1375). *Ceraurus gabrielsi* Zone.

Material. One hundred and eighty (180) individuals.

Holotype. Nearly complete cranidium (GSC 44074) from P 1945-1955 illustrated on Plate 12, figures 1-3.

Paratypes. GSC 40425, 40426, 44075-44093 from P 1685; GSC 44127, 44128 from P 1870; GSC 44094-44097, 44107, 44126 from P 1931; GSC 40435, 40436, 44098-44106, 44108-44125 from P 1945-1955.

Description. Cranidium semi-circular in outline, moderately vaulted. In lateral profile, posterior portion of glabella horizontal, anterior portion slopes steeply. Glabella moderately inflated, sub-rectangular in outline, expands slightly to markedly forward to maximum width across anterior lobe which is three fourths glabellar length (sag.). First glabellar furrow moderately deep, straight, extends slightly over one quarter way across glabella; connected to occipital furrow by slightly shallower, straight exsagittal furrow. Second and third furrows narrower (exsag.) and shallower than 1s, about the same width (tr.), nearly transversely directed with slightly backward curvature; sub-parallel, extend about one third way across glabella. 1p lobe isolated, roughly square in outline, slightly inflated; 2p and 3p lobes about the same length as 1p lobe, rectangular in outline, slightly inflated. Anterior lobe slightly greater than twice as wide as long; front edge evenly rounded. Anterior border moderately narrow, curved, becoming slightly longer (exsag.) laterally. In anterior view, preglabellar furrow rises slightly toward mid-line in even curve. Axial furrows moderately deep, diverge forwardly; each terminates in small anterior pit located just ahead of 3s furrow at junction with lateral border furrow. Occipital ring arched, lenticular to rectangular in outline, sagittal length approximately equal to length of 1p lobe; carries small median node. Occipital furrow nearly transverse; slightly deflected posteriorly behind 1p lobe. Cheek broadly triangular in outline, moderately convex (tr. and exsag.). Palpebral lobe small, crescentic, located far out on cheek; its midpoint is opposite or just behind 2s furrow; stands slightly below crest of glabella; continuous anteriorly with long and convex (tr.) palpebral ridge which proceeds forward and inward along straight path to meet axial furrow at, or just behind, 3s furrow. Palpebral furrow S-shaped, deep and short at mid-length of palpebral lobe; posteriorly it becomes narrower and curves laterally for a short distance before fading out behind visual surface of eye; anteriorly it becomes a row of pits that defines the adaxial side of palpebral ridge. Visual surface of eye not preserved; its base is curved through about 180°. Cheek, below eye, slopes steeply to lateral border furrow which follows even arc between right-angled juncture with posterior border and anterior pit. Lateral border furrow narrow and moderately deep, V-shaped in cross-section; posterior border transverse, slightly wider than lateral border furrow. Lateral border wide, evenly convex; extended posteriorly into relatively short, gradually tapering genal spine which is directed backward and slightly outward. Posterior border, initially, narrower (exsag.) than lateral border; approximately transversely directed, but follows slight curve around outer edge of articulating flange; distal part flatly convex and slightly wider (exsag.), curves down to base of genal spine. Anterior branch of facial suture proceeds forward and inward from palpebral lobe along straight path to cross anterior part of lateral border furrow and then toward mid-line along anterior margin of cephalon. In anterior view, suture follows stretched W-shaped path which is approximately parallel with preglabellar furrow; at the ventral edge of the "W", suture is joined by strongly dorsally divergent connective sutures. Posterior branch of facial suture follows even curve with slight forward convexity to point just past lateral border furrow, then it is sharply deflected backward to cross lateral border in straight line.

Three pits, or groups of pits, arranged in a triangle on anterior glabellar lobe. The forward pit is located on sagittal line just behind preglabellar furrow (Pl. 13, fig. 4). This pit may be replaced by 2 or more pits arranged in sagittal row (Pl. 11, fig. 3), by a diffuse group of pits (Pl. 13, fig. 3), or by 3 or more pits arranged in a row along the posterior side of the preglabellar furrow (Pl. 11, fig. 41). Posterior pair of pits flank sagittal line in front of, and just inside, adaxial edge of 3s furrows (Pl. 11, figs. 3, 41, Pl. 13, figs. 3, 4).

Dorsal surface of cephalon covered by relatively sparsely distributed and thorn-like to rounded tubercles which are superimposed on extremely fine background granulation. On the glabella, these tubercles commonly occur in scattered clusters [especially in collections from the lower and middle *Ceraurus gabrielsi* Zone (Pl. 11, fig. 3, Pl. 13, fig. 5)]. On the lateral and anterior cephalic borders and on the palpebral lobe and palpebral ridge, the tubercles are finer, more numerous, and of more rounded profile. Cheek, inside border furrows (with exception of palpebral lobe and palpebral furrow), rather coarsely pitted.

On interior, convex lateral doublure extends to impress of lateral border furrow. Posteriorly, doublure flattens and attenuates toward distal part of articulating flange. Anterior doublure includes rostral plate and is flatly convex and slopes posterolaterally. Adaxial part of 1s and corresponding part of 0s extended into high, spindle-shaped appendifers. Anterior pit expressed as high, mound-like elevation with a distinct and large pit on its anterior side.

Hypostome sub-triangular in outline, length (sag.) slightly less than maximum width (tr.) between anterior wings. Egg-shaped central body narrows backward from maximum width between anterior wings. It includes a pair of faintly expressed and oval maculae located at the confluence of the lateral and posterior border furrows. Lateral border furrows deep and wide (tr.) behind shoulders; converge slightly backward to merge with shallower posterior border furrow in even curve. Posterior border moderately narrow (sag.), merges with lateral border (a few specimens possess a tiny posterolateral spine), which expands slightly into rounded shoulders. Anterior border eliminated medially by anterior margin which reaches central body. Anterior border furrow, however, is complete and is expressed medially as a horizontal constriction at anterior margin (Pl. 12, fig. 32). Ventral surface of hypostome finely tuberculate, except within furrows and on posterior part of central body. A sagittal strip on the hypostome carries tiny circular impressions which appear as a broad row of pits (Pl. 12, figs. 31, 35, 38). The functional significance of these pits is not known. Similar pits and areas of thin shell material, in other parts of the *Ceraurus* exoskeleton and in other genera, have been interpreted to represent muscle attachments. It is possible that here they represent attachment points of muscles that support the

digestive tract. In this regard, it is important to note that the strip of pits on the hypostome is in direct line with the triangular pattern of pits on the anterior glabellar lobe. These pits may represent the ventral and anterior attachment points of the same muscle support system. On interior, doublure widens and rises forwardly from its narrowest point at posterior edge into a pair of high, obliquely disposed and plate-like posterior wings that restrict access to the opening into the hypostomal interior (Pl. 11, figs. 30, 33). In front of posterior wings, doublure descends abruptly into broad anterolaterally disposed antennal notch and then is recurved into a pair of triangular anterior wings. Posteroventral face of anterior wings impressed by deep elongate slot which, on anterodorsal face, appears as a stout, dorsally directed wing process. Anterior margin of hypostome from base of anterior wings consists of sharp-edged sutural contact with doublure and rostral plate. Because this contact is curved in both horizontal and vertical planes, movement of the hypostome would not be allowed (if the wing processes of the hypostome remain in contact with the anterior pit of the cephalic interior).

Number of thoracic segments not known. Axis convex, slightly less than one third width of segment. Articulating furrow shallow and long (sag.) medially, becomes deeper as it swings slightly forward laterally. Axial furrows narrow (tr.) and rather shallow. Inner portion of pleura inflated; diagonally crossed by deep pleural furrow which is directed posterolaterally. Outer part of pleura extended into gradually tapering, downwardly and outwardly curving spine which, distally, is distinctly faceted into anterolateral, lateral, and proximal facets - the juncture of each is marked by a row of tubercles (Pl. 11, figs. 28, 29, Pl. 13, fig. 2). Horizontal part of pleura bounded by anterior and posterior flanges that terminate distally in prominent marginal connective device and are defined on dorsal surfaces by deep flange furrows. Other articulating devices include axial furrow socket and process and ring socket and process. On interior, distal part of articulating furrow extended as high, tongue-shaped appendifers.

Pygidium, without spines, semicircular in outline, large, slightly vaulted (tr.) and nearly flat (sag.). Axis consists of articulating half ring, three lowly arched rings, and a transversely oval terminal piece. Anterior two rings (rarely third ring) defined laterally by narrow (tr.), shallow, and forwardly diverging axial furrows. Articulating furrow straight and short (sag.); first and second ring furrows somewhat longer (sag.), straight, deepest distally; third axial ring short (tr.), arched forward between a pair of small pits. Axial rings slightly convex (sag.), narrowing (tr.) and becoming shorter (sag.) posteriorly. Third axial ring and terminal piece poorly differentiated from pleural region. Pleural region moderately narrow; inflated opposite first axial ring and crossed by short diagonal pleural furrow. Flange furrow initiated by articulating furrow; isolates very narrow anterior band which, distally, lengthens into prominent marginal connective device. First and second interpleural furrows initially deep; proceed obliquely outward and backward from distal ends of first and second axial ring furrows; become shallower toward posterior margin where they divide bases of marginal spines. Third interpleural furrow represented by deep pits at lateral ends of terminal piece. First marginal spine of variable size and orientation; generally slender, backwardly and upwardly directed with slight outward curvature, broad based and gradually tapering to fine point; length equal to, or less than, width of pygidium across anterior margin (but varies considerably; compare Pl. 11, fig. 12 and Pl. 12, fig. 14; Pl. 11, fig. 17 and Pl. 12, fig. 18). Distal parts of spines generally parallel [but again, varies considerably; some are nearly parallel for their total length (Pl. 11, fig. 43, and Pl. 12, fig. 20) whereas others are evenly divergent (Pl. 13, fig. 8)]. Second and third pairs of marginal spines very short, triangular in larger specimens, lobate in smaller specimens; directed backward and slightly inward. Third spine pair separated by median convex portion which extends as far posteriorly as third spine pair and, in rare small specimens (Pl. 12, fig. 17) appears as a tiny fourth spine pair. Marginal spines elevated above narrow rim which constitutes posterior margin of pygidium. Doublure narrow, angulate, in posterior view, arched upward medially. Tiny appendifers appear on the distal ends of articulating furrow and axial ring furrows. Dorsal surface of pygidium covered by relatively large, thorn-like tubercles and coarse granules superimposed on extremely fine background granulation (Pl. 12, fig. 24). A nearly bald and U-shaped strip traverses bases of second and third spines and terminal piece.

Discussion. *Ceraurus gabrielsi* n. sp. is a relatively long-ranging species which, in Section P, extends through nearly 90 m of strata within the middle and upper Esbataottine Formation. Considerable variation is evident within this range and, initially, it was thought that two species were present [reflected in the recognition of *Ceraurus* n. sp. 1 and *Ceraurus* n. sp. 2 (Ludvigsen, 1975, Pl. 4, figs. 13, 14, 24, 25)]. The earlier specimens of *C. gabrielsi* at Section P (from P 1685; Pl. 11, figs. 1-36) tend to have more forwardly expanding glabellae, finer tuberculate ornament on the cephala, and shorter first pygidial spines than the later specimens (from P 1931 and P 1945-1955; Pl. 11, figs. 37-44, Pl. 12, figs. 1-49). In addition, the occipital rings of the earlier specimens tend to be bald. These apparent differences are diminished when the significant intra-population variation of the species is taken into account and are not now thought to be grounds for species separation.

A few pygidia of *Ceraurus gabrielsi* are very similar to those of *C. blussoni* n. sp. (for example, Pl. 12, figs. 14-16), but they differ in possessing a coarser granulate and tuberculate ornament and less erect and less divergent first pygidial spines. Further differences with *C. blussoni* are covered under that species.

Aside from the species in the Nahanni area, *Ceraurus gabrielsi* is somewhat similar to *"Paraceraurus" ruedemanni* (Raymond) from the Chazy Group in New York (Shaw, 1968, p. 70-73, Pl. 15, fig. 34, Pl. 16, figs. 1-11). Detailed comparison is difficult because the material of *"P." ruedemanni* is significantly larger than any available of *C. gabrielsi*. The Chazy species, however, is clearly distinguished by its unique pygidium with elongated second pygidial spines and the presence of longitudinal glabellar furrows that join the adaxial tips of the lateral glabellar furrows. A number of features of *"P." ruedemanni* indicate affinity with *C. gabrielsi* - the slightly inflated glabella with a subrectangular outline and wide (tr.) lateral glabellar furrows, the relatively short divergent genal spines, the small palpebral lobes located far out on the cheek

and opposite 2p lobe, the long and convex palpebral ridges, and the large and lowly vaulted pygidium. These features also serve to distinguish *"P." ruedemanni* and *C. gabrielsi* from younger species of *Ceraurus* in eastern North America.

Ceraurus gabrielsi is similar to *C. proicens* Tripp, 1967 from the upper Stinchar Limestone, Girvan but the latter species may be distinguished by the coarser tuberculate ornament on the glabella and the markedly divergent first pygidial spines.

Finally, a similarity of *Ceraurus gabrielsi* with certain Balto-Scandian species is important because it provides some evidence of the origin of this typically North American Ordovician genus. These species are *"Paraceraurus" exsul* (Beyrich) (Neben and Krueger, 1971, Pl. 26, figs. 20-22) from erratic boulders from the "oberen grauen Orthocerenkalk" of early Viruan age (Chazyan and slightly older; Bergström, 1971) and *Paraceraurus aculeatus* (Eichwald) (Öpik, 1937, Pl. 17, figs. 1-7) from the Kukruse Stage (Chazyan and Blackriveran; Bergström, 1971). Shaw (1968) assigned *Ceraurus ruedemanni* to *Paraceraurus* and, although this generic assignment may be open to question (Lane, 1971), it does direct attention to the affinity of the Chazy species to *Paraceraurus aculeatus*. *"Paraceraurus" exsul* has a long (sag.) parallel-sided and rather flat glabella, wide (tr.) lateral glabellar furrows, and small palpebral lobes located far out on the cheek and opposite 1s furrow. It differs from *C. gabrielsi*, chiefly by possessing longer genal and first pygidial spines.

Ceraurus gabrielsi and *"Paraceraurus" ruedemanni* may be viewed as taxa that provide a link between contemporary and older species of *Paraceraurus* and *"Paraceraurus"* from Balto-Scandia and younger species of *Ceraurus* from North America.

Ceraurus blussoni n. sp.

Plate 13, figures 9-29

Diagnosis. A *Ceraurus* with a sub-rectangular glabella, moderately arched (tr.) cranidium and moderately long genal spines. Cranidial ornament of fine granules superimposed on coarse tubercles. Pygidium semi-circular in outline; first spine is moderately long, second and third are very short.

Occurrence. Upper Sunblood Formation, Mary Range (B 1450). *Ceraurus gabrielsi* Zone.

Material. Fifteen (15) individuals.

Holotype. A cranidium (GSC 44129) from B 1450 illustrated on Plate 13, figures 9-11, 16.

Paratypes. GSC 44130-44141 from B 1450.

Discussion. *Ceraurus blussoni* n. sp. differs from *C. gabrielsi* n. sp. in having larger palpebral lobes, longer and more divergent genal and first pygidial spines, somewhat deeper lateral glabellar furrows, a sparser glabellar ornament consisting of larger and more rounded tubercles, and cephalic borders and pygidium ornamented by fine granules. From *C. hirsuitus* n. sp., *C. blussoni* differs in having shorter genal and first pygidial spines, a pygidium of semi-circular outline, a more rounded anterior facial suture/rostral suture continuum, less expanded (exsag.) distal portions of the anterior border of the cranidium, and by possessing an ornament of fine granules on the cephalic borders, thoracic segments, and pygidium.

A comparison of Plates 11, 12, 13 and 14 illustrates the similarities between *Ceraurus gabrielsi*, *C. blussoni* and *C. hirsuitus*. *Ceraurus blussoni* is interpreted as a morphological intermediate between *C. gabrielsi* and *C. hirsuitus*. The horizon yielding *C. blussoni* (high in the *C. gabrielsi* Zone at Section B) strongly suggests that this species may be a temporal intermediate, as well.

Ceraurus hirsuitus n. sp.

Plate 14, figures 1-25

1975 *Ceraurus* aff. *dentatus* Raymond and Barton, Ludvigsen, Pl. 4, figs. 3, 4.

Diagnosis. A *Ceraurus* with a sub-rectangular and weakly inflated glabella, wide (tr.) lateral glabellar furrows, eye located opposite 2p lobe, long stout and curving genal spines, and a relatively broad preglabellar field. Pygidium has a pair of very long, divergent spines followed by two small spine pairs. Glabella is coarsely tuberculate. Cephalic borders, genal spines, thoracic segments, and pygidium are non-tuberculate and covered by fine, hair-like spines.

Occurrence. Upper Esbataottine Formation, Sunblood Range (P 2010, P 2038, P 2050) and Flood Creek (?G 3340). *Cerauriella longispina* Zone.

Material. Thirteen (13) individuals.

Holotype. An incomplete cranidium (GSC 40415) from P 2038 illustrated on Plate 14, figures 1, 2.

Paratypes. GSC 40416, 44143-44155 from P 2038.

Description. Cranidium crescentic in outline; three times as wide across base of genal spines as long (sag.); moderately (tr.) and gently convex (sag.). Glabella sub-rectangular in outline; expands slightly forward to maximum width across anterior lobe which is equal to three quarters length (sag.). Glabella rises steeply out of flanking furrows, but median portion only slightly vaulted. Three pairs of moderately deep, lateral glabellar furrows oriented approximately perpendicular to axial furrows. 1s deep and long (exsag.); transversely directed; extends about one quarter across glabella; deep exsagittal furrow runs directly back to occipital furrow from inner end of 1s furrow. 2s and 3s furrows slightly wider (tr.) and shorter (exsag.) than 1s, transversely directed or with faint forward curvature. 1p lobe quadrate in outline, faintly inflated. Anterior lobe sub-rectangular in outline with evenly curved anterolateral corners; nearly three times as wide (tr.) as long (sag.). Median part of glabella has slight increased convexity and transverse portion immediately in front of occipital furrow swollen. Axial furrows moderately deep; diverge slightly forwardly to rather shallow anterior pit at 3s furrow. Occipital furrow broad (sag.) and ddep, nearly transverse but bowed slightly around posterior portion of 1p lobe. Occipital ring elliptical in outline; stands slightly higher than rest of glabella; protrudes posteriorly in broad arc; contains tiny median node. Anterior border slightly convex; narrow (sag.) and

rectinilinear medially, becomes longer (exsag.) distally. Cheek semi-oval in outline, slightly wider (tr.) than long (exsag.), moderately (tr.) and faintly convex (exsag.). Eye occupies mid-point of cheek, opposite 2p lobe; stands nearly as high as highest part of glabella. Palpebral lobe S-shaped; posteriorly, it curves around back edge of eye and, anteriorly, it merges with faintly convex palpebral ridge which proceeds obliquely inward in straight line to anterior pit. Visual surface of eye not seen, but its base is moderately curved in horizontal plane. Anterior branch of facial suture proceeds forward and inward in straight line to point just past anterior border furrow of cheek, then curves inward sub-parallel with preglabellar furrow and is joined by connective suture. In dorsal view the course of the rostral suture is straight; in anterior view the suture rises slightly toward sagittal line. Rostral plate not seen, but, judging by width (tr.) of rostral suture, must be as wide (tr.) as glabella across occipital furrow and probably rather short (sag.). From posterior edge of eye, facial suture swings outward with forward curvature. Border furrows of cheek moderately deep and narrow, V-shaped in cross-section. Lateral border furrow evenly bowed outward; joins nearly straight posterior border furrow at about 60°. Posterior border initially about half as wide (exsag.) as occipital ring; lateral to marginal connective device, posterior margin deflected backward before merging with genal spines. Lateral border broad and evenly convex; extended directly into a stout, gradually tapering genal spine which, initially, curves backward and outward and, distally, curves slightly inward. Genal spine oval in cross-section; extends posteriorly a distance equal to length of glabella.

Glabella, excluding occipital ring, covered by coarse, non-perforate tubercles which become somewhat denser toward front. Portion of glabella immediately in front of occipital furrow commonly non-tuberculate. Except for three pairs of tubercles arranged in two rows on mid-portion of glabella, tubercles are randomly distributed. Slightly smaller tubercles occur on cheek inside border furrow, excluding palpebral lobe but including palpebral ridge. Sparse tubercles stud posterior border of cheek; including single larger tubercle located above half-width of flange furrow. Entire cheek inside border furrow, except palpebral lobe and palpebral ridge, finely pitted. In addition, entire cephalon (and thoracic segments and pygidium) covered by very fine, hair-like spines. These spines also cover the outer half of cephalic doublure, but become somewhat coarser. Three or more small pits define corners of triangle located on mid-portion of anterior glabellar lobe.

Number of thoracic segments unknown. Axis high and arched. Articulating furrow straight medially; forwardly curving and deepest distally. Axial furrows relatively shallow, bowed outwardly. Pleura half as wide (tr.) as axis; inner two thirds strongly inflated, crossed by deep, diagonal pleural furrow. Outer part of pleura extended into relatively long spine which is directed downwardly, slightly outwardly, and progressively backwardly and inwardly toward posterior. Anterior edge of spine faceted. Articulating devices consist of a horizontal articulating flange that terminates distally in a prominent right-angled marginal connective device. Other articulating mechanisms consist of axial furrow socket and process, and ring socket and process. On interior, appendifers high and spindle-shaped.

Pygidium, exclusive of first spines, rectangular in outline, twice as wide (tr.) as long (sag.). Axis moderately arched; consists of 3 axial rings and rectangular terminal piece which decrease in width (tr.), length (sag.), and convexity toward rear. Axial furrows shallow and faint; obliquely disposed opposite each axial ring; converge toward rear in serrated fashion. Axial ring furrows moderately deep and straight between axial furrows; first furrow preceded by lenticular depressed portion containing a pair of transversely elongated bald spots. Deep interpleural furrows extend posterolaterally from distal ends of first and second axial ring furrow, shallowing markedly posteriorly. Similar interpleural furrow extends from third axial ring furrow and terminates in deep, circular or oval pit. Faint pleural furrow opposite first ring. Anterior pair of spines long, gradually tapering, gently outwardly and backwardly curving; in lateral view, spines directed obliquely upward at about 25°. First spines extend posteriorly a distance equal to twice width of pygidium at anterior margin. Second pair of spines very small, triangular. Third pair of spines smaller than second set; separated by broad, faintly curving median portion.

Discussion. The relatively wide (tr.) and short (exsag.) lateral glabellar furrows, the sub-rectangular and weakly inflated glabella, and the pygidium with a rectangular central part and possessing two small pairs of spines behind the first pair distinguished *Ceraurus hirsuitus* n. sp. from the type species, *C. pleurexanthemus* Green, *C. whittingtoni* Evitt, *C. tuberosus* Troedsson, *C. mackenziensis* n. sp., *C. globulobatus* Bradley, *C. milleranus* Miller and Gurley, and *C. mantranseris* Sinclair.

From *Ceraurus ruidus* Cooper (including *C. breviceps* Cooper, *C. convexus* Cooper, and *C. trapezoidalis* Esker; see Shaw, 1974, p. 29); *C. proicens* Tripp, 1967; and *C. hudsoni* Raymond, 1905; *C. hirsuitus* differs by possessing a more posteriorly placed eye, a sparser tuberculate ornament, a cephalic border that lacks tubercles, a broader preglabellar field, less inflated glabella, and stouter genal spines.

Ceraurus hirsuitus is most similar to the species group clustered around *C. dentatus* Raymond and Barton, 1913 and including *C. plattinensis* Foerste, 1920 and a manuscript species described by DeMott (1963, p. 137, Pl. 9, figs. 8-16, Pl. 10, figs. 4-7). These species possess sub-rectangular, slightly to moderately inflated glabellae with relatively wide (tr.) lateral glabellar furrows, eyes located opposite 2p lobe, long stout genal spines, and cephalic borders, genal spines, and pygidium lacking tubercles. *Ceraurus plattinensis* possesses a narrow preglabellar field, rounded anterolateral cranidial corners, inflated lateral glabellar lobes, and a very wide (exsag.) and deep 1s furrow and thus differs from *C. hirsuitus*.

Use of the name *Ceraurus dentatus* Raymond and Barton involves difficulties. The holotype (GSC 1775) was collected by Sir William Logan from an unknown stratigraphic horizon (possibly lower Trenton Group) at Vankleek Hill, east of Ottawa (Raymond, 1921). Although this specimen has been illustrated several times (Raymond and Barton, 1913; Raymond, 1921; Wilson, 1947), uncertainty exists about some of the features; for example, the extent to which it is exfoliated, the nature of the fine ornament (if any), and the exact configuration of the anterior portion of the

cephalon. The type specimen has since been lost (Bolton, 1966, p. 50) and, because the locality data are not sufficiently precise to allow a search for topotypic material, a problem exists about the diagnostic features of *C. dentatus*. The uncertainty surrounding the exact identity of *C. dentatus* makes it unwise to use this name until a neotype can be designated.

Ceraurus hirsuitus is a very rare species that occurs in only three collections from the highest beds of the Esbataottine Formation at Section P. The three collections have yielded over a thousand trilobite individuals, of which only thirteen belong to *C. hirsuitus*. This paucity stands in sharp contrast to the abundance of *C. gabrielsi* from lower in the Esbataottine and *C. mackenziensis* from the overlying Whittaker Formation. An examination of the specimens illustrated on Plate 14 will demonstrate that most of the skeletal fragments of *C. hirsuitus* are extensively encrusted by bryozoans. Most of the bryozoans probably grew on exuviae because commonly a single colony can be traced around sutural edges from the dorsal to the ventral side. It is quite possible, however, that the living trilobite acted as a host for some of the bryozoans.

A single cranidium (Pl. 14, figs. 16-19) displays a unique feature. The base of the right genal spine and adjacent genal corner of this specimen is deformed into a gall-like structure. On the dorsal side, this is expressed as a swelling on the area below the eye and extending to the lateral margin. This is accompanied by a slight forward displacement of the posterior branch of the facial suture and a near total effacement of the border furrow and cheek pitting at and inside the genal angle. On the ventral side, the doublure (as far inward as the marginal connective device) is stretched forwardly and inwardly as shown by the path of the facial suture. Only the basal portion of the genal spine is preserved, but it appears that the direction and, presumably, the length of the spine was not materially altered. Likewise, the swelling terminated just below the eye and just lateral to the articulating flange indicating that neither the vision nor the articulating ability of the trilobite was seriously impaired. The gall-like structure probably reflects the trilobite's response to a parasite. The infestation was localized in non-critical parts of the host's anatomy and, apparently, did not seriously hamper the vision, locomotion, or feeding of the trilobite. The parasite may have had access to the mouth of the trilobite because, on the interior, a narrow transverse furrow crosses the ridge formed by the axial furrow immediately behind the first glabellar furrow (Pl. 14, figs. 18, 19). This transverse furrow may indicate the course of some kind of conduit because it falls on a line which joins the centre of the gall and the presumed position of the mouth between the first glabellar lobes.

One can only speculate on the identity of the parasite, but the morphology of the gall is very similar to the ones recently described by Warn (1974) from columns of the Late Ordovician crinoid, *Heterocrinus*, and attributed to myzostomid infestation. Warn (1974, p. 506) noted that:

> Myzostomes are peculiar polychaete annelids, abundantly, and almost exclusively, parasitic on Recent crinoids. Most are ectoparasites that steal food from the ambulacra, but a few are endoparasites that form reproductive galls in crinoid arms and pinnules.

It seems quite feasible that similar worms were responsible for the gall in *Ceraurus hirsuitus*.

Ceraurus tuberosus Troedsson, 1928

Plate 17, figures 36-41

1928 *Ceraurus tuberosus* Troedsson, p. 71, Pl. 18, figs. 1-9 (not Pl. 17, fig. 13).

Occurrences. Cape Calhoun Formation at Cape Calhoun, northern Greenland and lower Whittaker Formation, Whittaker Range (I 1275). *Ceraurinella necra* Zone (in Canada).

Material. Eight (8) individuals.

Lectotype. Herein designated. An incomplete cranidium (Troedsson's no. 310) from the Cape Calhoun Formation illustrated by Troedsson (1928, Pl. 18, fig. 3).

Hypotypes. GSC 44240-44243 from I 1275.

Discussion. The material from the Whittaker Formation meets all essential criteria of *Ceraurus tuberosus* from the Cape Calhoun Formation, northern Greenland. The forwardly expanding glabella, the small isolated 1p lobe, the position of the palpebral lobes opposite 2p glabellar lobe, the long genal spines, and the densely tuberculate glabella are deemed particularly important. These features also serve to distinguish this species from the other Middle and Upper Ordovician species of *Ceraurus* from eastern North America. The pygidium illustrated by Troedsson (1928, Pl. 17, fig. 13) is excluded from *C. tuberosus* because it is very similar to the pygidia of *C. milleranus* from the Whittaker Formation (Pl. 15, figs. 53, 54, 56, 57).

Of the other species of *Ceraurus* from the Mackenzie Mountains, *C. tuberosus* is most similar to *C. mackenziensis* n. sp., but differs by possessing coarse tuberculate ornament, a shorter (sag.) preglabellar field, and a shorter (sag.) and more squat glabella. The anterior course of the facial suture of *C. tuberosus* runs along the front edge of the palpebral ridge, while in *C. mackenziensis* it passes well in front of it. In the Whittaker Formation, *C. tuberosus* is older than *C. mackenziensis* and could well have served as its ancestor.

Ceraurus mackenziensis n. sp.

Plate 15, figures 1-44

1928 *Ceraurus* cf. *pleurexanthemus* Green, Troedsson, p. 68, Pl. 16, fig. 22 (not figs. 20, 21).

1975 *Ceraurus* sp., Ludvigsen, Pl. 5, figs. 8, 9.

Diagnosis. A *Ceraurus* with a glabella that expands forward, short (tr.) lateral glabellar furrows, a large palpebral lobe opposite 2p lobe, very wide lateral cephalic borders that are indented in front of glabella, long palpebral ridge, and sparse low tubercles on glabella. Genal spines are long and upwardly curving. Pygidium is small and bears a single pair of very long, slender, and curving spines that diverge markedly.

Occurrences. Cape Calhoun Formation, northern Greenland, lower Whittaker Formation, Funeral Range (C 640, C 655, J 220) and Whittaker Range (H 1850, H 1920, H 1975, I 1350-1380, I 1410, ?Q 430). *Ceraurus mackenziensis* Zone (in Canada).

Material. About one hundred and forty (140) individuals.

Holotype. An incomplete cranidium (GSC 44156) from C 655 illustrated on Plate 15, figures 1-3.

Paratypes. GSC 40447, 40448, 44158-44162, 44164-44167, 44171, 44175-44180, 44182 from C 655; GSC 44157, 44163, 44168, 44172, 44173 from H 1920; GSC 44169, 44120, 44174, 44181, from J 220.

Description. Cephalon crescentic in outline, moderately (tr.) and slightly (sag.) vaulted. Width (tr.) across posterior margin equals one third length (sag.). Glabella inflated, expands markedly forward to maximum width (tr.) across anterior lobe which is equal to three quarters length (sag.). Three pairs of short (tr.) lateral glabellar furrows oriented approximately perpendicular to axial furrows. Glabellar lobes small, square or rectangular in outline; 1p lobe isolated. Anterior lobe semi-circular in outline, bounded by narrow, sharply incised preglabellar furrow whose semi-circular course is somewhat flattened medially. Anterior border relatively long and strongly curved (sag.), widens somewhat distally. Axial furrows moderately deep, nearly straight, diverge forward at about 15° to sagittal line in front of occipital furrow. Occipital ring arched about as high as glabella in front of occipital furrow, lenticular in outline. Occipital furrow deeply incised, straight or faintly concave forwardly. Cheek triangular in outline, wider (tr.) than long (exsag.), moderately convex (tr. and exsag.); eye occupies highest position, opposite 2p lobe. Palpebral lobe large, oval in outline, oriented exsagitally, stands nearly as high as highest part of glabella; continuous anteriorly with narrow, convex palpebral ridge which proceeds in even curve toward anterior pit. Visual surface of eye not well displayed; appears moderately curved (tr.) and strongly curved through about 180° in horizontal plane. Facial suture proceeds forward and inward from palpebral lobe in nearly straight line; well in front of, and at an angle to, palpebral ridge; at a level about mid-length of anterior lobe it curves slightly inward and then across anterior margin to meet connective suture; it continues toward mid-line as horizontal rostral suture. Posterior branch of facial suture proceeds outward in even, forwardly convex curve. Posterior border furrow narrow (exsag.), straight, deeply incised. Lateral border furrow somewhat shallower. Lateral border very broad, flat or slightly concave in cross-section, steeply inclined; in front of eye lateral margin deflected sharply upward and inward so that border is drastically narrowed. In anterior view, front margin of cephalon elevated into a broad, flat-topped portal between the eyes. Lateral margin continued posteriorly as long, gradually tapering genal spines which diverge slightly and possess distinct upward curvature.

Dorsal surface of cephalon finely granulate. Faint tubercles occur in a single irregular row on either side of sagittal line and scattered on front portion of anterior lobe. Three small pits in triangular pattern on anterior lobe; that is, a single pit on sagittal line behind preglabellar furrow flanked by a pair of pits just ahead of line joining 3s furrows. Few tubercles on posterior border of cheek. On interior, occipital doublure extends to occipital furrow. Adaxial parts of 0s and 1s extended as high, ventrally directed, spindle-shaped appendifers. Lateral part of doublure very broad.

Hypostome triangular in outline, considerably wider across anterior wings than long (sag.). Central body inflated; narrows markedly backward from maximum width just anterior of line joining anterior wings; front portion evenly rounded, extends nearly to anterior margin; pair of small oval maculae situated near lateral furrows at two thirds the length of hypostome. Lateral furrows initially deep, shallow posteriorly and medially. Lateral borders narrow and convex (tr.), converge backward to mid-line in V-shaped structure. Small shoulders located just behind anterior wings. Anterior furrow narrow, continuous across hypostome. Anterior margin broadly curved; in front of shoulders deflected up to define anterior wings which carry blunt, dorsally directed wing processes. On interior, doublure narrows evenly backward from base of anterior wings to very narrow strip at posterior edge. Doublure extended into a faint posterior wing and, in front of this, depressed into a broad, anterolaterally directed antennal notch.

Pygidium, without spines, triangular or semi-circular in outline and small. Consists of three axial rings; first longest (sag.) and widest (tr.), moderately arched, outlined laterally by narrow forwardly diverging axial furrows; second and third axial rings stand considerably below first and are narrower (tr.) and much shorter (sag.). First axial ring furrow deep, forwardly curving; second and third much narrower and shorter. Pleural field absent. First axial ring extended directly into very long, narrow, backwardly, outwardly and slightly upwardly curving spines which initially diverge at about 45° to sagittal line, distally they diverge slightly or become sub-parallel. Posterior margin between first spine pair evenly rounded without trace of spines. Beneath posterior margin and base of first spine, pygidium descends vertically. Doublure narrow, convex. Distal ends of articulating and first axial ring furrows carry small appendifers.

Discussion. The short glabellar furrows, the granular glabellar ornament with sparse tubercles arranged in two exsagittal rows, the posterior postion of the eye, the broad lateral cephalic borders, the long genal spines and the very long and diverging first pygidial spines effectively distinguishes *Ceraurus mackenziensis* n. sp. from other species. The specimen from the Cape Calhoun Formation of northern Greenland illustrated by Troedsson (1928, Pl. 16, fig. 22) under the name *C.* cf. *pleurexanthemus* probably belongs to this species. This specimen differs from the other cranidium assigned to *C.* cf. *pleurexanthemus* by Troedsson (1928, Pl. 16, fig. 21) in having the palpebral lobe located opposite 2p lobe (contrary to Troedsson's statement on p. 68). *Ceraurus mackenziensis* is closest to *C. tuberosus* Troedsson from lower in the Whittaker Formation in the study area and from the Cape Calhoun Formation from which it differs in having sparse and subdued tubercles on the glabella.

The greatly expanded and strut-like lateral cephalic borders of *C. mackenziensis* are gradually developed during ontogeny. This feature allowed the trilobite to rest on the cephalic borders while keeping its glabella elevated and approximately horizontal. The expanded borders would pose a problem during enrollment were they not abruptly curtailed in front of the eyes. The resulting portal could then receive the bases

of the long pygidial spines while the rest of the spines would project anterolaterally in front of the cephalon.

Ceraurus mackenziensis shares the distinctive triangular arrangement of three pits on the middle part of the anterior glabellar lobe with other species of *Ceraurus*, including *C. pleurexanthemus*, *C. whittingtoni*, *C. hirsuitus*, and *C. gabrielsi*, and with *Whittakerites planatus*.

Ceraurus milleranus Miller and Gurley, 1897

Plate 15, figures 45-57

1913 *Ceraurus milleranus* Miller and Gurley, Raymond and Barton, p. 538, Pl. 1, figs. 6-8 (?not Pl. 2, fig. 6).

1913 *Ceraurus milleranus*, Slocum, p. 71, Pl. 17, figs. 1-3.

1928 *?Ceraurus tuberosus* Troedsson, Pl. 17, fig. 13 (not Pl. 18, figs. 1-9).

1955 *Ceraurus milleranus*, Caster et al., Pl. 3, fig. 28 (not Pl. 3, fig. 27).

Occurrences. Maysville Group, Ohio; lower Maquoketa Shale, Iowa; ?Cape Calhoun Formation, northern Greenland; and lower Whittaker Formation, Dusky Range (R 625). *Whittakerites planatus* Zone (in Canada).

Material. Three (3) individuals.

Holotype. A complete exoskeleton (UC 6062) from the Maysville Group, Ohio.

Hypotypes. GSC 44183-44188 from R 625.

Discussion. An adequate description of *Ceraurus milleranus* has been presented by Slocum (1913, p. 71-73). The material from the Whittaker Formation differs in only a few minor characters from the type specimen - the posterior part of the glabella is narrower and the palpebral lobe is located opposite 3p lobe rather than 2s furrow. The short genal spines of the holotype diverge more widely than on the Whittaker cranidium. This may be ascribed to a slight flattening of the carapace, which is preserved on a shale chip - as Evitt (1953, p. 36) convincingly argued for similarly preserved specimens of *C. pleurexanthemus*. The overall similarity of the Whittaker material to the holotype of *C. milleranus* is striking and, for the first time, permits recognition of this species outside the mid-continent area. *Ceraurus mantranseris* Sinclair, 1947 from the middle Trenton Group of Quebec and *C. globulobatus* Bradly, 1930 from the Kimmswick Formation of Missouri are similar to *C. milleranus*, but possess longer genal spines and paired tubercles on the glabella.

The hypostome of *Ceraurus milleranus* is illustrated for the first time. It is similar to the hypostomes of *C. whittingtoni* and related species illustrated by Evitt (1953, Pl. 7), but it has a more triangular outline and a less inflated central body. The anterior wings are not as high and are less diverging and the anterior margin is more strongly curved (tr.). On the interior, the posterior wings extend to the inner edge of the posterior doublure and inwardly to restrict the opening between the lateral doublure to a narrow triangular gap.

Among the species of *Ceraurus* from the South Nahanni River area, *C. milleranus* is unique in possessing eyes that are located far foward, close to the lateral border furrow of the cheek. Only *C. maewestoides* n. sp. has similarly placed eyes. It has been argued before that the following species, *C. gabrielsi*, *C. blussoni*, *C. hirsuitus*, *C. tuberosus*, *C. mackenziensis*, and *Whittakerites planatus*, are connected in a graded phylogenetic series. For the duration of this series, the eye remains in a position opposite or behind 2p glabellar lobe. The sudden appearance of *C. milleranus*, which has its eye located opposite 3p lobe, suggests that the previous history of this species lies, not with species of the *C. gabrielsi-W. planatus* lineage, but with the *C. pleurexanthemus* and *C. whittingtoni* group of eastern North America.

Ceraurus maewestoides n. sp.

Plate 13, figures 30-33

Diagnosis. A *Ceraurus* with a forwardly expanding and smooth glabella possessing a pair of large mammillate swellings on the anterior lobe and, behind these, four tubercles arranged in a square. Palpebral lobes are located far out on the cheek and opposite 3p lobes. Genal spines are long and diverging.

Occurrence. Lower Whittaker Formation, Dusky Range (R 625). *Whittakerites planatus* Zone.

Material. A single cranidium.

Holotype. An incomplete cranidium (GSC 44142) from R 625 illustrated on Plate 13, figures 30-33.

Description. Cranidium crescentic in outline, two and one-half times as wide across base of genal spines as long (sag.), gently convex (tr.). Glabella moderately vaulted, widens forward to maximum width across anterior lobe. Axial furrows deep. Three pairs of short (tr.) glabellar furrows oriented approximately transversely; their adaxial tips connected by faint longitudinal furrow. Glabellar lobes small, oval in outline, inflated; only 1p lobe distinctly isolated. Anterior lobe almost totally occupied by pair of large mammillate swellings separated by narrow cleavage. Lateral parts of swellings occupy entire area between 3s furrows and preglabellar furrow; medially they rise steeply from glabellar floor. Preglabellar field narrow, ribbon-like. Occipital ring broad, moderately vaulted (tr.), flatly convex (sag.). Occipital furrow shallow and transverse medially; laterally it curves backward around 1p lobe. In addition to large anterior swellings, glabella has 4 large tubercles arranged in square between 2p and 3p lobes; single smaller tubercle occupies mid-point of each glabellar lobe. Fixed cheek triangular, moderately vaulted (tr.) and slightly convex (exsag.). Palpebral lobe oval in outline, occupies highest part, far out on cheek, opposite 3p lobe; low convex palpebral ridge continues to axial furrow. Anterior branch of facial suture runs along outer edge of palpebral ridge; posterior branch proceeds outward and backward in even curve. Posterior border furrow narrow, transverse. Genal spines apparently long, moderately stout, gradually tapering, diverge widely. Cheeks inside border furrows (except palpebral lobe and palpebral ridge) rather coarsely pitted. Three

large tubercles located on approximately exsagittal line between palpebral lobe and axial furrow. A few smaller tubercles located on posterior border and base of genal spine. Entire cranidium smooth, lacking granules.

Hypostome, thoracic segments, and pygidium unknown.

Discussion. The presence of a pair of prominent anterior swellings on the glabella effectively limits comparison with three species. *Ceraurus maewestoides* n. sp. is very similar to *C. binodosus* Cooper and Kindle (1936, p. 369, Pl. 53, fig. 20) from the Whitehead Formation at Percé from which it differs by lacking scattered tubercles on the cranidium (other than four prominent and regularly arranged tubercles on the glabella and three on the fixed cheek). The Gaspé species possesses markedly oblique 3s furrows, a large occipital tubercle, and the anterior swellings seem to be smaller than the ones on the Whittaker species. *Ceraurus bituberculatus* Troedsson (1928, p. 69, Pl. 17, fig. 12; not fig. 11, which is a species of *Borealaspis*) from the Cape Calhoun Formation of northern Greenland, has a wider (tr.) glabella that does not expand noticeably toward the front, widely spaced anterior swellings, more slender and less flaring genal spines, and less inflated lateral glabellar lobes. *Ceraurus bispinosus* Raymond and Barton (1913, p. 536, Pl. 1, figs. 3, 4) from the Black River Group near Tetreauville, Quebec also has a pair of swellings on the anterior lobe, but differs markedly from *C. maewestoides* in possessing densely distributed tuberculate ornament on the cranidium, widely set eyes, deep occipital furrow, and a preglabellar furrow that curves around the front edge of the anterior swellings.

A single specimen from the *Ceraurus mackenziensis* Zone may belong to *Ceraurus maewestoides*. This cranidium (Pl. 17, figs. 34, 35) possesses the pair of apparently smooth mammillate swellings on the front part of the glabella, but the maximum width appears to be across 3p lobe instead of across the anterior lobe and the four tubercles arranged in a square between 2p and 3p lobes on the holotype cannot be seen on the older cranidium.

Genus *Ceraurinus* Barton, 1913

Type species. *Ceraurinus marginatus* Barton, 1913 probably from the Cobourg Formation of southern Ontario (Ludvigsen, 1977a).

Diagnosis. See Ludvigsen (1977a, p. 963).

Discussion. The rather troubled nomenclatural history of *Ceraurinus* has been reviewed elsewhere (Ludvigsen, 1977a). In that paper, it was concluded that the holotype of *Ceraurinus marginatus* probably came from the Cobourg Formation of southern Ontario from the area between Georgian Bay and Lake Ontario and not, as previously thought, from the Upper Ordovician rocks of Manitoulin Island. The discovery that *C. marginatus* possesses a pygidium with carinate first spines led to the conclusion that *Remipyga* Whittington, 1954 is a junior subjective synonym of *Ceraurinus*.

Ceraurinus serratus n. sp.

Plate 18, figures 1-32

?1928 *Ceraurinus icarus* (Billings), Troedsson, Pl. 19, fig. 1.

1975 *Remipyga* cf. *daedalus* (Cox), Ludvigsen, Pl. 5, figs. 6, 7.

1977a *Ceraurinus* n. sp., Ludvigsen, Text-fig. 3.

Diagnosis. A *Ceraurinus* with flat, carinate, and curved first pygidial spines and pointed, digitate, non-carinate second and third pygidial spines whose tips fall on a gentle curve that almost reaches a line joining tips of first spines.

Occurrences. Cape Calhoun Formation(?), northern Greenland and lower Whittaker Formation, Funeral Range (C 655), Whittaker Range (H 1850, H 1920, H 1975, I 1590, Q 430, Q 530), and Dusky Range (R 625). *Ceraurus mackenziensis* Zone and *Whittakerites planatus* Zone (in Canada).

Material. About forty (40) individuals.

Holotype. A pygidium (GSC 40446) from I 1590 illustrated on Plate 18, figures 10, 11.

Paratypes. GSC 44244-44246, 44248, 44250, 44252, 44256, 44261-44263 from C 655; GSC 40446, 44249, 44251, 44253, 44255, 44259, 44260 from I 1590; GSC 44247, 44254, 44257, 44258 from Q 530.

Description. Cephalon semi-circular in outline and moderately (tr.) and slightly (sag.) convex. Glabella lowly convex; rectangular in outline, width two thirds length. Axial furrows deep, narrow; faintly bowed laterally between occipital furrow and 3s furrow; continuous with preglabellar furrow which curves around anterior lobe and becomes transversely directed medially. Three pairs of relatively deep glabellar furrows extend about one fourth to one third way across glabella. 1s straight, transverse or slightly backwardly directed, deepens adaxially, inner edge connected to short longitudinal furrow which joins occipital furrow. 2s straight, transverse. 3s slightly bowed forwardly. Glabellar lobes square to trapezoidal in outline, not noticeably inflated. Anterior lobe rectangular in outline with evenly rounded anterolateral corners, 3 times as wide (tr.) as long (sag.). Occipital ring slightly convex (sag.) and moderately convex (tr.), lenticular to rectangular in outline, tiny occipital node occupies median position; stands as high as or slightly higher than glabella in front of occipital furrow which is straight medially and curves backward and outward behind 1p lobe. Preglabellar field relatively broad, slightly convex (sag.). Cheek triangular in outline, slightly convex (exsag.); lateral parts decline at about 45°. Palpebral lobe ovate, about twice as long (exsag.) as wide (tr.); located opposite posterior part of 3p lobe and 2s furrow; stands slightly lower than glabella. Faint palpebral ridge proceeds inward a short distance, but fades out before reaching axial furrow. Palpebral furrow short, sigmoid. Visual surface of eye strongly curved in horizontal plane, less so vertically. Base of eye nearly reaches lateral border furrow. Anterior branch of facial suture proceeds forward and inward in smooth curve; in anterior view, suture descends slightly at juncture with connective suture and rises again slightly toward

mid-line to form rostral suture. Posterior branch of facial suture nearly straight as far as lateral border furrow, than curves backward. Posterior border furrow narrow (exsag.), moderately deep; lateral border furrow shallower, dies out anteriorly before reaching anterior branch of facial suture. Lateral border broad, flat to slightly concave; posterior border half as wide, flatly convex. Genal spines short and stout, oval in cross-section, faintly carinate, diverge very slightly. Entire surface of cephalon finely granulate; cheek, inside border furrow, finely pitted.

On interior, lateral doublure broad, flatly convex. Adaxial parts of 1s furrows and corresponding parts of 0s furrow extended as high appendifers. Anterior pit appears on interior just in front of 3s furrow as relatively high mound carrying a small pit on anterior side.

Hypostome shield-shaped, about as long (sag.) as wide (tr.) between shoulders; composed of ovate and slightly inflated central body with a pair of faint, obliquely disposed maculae located in line with shoulders. Central body completely circumscribed by relatively shallow border furrows which reach anterior margin medially. From distinct shoulders, lateral margin converges backward, with slight inward curvature, to obtuse and sharp posterolateral corners. Posterior margin faintly convex posteriorly. Anterior wings flare slightly, extend laterally as far as shoulders. On interior, posterior part of doublure narrow, expands forwardly into obliquely disposed posterior wings which extend dorsally nearly as far as anterior wings. In front of shoulder, doublure deflected downward into fairly broad antennal notch and then recurved up into dorsolaterally disposed anterior wing which carries a short, blunt, dorsally directed wing process.

Number of thoracic segments not known. Axis convex; outlined by deep, forwardly divergent axial furrows; articulating furrow stretched W-shaped. Inner portion of pleura inflated; crossed by deep, diagonal pleural furrow. Outer portion of pleura extended into broad, blunt, paddle-shaped spine which is progressively backwardly swept toward the rear. On inner surface, a pair of large, blunt, tongue-shaped, ventromedially directed appendifers arise from outer parts of articulating furrow. Articulating devices consist of relatively large axial furrow process and socket, ring socket and process, and relatively broad (exsag.) articulating flange which terminates laterally at large, open box-like marginal connective device. Base of pleural spine defined by narrow (tr.) ridge.

Pygidium, including spines, sub-rectangular in outline and flat; width (tr.) slightly more than twice length (sag.). Axis triangular; consists of three low rings that narrow posteriorly to small oval terminal piece. Rings separated by relatively shallow, slightly forwardly curving ring furrows which terminate in deep elongate pits; first two rings defined laterally by faint axial furrows. Pleural field very narrow; crossed by single, short, faint pleural furrow opposite first axial ring. First marginal spine flat, paddle-shaped, directed outward and backward; carries distinct median carina for its total length; in posterior view, first spines can be seen to slope outwardly at about 20° to horizontal. Second and third pairs shorter, pointed, non-carinate; well separated from each other and from first spine pair; their tips fall on a gentle, posteriorly convex curve which, medially, nearly reaches a line joining tips of first spines. On interior, doublure narrow, convex, broadly V-shaped. Distal parts of articulating furrows and first and second axial ring furrows extended into small appendifers.

Discussion. Of the North American species of *Ceraurinus*, well-preserved pygidia are known for *C. marginatus* Barton, *C. icarus* (Billings), and *C. glaber* (Whittington) (Ludvigsen, 1977a). From these, *C. serratus* n. sp. differs in possessing second and third spines that are non-carinate and that do not extend beyond the first carinate spine pair. A cranidium of *C. platycanthus* Bradley (Ludvigsen, 1977a, Pl. 1, fig. 8) bears some resemblance to the large cranidium of *C. serratus* (Pl. 18, fig. 9), but differs in having a broader (tr.) cranidium, eyes placed far out on the cheek, and shallower glabellar and axial furrows.

Genus *Whittakerites* Ludvigsen, 1976

Type species. *Whittakerites planatus* Ludvigsen, 1976 from the lower Whittaker Formation, southern Mackenzie Mountains.

Diagnosis. A genus of Cheirurinae with long (sag.) and weakly convex glabella which expands only slightly forward. Three pairs of relatively wide (tr.) and equally spaced glabellar furrows are approximately transversely directed. Glabella is finely granulate, lacking tubercles. Eye is located opposite 1s furrow; palpebral ridge is very long. Anterior border is flat and broad and arcuate toward the front. Genal spines are long and diverging. Anterior pair of pygidial spines are stout and long; posterior margin between these spines is nearly straight, but includes a single pair of tiny spines.

Whittakerites planatus Ludvigsen, 1976

Plate 16, figures 1-47

1976 *Whittakerites planatus* Ludvigsen, p. 950, Pl. 1, figs. 1-14.

Occurrences. Lower Whittaker Formation, Whittaker Range (I 1590, Q 530) and Dusky Range (R 625). *Whittakerites planatus* Zone.

Material. One hundred and eighty-three (183) individuals.

Holotype. An incomplete cranidium (GSC 44191) from Q 530 illustrated on Plate 16, figures 4, 5.

Paratypes. GSC 44194, 44216, 44217, from Q 530; GSC 44192, 44198, 44203, 44204, 44219, 44221, 44222 from I 1590.

Hypotypes. GSC 44189, 44190, 44196, 44199, 44200, 44205, 44207, 44208, 44210 - 44215, 44218 from I 1590; GSC 44193, 44195, 44197, 44206, 44209 from Q 530; GSC 44201, 44202 from R 625.

Discussion. This species has been fully described recently (Ludvigsen, 1976). The additional illustrations included herein show the variability of this species, particularly in the disposition of the first pygidial spines, and facilitate comparison with its probable ancestor, *Ceraurus mackenziensis* n. sp. (Pl. 15, figs. 1-44).

Genus *Borealaspis* Ludvigsen, 1976

Type species. *Borealaspis whittakerensis* Ludvigsen, 1976 from the lower Whittaker Formation, southern Mackenzie Mountains.

Diagnosis. A genus of Cheirurinae with an evenly inflated bulb-shaped glabella. Maximum width of glabella is across 3p lobe. Glabella may possess a pair of swellings or spines on the anterior lobe and a single median occipital or preoccipital spine. Occipital ring stands lower than glabella in front of occipital furrow. Palpebral lobes are small and located opposite 3p lobe or 3s furrow. In front of eye, facial suture descends vertically.

Borealaspis whittakerensis Ludvigsen, 1976

Plate 17, figures 1-21

1975 *"Ceraurus"* cf. *numitor* (Billings), Ludvigsen, Pl. 5, fig. 11.

1976 *Borealaspis whittakerensis* Ludvigsen, p. 953, Pl. 2, figs. 1-7.

Occurrence. Lower Whittaker Formation, Funeral Range (C 655). *Ceraurus mackenziensis* Zone.

Material. Thirteen (13) individuals.

Holotype. A cranidium (GSC 40450) from C 655 illustrated on Plate 17, figures 1-5.

Paratypes. GSC 44225-44227 from C 655.

Hypotypes. GSC 44228, 44229 from C 655.

Discussion. The species has been fully described recently (Ludvigsen, 1976).

Borealaspis biformis Ludvigsen, 1976

Plate 17, figures 13-33

1928? *Ceraurus bituberculatus* Troedsson, p. 69, Pl. 17, fig. 11 only.

1976 *Borealaspis biformis* Ludvigsen, p. 957, Pl. 2, figs. 8-18.

Occurrences. Cape Calhoun Formation, northern Greenland(?), lower Whittaker Formation, Funeral Range (C 570-590, J 220), Whittaker Range (H 1850, H 1920, I 1275, I 1410, I 1590, Q 530), and Dusky Range (R 625). *Ceraurinella necra* Zone, *Ceraurus mackenziensis* Zone, *Whittakerites planatus* Zone (in Canada).

Material. Twenty-eight (28) individuals.

Holotype. A cranidium (GSC 44230) from C 570-590 illustrated on Plate 17, figures 13-16.

Paratypes. GSC 44231-44235 from C 570-590; GSC 44238 from H 1920.

Hypotypes. GSC 44236, 44237 from C 570-590.

Discussion. This species has been fully described recently (Ludvigsen, 1976).

Cheirurinid gen. and sp. indet.

Plate 16, figures 48-51

Occurrence. Lower Whittaker Formation, Dusky Range (R 625). *Whittakerites planatus* Zone.

Material. Two (2) pygidia.

Figured specimens. GSC 44223, 44224 from R 625.

Description. Pygidium without first spines, broadly triangular. Anterolateral corners acute in front of first spines. Axis short (sag.), consists of two moderately convex (tr.) rings outlined by narrow axial ring furrows that terminate laterally in deep pits. Position of a possible third axial ring furrow is indicated by a small pit located at mid-point of central pygidial spine. Faint axial furrows opposite first ring; pleural field not present. Stout, sausage-shaped first pygidial spine arises directly from distal end of first ring; spine directed obliquely backward and outward with slight curvature, and upward at about 40°; length of spine slightly greater than one half width of pygidium across anterior margin. Central three spines blunt and rounded, directed backward and slightly upward; much shorter and narrower than first, median spine wider (tr.) than flanking spines. Beneath spines, pygidial field descends vertically and is recurved into convex doublure. Fine tubercles on dorsal surface become sparser toward axial furrows and denser on ventral side of pygidial spines and on doublure.

Discussion. The pygidia at hand were found in a single collection from the Whittaker Formation. A search for associated cranidia proved unsuccessful. These pygidia bear some resemblance to those of *Ceraurinella necra* and *C. brevispina* in possessing a longer first spine pair followed by three shorter spines, but this resemblance is merely superficial. They differ from those of *Ceraurinella* in having only two axial rings and in possessing five pygidial spines that are all directed obliquely upward. In *Ceraurinella* only the first spine pair is set at an oblique angle. This material probably belongs to a new genus, but its establishment must await discovery of associated cranidia.

Subfamily ACANTHOPARYPHINAE
Whittington and Evitt, 1954

Diagnosis. See Lane (1971, p. 66).

Discussion. Chatterton and Ludvigsen (1976, p. 57) added *Heliomeroides* and *Heliomera* to the list of genera assigned to this subfamily by Lane (1971).

Genus *Acanthoparypha* Whittington and Evitt, 1954

Type species. *Acanthoparypha perforata* Whittington and Evitt, 1954 from the Edinburg Formation of Virginia.

Acanthoparypha evitti Chatterton and Ludvigsen, 1976

1975 *Acanthoparypha* n. sp. 1, Ludvigsen, Pl. 3, figs. 20, 21.

1976 *Acanthoparypha evitti* Chatterton and Ludvigsen, p. 59, Pl. 10, figs. 1-41.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 110, A 125, A 140, P 1485, P 1497, P 1512) and Whittaker Range (H 800-820). *Ceraurinella nahanniensis* Zone.

Material. Sixty-five (65) individuals.

Acanthoparypha echinoderma
Chatterton and Ludvigsen, 1976

1976 *Acanthoparypha echinoderma* Chatterton and Ludvigsen, p. 62, Pl. 12, figs. 1-15, 20-25.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 110, A 125, P 1512, P 1520). *Ceraurinella nahanniensis* Zone.

Material. Sixty (60) individuals.

Acanthoparypha? goniopyga n. sp.

Plate 19, figures 1-18

1975 *Acanthoparypha* sp., Ludvigsen, Pl. 5, fig. 10.

Diagnosis. An *Acanthoparypha?* with weakly inflated, forwardly narrowing glabella and strongly divergent genal spines. Pygidium with nearly vertical anterior portion lacking axial rings or furrows, but possessing a pair of slot-like pits and four pointed spines that are square in cross-section.

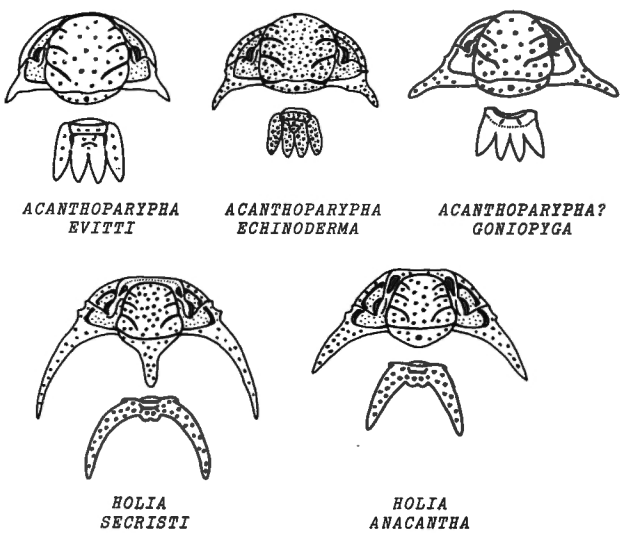

FIGURE 17. Outline drawings of cephala and pygidia of three species of *Acanthoparypha* and two species of *Holia* from the Esbataottine and lower Whittaker Formations of the South Nahanni River area. Not to scale.

Occurrences. Lower Whittaker Formation, Whittaker Range (H 1850, I 1275, I 1350-1380, I 1410, Q 130) and Funeral Range (C 655). *Ceraurinella necra* Zone and *Ceraurus mackenziensis* Zone.

Material. Twenty-nine (29) individuals.

Holotype. A pygidium (GSC 44271) from I 1275 illustrated on Plate 19, figures 7-9.

Paratypes. GSC 40449, 44278 from C 655; GSC 44272, 44274 from H 1850; GSC 44273, 44275, 44276 from I 1275; GSC 44277, 44279 from I 1410.

Discussion. The cranidium of *Acanthoparypha? goniopyga* n. sp. is essentially like those of other species of *Acanthoparypha.* The weakly inflated glabella, strongly divergent genal spines, and sigmoidal first lateral glabellar furrows appear diagnostic. The latter feature indicates an affinity with *A. subcircularis* (Bradley, 1930) from the Kimmswick Formation of Illinois. The pygidium of *A.? goniopyga* differs from any previously described *Acanthoparypha* pygidium in lacking axial furrows, axial rings, or axial ring furrows. The anterior part of the pygidium is sharply flexed from the base of the marginal spines into a near-vertical position below an articulating furrow that extends two thirds the distance across the anterior margin. The upturned portion of the pygidium is scored by a pair of dorsally convergent slot-like pits which, by their position and orientation, appear to represent the second axial ring furrow as seen in *Acanthoparypha evitti* Chatterton and Ludvigsen (compare Pl. 19, figs. 7, 8 and Chatterton and Ludvigsen, 1976, Pl. 10, figs. 12, 13). The pygidium of *A.? goniopyga* is also unique in possessing marginal spines that are square in cross-section.

From the material at hand it appears probable that *A.? goniopyga* was derived from a species of *Acanthoparypha* (probably *A. evitti* or *A. chiropyga* Whittington and Evitt), but it is not clear whether the singularity of the pygidium demands a separate generic home for this species. The post-Chazyan history of *Acanthoparypha* is vague at the present time. Only two other species are known from this interval in North America, *A. trentonensis* (Clarke) and *A. subcircularis* (Bradley), both of which are known only from incomplete cranidia.

Genus *Pandaspinapyga* Esker and Levin, 1964

Type species. *Acanthoparypha projecta* Esker, 1961 from the Kimmswick Limestone, Missouri.

Pandaspinapyga dactyla
Chatterton and Ludvigsen, 1976

1975 *Pandaspinapyga* sp., Ludvigsen, Pl. 3, fig. 24.

1976 *Pandaspinapyga dactyla* Chatterton and Ludvigsen, p. 63, Pl. 12, figs. 16-19.

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 125, P 1485). *Ceraurinella nahanniensis* Zone.

Material. Two (2) pygidia.

Pandaspinapyga cf. *stubblefieldi* (Bancroft)

Plate 19, figures 30-32

1961 *Acanthoparypha stubblefieldi* (Bancroft), Dean, p. 314, Pl. 4, figs. 1, 3-6, 11.

1971 *Pandaspinapyga stubblefieldi* (Bancroft) Lane, p. 68, Pl. 15, figs. 3-6.

Occurrence. Upper Sunblood Formation, Sunblood Range (P 1187), *Bathyurus granulosus* Zone.

Material. Three (3) individuals.

Figured specimens. GSC 44287, 44288 from P 1187.

Discussion. From the slightly younger *Pandaspinapyga dactyla* Chatterton and Ludvigsen, 1976, *P.* cf. *stubblefieldi* (Bancroft) differs in possessing shorter and less diverging pygidial spines, shorter (sag.) and more convex (sag.) axial rings, shallower and narrower (sag.) axial ring furrows, angular anterolateral pygidial corners, and in lacking axial furrows opposite the second ring. The furrows which extend posteriorly from the second axial ring furrow have different courses in the two species. In *P. dactyla* these furrows converge posteriorly to partially enclose a shield-shaped area which includes the terminal piece. In *P.* cf. *stubblefieldi* these furrows curve outward and backward from the faint ring furrow, but do not converge. *Pandaspinapyga* cf. *stubblefieldi* lacks pits on the pygidial spines and possesses high, unperforated tubercles on the first two axial rings.

The pygidium of *P.* cf. *stubblefieldi* from the Sunblood Formation differs in a few minor points from that of *P. stubblefieldi* from the Caradocian of Shropshire. The Sunblood species has shallower pygidial furrows and slightly longer spines. The British species appears to possess a short pleural furrow opposite the first axial ring instead of a row of small pits as seen in *P.* cf. *stubblefieldi*, but this could equally well be a result of imperfect preservation. The incomplete cranidial fragment of *P.* cf. *stubblefieldi* shows the course of the posterior branch of the facial suture, the moderately long and slightly curving genal spine, and a trace of an uninflated first glabellar lobe. The latter feature further allies the species to *P. stubblefieldi* and serves to differentiate it from *P. projecta* and *P. salsa*.

Genus *Holia* Bradley, 1930

Type species. *Holia magnaspina* Bradley, 1930 from the Kimmswick Limestone of Missouri and Illinois.

Holia secristi Whittington and Evitt, 1954

1954 *Holia secristi* Whittington and Evitt, p. 81, Pl. 30, figs. 29-42, Pl. 31, figs. 1-43, Pl. 32, figs. 1-5.

1975 *Holia* cf. *secristi* Ludvigsen, Pl. 3, figs. 7, 8.

1976 *Holia secristi*, Chatterton and Ludvigsen, p. 64, Pl. 11, figs. 1-42.

Occurrences. Lincolnshire Formation, Tumbling Run, Shenandoah County, Virginia and lower Esbataottine Formation, Sunblood Range (A 110, A 125, P 1485, P 1497, P 1512, P 1520). *Ceraurinella nahanniensis* Zone (in Canada).

Material. Sixty-three (63) individuals.

Holia anacantha n. sp.

Plate 19, figures 20-29

Diagnosis. A *Holia* lacking an occipital spine and possessing stout and straight first pygidial spines.

Occurrence. Lower Whittaker Formation, Funeral Range (C 570-590). *Ceraurinella necra* Zone.

Material. Ten (10) individuals.

Holotype. An incomplete pygidium (GSC 44280) from C 570-590 illustrated on Plate 19, figures 27-29.

Paratypes. GSC 44281-44286 from C 570-590.

Discussion. Although the available material is sparse and rather poorly preserved, this species is obviously distinct from any of the three previously described species of *Holia*. *Holia cimelia* Whittington and Evitt, 1954 from the Edinburg Formation and *H. secristi* Whittington and Evitt, 1954 from the Lincolnshire and lower Esbataottine Formations each possess a distinct and long median occipital spine and first pygidial spines which curve outward and backward. The type species, *H. magnaspina* Bradley, 1930 from the Kimmswick Limestone, is known only from two incomplete cranidia. Its distinctive features are the broad, flat, and triangular occipital spine and the swellings at the distal ends of the occipital ring.

The outline and ornament of the cranidium of *H. anacantha* are very similar to those of *H. secristi*. Aside from the absence of an occipital spine, the only differences seem to be a slightly longer 3s furrow and a more elongate (exsag.) anterior pit. The moderately large, but crushed, cranidium of *H. anacantha* (Pl. 19, fig. 22) displays a long (sag.) and flat occipital ring with the slightest trace of a median node. The latter feature is better shown on the smaller cranidium (Pl. 19, fig. 21). The pygidium of *H. anacantha* possesses first spines which diverge at about 30° to the sagittal line and, in lateral view, are directed upward at about 40°. The spines are, basally, much stouter than those of *H. cimelia* or *H. secristi* and are straight for their total length. The ornament on the pygidium is considerably coarser than that seen on the other species of *Holia*.

Holia anacantha is morphologically closer to the older *H. secristi* than to its near-contemporary from the mid-continent, *H. magnaspina*, and could well have been derived from *H. secristi* by paedomorphosis. In meraspid cranidia of *H. secristi*, the occipital spine is reduced to a short triangular spike (Chatterton and Ludvigsen, 1976, Pl. 11, fig. 15) and its absence in *H. anacantha* could be ascribed to neoteny.

Genus *Heliomera* Raymond, 1905

Type species. *Cheirurus sol* Billings, 1865 from the Table Head Formation, Newfoundland.

Heliomera cf. *sol* (Billings, 1865)

Plate 19, figures 33-35

1951 *Heliomera sol* (Billings), Evitt, p. 603, Pl. 85, figs. 24-29.

1965a *Heliomera sol*, Whittington, p. 417, Pl. 63, figs. 1-6, 8, 12.

1975 *Heliomera* cf. *sol*, Ludvigsen, Pl. 1, fig. 18.

Occurrence. Sunblood Formation, Mary Range (B 145). *Orthidiella-"Goniotelina"* Fauna. Fifty metres below a collection yielding conodonts of Fauna 4 (late Whiterockian) of Sweet et al. (1971) (Tipnis et al., 1978).

Material. A single incomplete cranidium (GSC 40334) from B 145.

Discussion. Whittington (1963, p. 88; 1965a, p. 418) summarized the diagnostic features of *Heliomera sol* (Billings), *H. albata* Whittington, and *H. alacer* (Whittington). The outline and inflation of the single available glabella and the evenly curved path of the 2s glabellar furrow (in lateral view) suggest that the Sunblood material is closest to *H. sol*. Whittington (1965a, p. 418) pointed out that *H. sol* is very similar to *H. alacer*; the glabellar differences being the more inflated lateral lobes and the anteromedian row of pits on the latter species. The present material shows slightly less inflated lateral glabellar lobes than does *H. alacer* and the row of pits on the front part of the median lobe does not appear to be present.

The reassessment of the two similar genera, *Heliomera* and *Heliomeroides* (see discussion in Chatterton and Ludvigsen, 1976, p. 65), suggests that *Heliomera* is confined to strata of Whiterockian age - presently known from the middle Table Head Formation and the enormous limestone boulder at Lower Head, western Newfoundland (Whittington, 1963, 1965a); the bioherm in the Antelope Valley Limestone at Meiklejohn Peak in Nevada (Ross, 1972); and the Sunblood Formation, Mackenzie Mountains. *Heliomeroides* has a considerably longer range - from Chazyan to Ashgillian.

Genus *Heliomeroides* Evitt, 1951

Type species. *Heliomeroides teres* Evitt, 1951 from the Lincolnshire Formation, Virginia.

Heliomeroides teres Evitt, 1951

1951 *Heliomeroides teres* Evitt, p. 594, Pl. 85, figs. 1-5, Pl. 86, figs. 1-8, Pl. 87, figs. 1-4.

1967 *Heliomera chipperfieldi* Tripp, p. 66, Pl. 4, figs. 14-17.

1968 *Heliomeroides akocephala* Shaw, p. 69, Pl. 4, figs. 14, 15, 22, 23, 28.

1975 *Heliomeroides teres*, Ludvigsen, Pl. 3, figs. 5, 6.

1976 *Heliomeroides teres*, Chatterton and Ludvigsen, p. 65, Pl. 12, figs. 26-43.

Occurrences. Lincolnshire Formation, Tumbling Run, Shenandoah County, Virginia; Chazy Group, Lake Champlain, New York State; upper Stinchar Limestone, Stinchar Valley, Girvan, Scotland; and lower Esbataottine Formation, Sunblood Range (A 110, P 1485, P 1497). *Ceraurinella nahanniensis* Zone (in Canada).

Material. Nine (9) individuals.

Subfamily SPHAEREXOCHINAE Öpik, 1937

Genus *Sphaerexochus* Beyrich, 1845

Type species. *Sphaerexochus mirus* Beyrich from the Wenlockian of Bohemia.

Sphaerexochus arenosus
Chatterton and Ludvigsen, 1976

1975 *Sphaerexochus* n. sp. 1, Ludvigsen, Pl. 3, figs. 1, 2.

1976 *Sphaerexochus arenosus* Chatterton and Ludvigsen, p. 66, Pl. 13, figs. 1-48.

Diagnosis. See Chatterton and Ludvigsen (1976, p. 67).

Occurrences. Lower Esbataottine Formation, Sunblood Range (A 110, A 125, A 247, P 1485, P 1497, P 1512, P 1520). *Ceraurinella nahanniensis* Zone and *Bathyurus ulu* Zone.

Material. Five hundred and twenty-eight (528) individuals.

Sphaerexochus atacius n. sp.

Plate 19, figures 36-58

1975 *Sphaerexochus* n. sp. 2, Ludvigsen, Pl. 4, figs. 8, 9.

Diagnosis. A *Sphaerexochus* with deep sigmoidal first glabellar furrows that terminate well in front of occipital furrow; slightly inflated basal glabellar lobes; and very faint second and third glabellar furrows. Pygidium has three pairs of short, square-tipped

spines that are nearly conjoined and are accentuated by broad granulated median band.

Occurrences. Upper Esbataottine Formation, Sunblood Range (P 2010, P 2038). *Ceraurinella longispina* Zone.

Material. One hundred (100) individuals.

Holotype. A cranidium (GSC 40420) from P 2038 illustrated on Plate 19, figures 36-38, 58.

Paratypes. GSC 40421, 44289-44301 from P 2038.

Discussion. According to Lane's (1971, p. 53) diagnosis of *Sphaerexochus*, *S. atacius* n. sp. does not belong to this genus because the first glabellar furrows are definitely incomplete and the basal glabellar lobes are not isolated. However, in all other respects *S. atacius* is a typical member of the genus. The incomplete furrows may be viewed as an extreme condition of the variably developed 1s furrow seen in *S. arenosus* Chatterton and Ludvigsen, 1976 from lower in the Esbataottine Formation which changes from shallow or deep to complete or nearly effaced medially. The fact that at least some of the cranidia of *S. parvus* Billings illustrated by Shaw (1968, Pl. 14, figs. 9, 16) show an incomplete 1s furrow demonstrates that the diagnosis of *Sphaerexochus* should be modified to allow reception of these species.

The following features distinguish *Sphaerexochus atacius* from *S. arenosus*:

1. The first glabellar furrows are deep and generally narrower and do not extend to the occipital furrow. The basal glabellar lobes are longer (exsag.) and slightly more inflated.

2. The granulate ornament is considerably finer (compare Pl. 19, fig. 58 and Chatterton and Ludvigsen, 1976, Pl. 13, fig. 45).

3. The anterior branch of the facial suture is deflected around a relatively large anterior pit and the anterior cranidial margin is only faintly bowed toward the front. In *S. arenosus* the facial suture passes closer to the anterior pit and the anterior cranidial margin is strongly bowed toward the front (compare Pl. 19, fig. 56 and Chatterton and Ludvigsen, 1976, Pl. 13, fig. 21).

4. On the segments, the pleural portion slopes outward at about the same orientation as the outer portions of the axis and the axial furrow is very faint. In *S. arenosus* the inner parts of the pleurae are nearly horizontal and the position of the axial furrow is emphasized by a distinct slope change (compare Pl. 19, fig. 52 and Chatterton and Ludvigsen, 1976, Pl. 13, fig. 40).

5. The lateral margins of the hypostomes are more convergent posteriorly, the lateral and posterior borders and doublure are narrower, and the anterior wings are higher and more divergent (compare Pl. 19, fig. 52 and Chatterton and Ludvigsen, 1976, Pl. 13, figs. 32, 33).

6. The pygidial spines are shorter, broader, and closely aligned. The spines are square-tipped and each spine carries a broad granulate band. The pygidial spines of *S. arenosus* are clavate, distinctly separated with rounded terminations, and each carries a narrow granulate band (compare Pl. 19, figs. 43, 44 and Chatterton and Ludvigsen, 1976, Pl. 13, figs. 30, 31).

Genus *Kawina* Barton, 1916

Type species. *Cheirurus vulcanus* Billings, 1865 from Cow Head, Newfoundland (redescribed by Whittington, 1963, p. 91).

Kawina sp.

Plate 21, figures 49, 50

1975 *Kawina* sp., Ludvigsen, Pl. 1, fig. 19.

Occurrence. Sunblood Formation, Sunblood Range (P 55). This collection occurs between two samples yielding Fauna 4 conodonts (late Whiterockian) of Sweet et al. (1971) (Tipnis et al., 1978).

Material. Two (2) individuals.

Figured specimens. GSC 40335 from P 55.

Discussion. The pygidium of *Kawina* sp. differs from most species of *Kawina* in possessing three axial rings, but no terminal piece. In this respect it is similar to the *Kawina* sp. from the upper Antelope Valley Limestone, Nevada illustrated by Ross (1970, Pl. 18, figs. 16-18) and the *Kawina* sp. from the Oil Creek Formation, Oklahoma illustrated by Shaw (1974, Pl. 7, fig. 20). The absence of a terminal piece may suggest an assignment to *Xystocrania* Whittington, 1965a; but the *Kawina* from the Sunblood Formation differs from both species of *Xystocrania* in which pygidia are known, *X. unicornica* (Hintze, 1953) and *X.* cf. *perforator* (Billings) (see Ross, 1970) in that the spines are fused for nearly half their length.

Subfamily DEIPHONINAE Raymond, 1913

Diagnosis. Lane's (1971, p. 58) diagnosis of this subfamily was revised by Chatterton and Ludvigsen (1976, p. 73).

Genus *Sphaerocoryphe* Angelin, 1854

Type species. *Sphaerocoryphe dentata* Angelin, 1854 from the Late Ordovician of Sweden.

Sphaerocoryphe cf. *pemphis* Lane, 1971

1971 *Sphaerocoryphe pemphis* Lane, p. 62, Pl. 14, figs. 1-18.

1976 *Sphaerocoryphe* cf. *pemphis*, Chatterton and Ludvigsen, p. 73, Pl. 15, figs. 44-46.

Occurrence. Lower Esbataottine Formation, Sunblood Range (A 125). *Ceraurinella nahanniensis* Zone.

Material. One (1) individual.

Sphaerocoryphe robustus Walcott, 1875

Plate 18, figures 33-53

1875 *Sphaerocoryphe robustus* Walcott, p. 273, figs. 18a, b.

1947 *Sphaerocoryphe robustus*, Wilson, p. 52, Pl. 10, figs. 1, 2a.

1968 *Sphaerocoryphe robustus*, Shaw, Pl. 14, fig. 1.

1975 *Sphaerocoryphe* sp., Ludvigsen, Pl. 5, figs. 12, 13.

1978d *Sphaerocoryphe robustus*, Ludvigsen, Fig. 32D

Occurrences. Trenton Group, New York State, Ontario, Quebec (see Ludvigsen, 1978b, Fig. 3); lower Whittaker Formation, Funeral Range (C 655, J 220), Whittaker Range (H 1920, I 1275, I 1350-1380), and Dusky Range (R 625). *Ceraurinella necra* Zone, *Ceraurus mackenziensis* Zone, and *Whittakerites planatus* Zone (in District of Mackenzie).

Material. About thirty-five (35) individuals.

Holotype. A complete exoskeleton (MCZ 7567) from the Trenton Group at Trenton Falls, New York illustrated by Shaw (1968, Pl. 14, fig. 1) and by Ludvigsen (1978c, Fig. 32D).

Hypotypes. GSC 40451, 44264-44270 from C 655; GSC 40452 from H 1920.

Description. Cranidium, without swollen part of glabella and genal spines, crescentic in outline, three times as wide as long (sag.); slightly vaulted (tr.) and strongly convex (sag.). In lateral view, anterior margin descends nearly vertically from palebral lobe and curves underneath posterior portion of swollen part of glabella. Occipital ring arched, short (sag.); stands well above posterior portion of glabella. Occipital furrow transverse, deepest distally. Portion of glabella behind swollen portion, sub-rectangular in outline, moderately arched; defined laterally by very shallow and broad axial furrows which curve around slightly inflated 1p lobes of triangular outline. That part of glabella between inflated 1p lobes is flat to slightly concave. Holloway and Campbell (1974, p. 419) employed the term "pre-occipital depression" for this feature and emphasized that it consists of the occipital furrow and part of the median glabellar lobe. In front of 1s furrow, axial furrows diverge and become deep furrows that undercut swollen part of glabella and then descend to become deep inwardly and upwardly directed preglabellar furrow. 2p lobe obsolescent; its position shown by 1s and 2s apodemal pits on interior (Pl. 18, fig. 37). Glabella dominated by swollen anterior portion which is spherical, unfurrowed; it occupies two thirds total glabellar length (sag.) and is one and one half times as wide (tr.) as occipital ring. In lateral profile, swollen portion stands higher than occipital ring and extends below level of base of genal spines; its "centre of gravity" is located slightly below level of eyes. It is isolated from posterior portion of glabella by relatively long (exsag.) furrows that shallow adaxially and that, apparently, represent combined 1s and 2s furrows. Posterior portion of fixed cheek nearly horizontal; anterior portion nearly vertical in front of eyes. Palpebral lobe small, lenticular in outline, sharply raised over floor of cheek; located opposite combined 1s and 2s furrows; stands lower than crest of posterior portion of glabella; defined adaxially by narrow palpebral furrow which, posteriorly, is continuous with faint furrow bounding sutural ridge and, anteriorly, curves steeply down and terminates in front of visual surface of eye. Anterior branch of facial suture descends vertically in front of palpebral lobe and curves underneath posterior portion of swollen part of glabella along path sub-parallel with preglabellar furrow. A forwardly deflected anterior border is thus isolated. Posterior branch of facial suture positioned on short (exsag.) sutural ridge; curves outward and downward with faint forward curvature. Cheek, adaxially of palpebral lobe, slopes steeply toward deep axial furrow. Deep posterior border furrow of cheek is lateral continuation of occipital furrow; terminates abruptly at base of genal spine; bounds narrow and convex (exsag.) posterior border. Only posterior part of lateral border furrow seen; appears to be deep and wide (tr.), interrupted by narrow sutural ridge. Lateral border convex, slightly wider (tr.) than length (exsag.) of posterior border. A pair of small, nub-like lateral cephalic spines located on ventrolateral part of lateral border between posterior branch of facial suture and base of genal spine (Pl. 18, fig. 37). On smaller cranidia (Pl. 18, fig. 43), these spines are relatively longer and laterally curving. Distinct, rounded (exsag.) ridge proceeds transversely across fixed cheek, halfway between eye and posterior margin. This ridge is bounded by the posterior border furrow and by the depressed area surrounding eye and continues part way down genal spine; so that the base of the genal spine is carinate. Genal spine stout, curving, gradually tapering; extends posteriorly as far as one half length (sag.) of cranidium. On interior, 0s, 1s, and 2s apodemal pits appear as rounded knobs along forwardly diverging axial furrows. Occipital doublure extends to faint ridge representing occipital furrow. Doublure encases genal spine and, adaxially, thins toward tiny marginal connective device. Swollen portion of glabella is rather coarsely granulate; remainder of dorsal surface of cranidium (except furrows) is finely granulate.

Free cheek, rostral plate, and thoracic segments have not been recognized in these collections.

Hypostome trapezoidal in outline with straight and parallel anterior and posterior margins; lateral margins converge posteriorly from maximum width (tr.) at faintly defined shoulders to obtusely angled posterolateral corners. Central body ovoid in outline, arched (tr.); bracketed by deep, outwardly bowed lateral border furrows, posteriorly by narrow (tr.) and short (sag.) posterior border furrow, and anteriorly by faint anterior border furrow that deepens laterally. Faint maculae proceed obliquely inward and backward from juncture of lateral and anterior border furrows. Lateral and posterior borders convex, tube-like. In posterior view, the posterior border thickened medially. Anterior border narrow, deflected upward at nearly right angle to rest of hypostome. Anterior margin straight medially where it forms the sutural contact with the rostral plate; in front of maculae, it is notched to form sutural contact with doublure of free cheek and continues laterally into small dorsolaterally directed anterior wing. Faint antennal notch separates anterior wing from shoulder. On interior, doublure nearly reaches high rounded ridge forming interior impress of lateral border furrow. Macula expressed as relatively high ridge that separates distal portions

of anterior and posterior lobes of central body. Ventral surface of hypostome sparsely granulate.

Pygidium (without second marginal spines) crescentic in outline, three times as wide (tr.) as long (sag.); composed of anterior segment which, apparently, duplicates morphology of the thoracic segments; followed by three segments. First axial ring short (sag.), highly arched, bounded by narrow (tr.) axial furrows, outlined by short (sag.) articulating furrow, relatively long (sag.) first axial ring furrow which is continuous laterally with deep interpleural furrow. Pleural field, opposite first axial ring, composed of a transverse and convex (exsag.) band which, distally, is produced into pair of short, stout, square-tipped, ventrally directed spines. Second axial ring stands well below first axial ring and is only faintly outlined by the axial furrows; extended posteriorly into pair of long, stout, curved, gradually tapering spines which proceed outward and backward; and, distally, converge to form tong-shaped continuum. Spines carry distinct carinae that appear to be extensions of the faintly arched second axial ring. Third and fourth axial rings very short (sag.) and narrow (tr.); confined to lenticular depression outlined, anteriorly, by second axial ring furrow and, posteriorly, by approximately transverse furrow joining elongate slots at posterior ends of second, third, and fourth axial ring furrows (Pl. 18, fig. 53). Posterior border of pygidium between bases of great spines, formed by short and convex (sag.) band which curves slightly posteriorly. Doublure narrow, convex; forms stretched U-shaped curve between bases of second marginal spines and, beneath posterior border, is extended into a pair of triangular, transversely oriented spines which are ventrally produced (Pl. 18, figs. 45, 51).

Discussion. The material from the Whittaker Formation is assigned to *Sphaerocoryphe robustus* Walcott despite a few differences. The holotype from Trenton Falls, New York (Shaw, 1968, Pl. 14, fig. 1; Ludvigsen, 1978c, Fig. 32D) shows a more inflated fixed cheek inside the border furrows and a slightly longer posterior glabellar portion (behind the swollen anterior glabellar portion) than the Whittaker material and the palpebral lobes appear to be located farther out on the cheek. It is difficult to evaluate these points in light of the considerable differences that, apparently, distinguish the twenty or so named species of *Sphaerocoryphe* (Shaw, 1968; Lane, 1971; Webby, 1974). *Sphaerocoryphe* undergoes extensive morphological change during its ontogeny and it is difficult to ascertain the diagnostic value of many of these features. Only in exceptionally preserved specimens may features such as the small, anteroventrally directed lateral cephalic spines and the triangular and ventrally directed posterior pygidial spines of *S. robustus* be seen.

It is clear from the aspect of the hypostomal suture on the hypostome and the downwardly deflected anterior cranidial margin of *Sphaerocoryphe robustus* that the hypostome would be positioned at a high angle to the remaining exoskeleton. Holloway and Campbell (1974, p. 420, 421) suggested that the hypostomes of the Deiphoninae were moveable and cited, as evidence, the well-developed articulating devices of *Deiphon*, the "embayments in the anterior border of the cephalon on either side of the hypostomal suture that received the posterior spines of the pygidium", and the "deep furrow across the anterior half of the hypostome (that) probably also fitted into the doublure of the pygidium". The presence of articulating devices do not, necessarily, require the ability of total enrolment and the "embayments" may be viewed as antennal notches rather than receptors of the posterior pygidial spines. The variably developed anterior border furrow of the hypostome and the variety of morphologies of the doublure of the pygidium (including stout, ventrally directed spines) argue against a close connection of these features. Furthermore, the sharp-edged and laterally indented hypostomal suture suggests that rotation of the hypostome of *S. robustus* would not be allowed. In fact, none of the cheirurids investigated during the present study possesses hypostomal sutures that display a morphology suggesting that it was a surface of rotation.

Family ENCRINURIDAE Angelin, 1854

Subfamily ENCRINURINAE Angelin, 1854

Diagnosis. See Evitt and Tripp (1977, p. 121).

Genus *Encrinuroides* Reed, 1931

Type species. *Cybele sexacostata* Salter, 1848 from the Ashgillian of Wales.

Encrinuroides rarus (Walcott, 1877)

Plate 21, figures 42-48

1877 *Ceraurus rarus* Walcott, p. 68.

1877 *Encrinurus raricostatus* Walcott, p. 69.

1897 *Encrinurus vannulus* Clarke, p. 739, Text-figs. 56, 57.

1913 *Encrinurus rarus*, Raymond and Burton, p. 541, Pl. 2, fig. 3.

1928 non *Encrinurus rarus(?)*, Troedsson, p. 59, Pl. 16, figs. 4-9.

1963 *Encrinuroides rarus*, DeMott, p. 168, Pl. 11, figs. 13-25.

1975 *Encrinuroides rarus*, Ludvigsen, Pl. 3, figs. 22, 23.

1976 *Encrinuroides rarus*, Chatterton and Ludvigsen, p. 74, Pl. 15, figs. 1-43.

Occurrences. Platteville Group, Wisconsin and Esbataottine Formation, Sunblood Range (A 110, A 125, A 247, A 365, A 615, P 1485, P 1497, P 1785), Flood Creek (G 3195, G 3340). *Ceraurinella nahanniensis* Zone, *Bathyurus ulu* Zone, *Ceraurus gabrielsi* Zone, *Ceraurinella longispina* Zone (in Canada).

Material. One hundred and thirty-one (131) individuals.

Hypotypes. GSC 44345 from A 385, GSC 44346-44348 from A 615.

Discussion. This species was described recently by Chatterton and Ludvigsen (1976) who illustrated well-preserved specimens from the lower Esbataottine Formation (*Ceraurinella nahanniensis* Zone) in the Sunblood Range. *Encrinuroides rarus* extends through the entire Esbataottine Formation and a few specimens are illustrated herein from the upper part of the formation at Section A.

Subfamily CYBELINAE Holliday, 1942

Discussion. See Evitt and Tripp (1977, p. 142) for diagnosis of subfamily and list of included genera.

Genus *Cybeloides* Slocum, 1913

Type species. *Cybeloides iowensis* Slocum, 1913 from the Maquoketa Group of Iowa.

Cybeloides cimelia Chatterton and Ludvigsen, 1976

Plate 21, figures 1-41

1962 *Cybeloides* sp., Norford, Pl. 4, fig. 2.

1963 *Cybeloides platylobus* DeMott (nomen nudum), p. 175, Pl. 12, figs. 5, 6.

1975 *Cybeloides* cf. *prima* (Raymond), Ludvigsen, Pl. 3, figs. 18, 19, Pl. 4, figs. 5, 6.

1976 *Cybeloides cimelia* Chatterton and Ludvigsen, p. 69, Pl. 14, figs. 1-43, Pl. 22, fig. 1.

Diagnosis. See Chatterton and Ludvigsen (1976, p. 70).

Occurrence. Esbataottine Formation, Sunblood Range (A 110, A 125, A 140, A 147, A 365, A 385, P 1440, P 1485, P 1497, P 1512, P 1785, P 2010, P 2038, P 2050, GSC loc. 32936) and Flood Creek (G 3195); upper Sunblood Formation, Mary Range (B 1510-1520). *Ceraurinella nahanniensis* Zone, *Bathyurus ulu* Zone, *Ceraurus gabrielsi* Zone, and *Ceraurinella longispina* Zone (in Canada).

Material. Six hundred and five (605) individuals.

Hypotypes. GSC 44341-44344 from A 365; GSC 44332-44335 from G 3195; GSC 43546, 44336-44340 from P 1485; GSC 40417, 40418, 44322-44331 from P 2038.

Discussion. *Cybeloides cimelia* has been fully described by Chatterton and Ludvigsen (1976) who illustrated well-preserved material of this species from the lower part of the Esbataottine Formation (*Ceraurinella nahanniensis* Zone) in the Sunblood Range. Additional material from higher in the Esbataottine Formation (*Ceraurus gabrielsi* and *Ceraurinella longispina* Zones; Pl. 21, figs. 1-41) shows that *C. cimelia* displays considerable intra-specific variation; in particular, in the sizes of cephalic tubercles (compare Pl. 21, figs. 7, 13 and Pl. 21, figs. 26, 41). *Cybeloides cimelia* appears to have the longest stratigraphic range of any of the trilobites under consideration (184.5 m in Section P) and occurs discontinuously through the Esbataottine Formation from upper Chazyan to Rocklandian strata.

Cybeloides anna n. sp.

Plate 20, figures 15-36

Diagnosis. A *Cybeloides* with parallel-sided glabella of pentagonal outline, obliquely disposed and slot-like apodemal pits, and moderately inflated lateral tricomposite lobes whose long axes are aligned exsagittally. Glabellar tubercles large and paired. Median pit on anterior glabellar lobe forms apex of triangle that apparently represents an area of muscle insertion. Lateral cephalic border broad; lateral marginal spine short and stout.

Occurrence. Upper Sunblood Formation, Sunblood Range (P 1187). *Bathyurus granulosus* Zone.

Material. Thirty-seven (37) individuals.

Holotype. An incomplete cranidium (GSC 44309) from P 1187 illustrated on Plate 20, figures 15, 16, 28.

Paratypes. GSC 44310-44321 from P 1187.

Discussion. From *Cybeloides prima* Raymond, *C. virginiensis* Cooper (Evitt and Tripp, 1977), and *C. spinifera* Tripp; *C. anna* n. sp. differs in possessing a parallel-sided glabella with exsagittally oriented lateral tricomposite lobes that lack tubercles. *Cybeloides anna* is most similar to *C. cimelia* Chatterton and Ludvigsen from which it differs in a few persistent characters. The axial furrows of *C. anna* diverge only slightly from the distal end of the occipital furrow and the glabella is parallel-sided and pentagonal in shape. The longitudinal glabellar furrows are very shallow between 2s and 3s pits and the lateral tricomposite lobes are moderately inflated and exsagittally directed. The pit on the median part of the anterior glabellar lobe is located just behind a line joining the anterior pair. The lateral marginal spine is short and stout. In *C. cimelia*, the axial furrows diverge widely from the distal end of the occipital furrow resulting in a sub-circular glabella. The longitudinal furrows are deep and the lateral tricomposite lobes are swollen and their long axes diverge slightly toward the front. The pit on the anterior part of the median glabellar lobe is located at the intersection of lines joining the anterior two tubercle pairs. The lateral marginal spine is relatively long and gently curving.

The prominent pit located on the mid-point of the anterior lobe of most species of *Cybeloides* has been judged to be a point of muscle attachment (Tripp, 1954, p. 681). This interpretation receives support from additional features associated with the anterior pit in *C. anna* (Pl. 20, fig. 28). In this species the pit forms the right-angled apex of an equilateral triangle whose base is approximately defined by two widely spaced tubercles located on the anterior margin. These tubercles are shared with the rostral plate (Pl. 20, fig. 30) and, thus, they define the width of the rostral suture. The equal sides of the triangle are faintly excavated into the fine granulose ornament as very narrow and bald furrows. The area enclosed by the triangle possesses fine, elongate pits. This pitting is better expressed on the interior (Pl. 20, fig. 36) where it appears as a triangular cluster of small shallow depressions. Analogous muscle insertion patterns are seen in many genera of the Phacopina (Eldredge, 1971), in *Ceraurus* (Evitt, 1953), and in *Ceraurus* and *Whittakerites* (this paper). In the latter genera the outline of the pattern is an anteriorly pointing triangle, while in *Cybeloides* (and in the Phacopina) the triangle points toward the posterior. If these patterns reflect attachment of muscles that support the anterior portion of the digestive tract (Eldredge, 1971), then a change in the outline of the muscle insertion patterns should signify a change in the visceral organization and, presumably, different feeding habits.

Genus *Cybellela* Reed, 1928

Type species. *Zethus rex* Nieszkowski, 1857 from the Middle Ordovician of Estonia.

Discussion. Whittington (1965b) upheld the validity of *Cybellela* - a taxon which Öpik (1937) had regarded as a subgenus of *Cybele* Loven, and Henningsmoen (in Moore, 1959) had considered to be a junior synonym of *Atractopyge* Hawle and Corda. Dean (1971a) recently redescribed the type species of *Atractopyge*, *A. verrucosa* (Dalman), and suggested that some of the species assigned to *Cybellela* by Whittington (1965b), including *C. dentata* (Esmark) and *C. aspera* (Linnarsson), should probably be assigned to *Atractopyge*. A decision on the validity of *Cybellela* must be postponed until the type species is redescribed.

Cybellela? thor n. sp.

Plate 20, figures 1-14

1973 *?Paracybeloides* sp., Norford, in Gabrielse et al., p. 57.

Diagnosis. A *Cybellela* with parallel-sided glabella of pentagonal outline, three pairs of deep, slit-like lateral glabellar furrows which do not reach axial furrow, and faint preglabellar furrow. Lateral glabellar lobes short (exsag.), slightly inflated. Palpebral lobes high; palpebral ridge distinct. Occipital ring carries short, asymmetrical, hammer-shaped spine. Pygidium high, short (sag.); includes four sets of pleural ridges. Axis traversed by only one ring.

Occurrence. An unknown horizon within the Sunblood Formation about 10 km southwest of Section P. GSC locality 58678 (61°41'N, 126°04'W). Associated with *C.? thor* in this collection is a species of *Calyptaulax* that is similar to *C. incepta* Whittington from the lower Table Head Formation of Newfoundland. The occurrence of *C.? thor* in the Sunblood Formation in this area indicates a Chazyan or earlier age; the co-occurrence with *C.* cf. *incepta* suggests a Whiterockian age.

Material. Eleven (11) individuals.

Holotype. An incomplete cranidium (GSC 44302) from GSC locality 58678 illustrated on Plate 20, figures 1-3.

Paratypes. GSC 44303-44308 from GSC locality 58678.

Description. Cranidium crescentic in outline, about two and one half times as wide as long (sag.) and moderately vaulted (tr.); front margin defined by very narrow evenly curved preglabellar furrow. Preglabellar field very narrow on lateral flanks, slightly wider medially where it consists of a row of three large tubercles. Lateral glabellar furrows deep slits; 1s furrow approximately transverse, 2s and 3s increasingly obliquely disposed. Furrows terminate slightly inside axial furrow; a narrow (tr.), faintly inflated "incipient lateral tricomposite lobe" defined by abaxial tips of glabellar furrows and shallow axial furrow. Lateral glabellar lobes short (exsag.), rectangular to rhomboid in outline; confluent with "tricomposite lobe"; stand lower than inflated median glabellar lobe. Anterior lobe long (sag.), rhomboid; includes a prominent pit at mid-point. Occipital ring lenticular in outline, arched, as wide (tr.) as glabella in front of occipital furrow; mid-portion extended dorsally as stout, broad-based, slightly curving spine which, distally, expands into a pair of knob-like terminations which may be unequally developed (Pl. 20, fig. 8) or may comprise three knobs (Pl. 20, fig. 6). Occipital furrow moderately shallow and forwardly curving behind median glabellar lobe; descends distally into deep, transversely disposed pits behind 1p lobe. Fixed cheek moderately vaulted (tr.), but convexity appears greater due to highly elevated palpebral lobe located opposite 2s furrow. Palpebral lobe oval in outline, slopes inwardly; stands considerably higher than glabella. Narrow palpebral ridge descends from palpebral lobe and runs obliquely forward to join glabella just in front of 3s furrow immediately behind shallow anterior pit. Anterior branch of facial suture parallels course of palpebral ridge, passes front edge of anterior pit, and parallels lateral part of faint preglabellar furrow. In dorsal view, entire path of suture from palpebral lobe to juncture with connective suture defined by straight line. Posterior branch of facial suture swings outward with gentle forward curvature. Posterior border furrow narrow, transversely directed outward from distal end of occipital furrow. Nature of genal angle not known. Free cheek similar to that described for *Cybeloides cimelia* Chatterton and Ludvigsen with the exception that the lateral marginal spine is shorter and the tubercles on the lateral and anterior border are more numerous.

Ornament consists of pervasive, fine, even granulation. In addition, scattered tubercles, which rarely are perforated, occur on anterior glabellar lobe and on median lobe as three or four tubercle pairs. Irregular group of seven to eight tubercles surrounds eye. Three distinct tubercles occur on median part of strip-like preglabellar field.

On interior, lateral glabellar furrows and corresponding part of occipital furrow expressed as moderately high, plate-like apodemes. Occipital doublure extends nearly to occipital furrow.

Pygidium shield-shaped to triangular in outline, height about equal to width (tr.) and one and one half times length (sag.). Axis slightly convex, about one third width of pygidium; narrows very gradually to blunt termination at about two thirds pygidial length. In lateral view crest of axis slopes at 45°, post-axial field descends nearly vertically to margin. Axis outlined by shallow axial furrows and is composed of single, short (sag.), band-like axial ring followed by about thirteen ring furrows which are evident as closely spaced notches on lateral flanks of axis. Each of four pleura divided by a pleural furrow into a finely pitted depressed anterior pleural band carrying a faint accessory rib and into a convex posterior pleural band which curves downward and backward to terminate as sharp, hollow, backwardly directed free spines immediately above margin. Entire pygidium finely granulate. Four or five pairs of small tubercles flank sagittal line on axis. Larger and often perforated tubercles occur on posterior pleural bands.

Discussion. Cybella? thor n. sp. is herein viewed as a taxon that spans the morphological gulf between *Atractopyge* and *Cybellela* on one hand and *Cybeloides* on the other. With *Atractopyge* and *Cybellela* it shares a common glabellar, cranidial, and pygidial outline, but many morphological deviations from these two genera point to close affinity with *Cybeloides*. The following features distinguish *C.? thor* from the *Atractopyge/Cybellela* group of species and, at the same time, ally it to *Cybeloides*:

1. The preglabellar furrow is very faint. The preglabellar field is narrow (tr.) and short (sag.) and is only obvious medially where it is occupied by three tubercles. *Atractopyge* and *Cybellela* have complete preglabellar furrows and relatively long (sag.) preglabellar fields. *Cybeloides* has neither. *Atractopyge/Cybellela* have many spine-like tubercles on the anterior margin; *C.? thor* has three; *Cybeloides anna* has three or two; *Cybeloides cimelia*, *C. prima*, and *C. iowensis* have two; and *C. girvanensis* and *C. loveni* have one. Whether this sequence is phylogenetically based remains to be proven. Fewer tubercles on the anterior margin seem to denote successively younger species.

2. The lateral glabellar furrows terminate before reaching the axial furrow isolating an "incipient lateral tricomposite lobe". In species of the *Atractopyge/Cybellela* group, the lateral glabellar furrows typically reach the axial furrow. In *Cybeloides*, the lateral glabellar furrows are reduced to apodemal pits and the lateral tricomposite lobe is isolated and swollen.

3. The tuberculate ornament is sparser than that seen on most species of *Atractopyge* and, on the median lobe, is reduced to three or four tubercle pairs. The arrangement of paired tubercles is similar to that seen on many species of *Cybeloides* and *Cybellela*.

4. A prominent pit is present at the mid-point of the anterior lobe. A similar pit is seen on msot species of *Cybeloides*, but it has not been noted in the *Atractopyge/Cybellela* group of species.

5. The occipital ring carries a moderately high and stout spine. To my knowledge an occipital spine is not present in any species of the *Atractopyge/Cybellela* group, but is common in many species of *Cybeloides* in the Middle Ordovician. It appears to be secondarily reduced in such Late Ordovician species as *Cybeloides iowensis*, *C. girvanensis*, and *C. loveni*.

6. The pygidium is similar to both of the generic groups being compared, but differs from the *Atractopyge/Cybellela* group in that the axis is traversed by only a single ring - a feature that it shares with all described species of *Cybeloides*.

In northern Europe, species of the *Atractopyge/Cybellela* group range from strata of Llanvirnian to Ashgillian age (Whittington, 1965b; Dean, 1971a), but a pygidium from the Glaukonitkalk (Arenigian) has also been assigned to *Atractopyge* (Neben and Krueger, 1971). With the exception of *A. condylosa* Dean, 1971b from Newfoundland, species of this group have not been previously described from North America. Species of *Cybeloides* have an age range of Chazyan to Richmondian in North America and late Caradocian to Ashgillian in Britain (Ingham, 1968) - if one disregards the occurrences in the Girvan area (Tripp, 1954, 1962) which must be considered part of Ordovician North America.

Evitt and Tripp (1977) have redescribed and extensively figured *Bevanopsis ulrichi* Cooper, 1953 from the Botetourt and Edinburg Formations of Virginia. That species is, in cranidial and pygidial morphology, very similar to *Cybellela? thor* and *Bevanopsis* may be a junior synonym of *Cybellela*.

Unfortunately, the age of *Cybellela? thor* is not definitely known. It is of Chazyan or earlier age and probably of Whiterockian age. In other words, the species is an approximate contemporary of the earliest species of the *Atractopyge/Cybellela* group and older than any species of *Cybeloides*. It is here suggested that *C.? thor* was derived from, or shared a common ancestor with, the *Atractopyge/Cybellela* group and that it served as an ancestor to *Cybeloides*.

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APPENDIX 1

LOCALITY DATA FOR MEASURED SECTIONS

Locality data for eleven measured sections of Ordovician formations in the southern Mackenzie Mountains (Fig. 1). For each trilobite-bearing collection, the distance (in metres) above the base of the measured section is given along with its zonal assignment. Note that these collections have also yielded ostracodes (Copeland, 1974, 1978), conodonts (Tipnis et al., 1978), and brachiopods (Wigington, 1977; Mitchell, 1978).

SECTION A. SUNBLOOD RANGE

61°31'N, 125°44'W, measured from cairn on Sunblood Mountain. Collected by R. Ludvigsen, B.D.E. Chatterton and J.W. Harrington.

WHITTAKER FORMATION - 191.0-360.0 m

ESBATAOTTINE FORMATION - 6.5-191.0 m

186.5 m	A 615	*C. longispina* Zone
117.0 m	A 385	*C. gabrielsi* Zone
110.5 m	A 365	*C. gabrielsi* Zone
75.0 m	A 247	*B. ulu* Zone
73.0 m	A 240	*B. ulu* Zone
66.5 m	A 220	*B. ulu* Zone
57.5 m	A 190	*B. ulu* Zone
48.5 m	A 160	*C. nahanniensis* Zone
42.5 m	A 150	*C. nahanniensis* Zone
38.0 m	A 125	*C. nahanniensis* Zone
35.0 m	A 115	*C. nahanniensis* Zone

SUNBLOOD FORMATION - 0-6.5 m (incomplete)

SECTION B. MARY RANGE

61°19'N, 125°23'W, 10 km southwest of the confluence of Mary River and May Creek. Collected by R. Ludvigsen and B.D.E. Chatterton.

SUNBLOOD FORMATION - 0-510.0 m (incomplete)

457.5-460.5 m	B 1510-1520	*C. longispina* Zone
440.0 m	B 1450	*C. gabrielsi* Zone
398.5 m	B 1315	*B. granulosus* Zone
392.5 m	B 1295	*B. granulosus* Zone
382.5 m	B 1265	*B. granulosus* Zone
353.0 m	B 1165	*B. granulosus* Zone
333.5 m	B 1100	*B. nevadensis* Zone
304.5 m	B 1005	*B. nevadensis* Zone
240.0 m	B 795	*B. nevadensis* Zone
44.0 m	B 145	Whiterockian

SECTION C. FUNERAL RANGE

61°31'N, 124°52'W, measured 6 km west of Prairie Creek, from drag fold above Gate Fault. Collected by R. Ludvigsen and B.D.E. Chatterton.

WHITTAKER FORMATION - 0-203.0 m (incomplete)

198.5 m	C 655	*C. mackenziensis* Zone
193.0 m	C 640	*C. mackenziensis* Zone
173.0-179.0 m	C 570-590	*C. necra* Zone

SECTION D. NATLA RIVER

63°09'N, 127°58'W, measured 10 km east of east branch of Natla River. Collected by R. Ludvigsen, D.G. Perry, and U. Upitis.

WHITTAKER FORMATION (Ordovician part) - 492-545.5 m

SUNBLOOD FORMATION - 272.5-492.0 m

416.5 m	D 1375	*C. gabrielsi* Zone
406.5 m	D 1342	*C. gabrielsi* Zone
127 m above base of Sunblood	GSC loc. 69001	*C. gabrielsi* Zone

BROKEN SKULL FORMATION - 0-272.5 m (incomplete)

SECTION G. FLOOD CREEK

62°07'N, 126°41'W, measured on east-west ridge between Flood Creek and Clearwater Creek. Collected by R. Ludvigsen.

ROAD RIVER FORMATION - 1345.5-1403.5 m (incomplete)

WHITTAKER FORMATION - 1021.0-1345.5 m

ESBATAOTTINE FORMATION - 942.0-1021.0 m

1012.0 m	G 3340	*C. longispina* Zone
968.0 m	G 3195	*C. longispina* Zone

SUNBLOOD FORMATION - 0-942.0 m

841.0 m	G 2795	*B. granulosus* Zone

SECTION H. WHITTAKER RANGE

62°31'N, 124°51'W, 5 km northwest of north tip of Trench Lake. Collected by R. Ludvigsen and B.D.E. Chatterton

WHITTAKER FORMATION - 405.0-610.0 m (incomplete

600.0 m	H 1975	*C. mackenziensis* Zone
582.0 m	H 1920	*C. mackenziensis* Zone
560.5 m	H 1850	*C. mackenziensis* Zone

ESBATAOTTINE FORMATION - 221.5-405.0 m

399.5 m	H 1300	*C. gabrielsi* Zone
310.0 m	H 1020	*C. gabrielsi* Zone
273.0	H 900	*C. gabrielsi* Zone
232.5-238.5 m	H 800-820	*C. nahanniensis* Zone

SUNBLOOD FORMATION - 0-221.5 m (incomplete)

123.5 m	H 410	*B. granulosus* Zone

SECTION I. WHITTAKER RANGE

62°29'N, 124°47'W, measured 6 km west of Trench Lake. Collected by D.G. Perry and A.C. Lenz.

WHITTAKER FORMATION - 251.5-638.0 m (incomplete)

481.5 m	I 1590	*W. planatus* Zone
427.0 m	I 1410	*C. mackenziensis* Zone
409.0-419.0 m	I 1350-1380	*C. mackenziensis* Zone
387.0 m	I 1275	*C. necra* Zone

ESBATAOTTINE FORMATION - 54.5-251.5 m

237.0 m	I 780	*C. gabrielsi* Zone

SUNBLOOD FORMATION - 0-54.5 m (incomplete)

SECTION J. FUNERAL RANGE

61°29'N, 125°03'W, measured 11 km northeast of The Gate of the South Nahanni River. Collected by B.D.E. Chatterton and J.F. Conrad.

WHITTAKER FORMATION - 0-234 m (incomplete)

143.0 m	J 220	*C. mackenziensis* Zone

SECTION P. SUNBLOOD RANGE

61°43'N, 125°56'W, 16 km northwest of Sunblood Mountain. Collected by R. Ludvigsen. GSC locality numbers are included in brackets.

WHITTAKER FORMATION - 622.0-687.0 m

ESBATAOTTINE FORMATION - 431.5-622.0 m

621.1 m	P 2050 (C-26301)	*C. longispina* Zone
619.5 m	P 2038 (C-26302)	*C. longispina* Zone
609.0 m	P 2010 (C-26303)	*C. longispina* Zone
589.5-592.5 m	P 1945-1955 (C-26305)	*C. gabrielsi* Zone
585.0 m	P 1931 (C-26306)	*C. gabrielsi* Zone
566.5 m	P 1870 (C-26307	*C. gabrielsi* Zone
541.0 m	P 1785 (C-26308)	*C. gabrielsi* Zone
510.5 m	P 1685 (C-26310)	*C. gabrielsi* Zone
504.5 m	P 1665 (C-26311)	*C. gabrielsi* Zone

SECTION P (continued)

492.5 m	P 1625 (C-26312)	*B. ulu* Zone
483.5 m	P 1595 (C-26313)	*B. ulu* Zone
480.5 m	P 1585 (C-26314)	*B. ulu* Zone
477.0 m	P 1575 (C-26315)	*B. ulu* Zone
460.5 m	P 1520 (C-26317)	*C. nahanniensis* Zone
458.0 m	P 1512 (C-26318)	*C. nahanniensis* Zone
453.5 m	P 1497 (C-26319)	*C. nahanniensis* Zone
450.0 m	P 1485 (C-26320)	*C. nahanniensis* Zone
436.5 m	P 1440 (C-26321)	*C. nahanniensis* Zone

SUNBLOOD FORMATION - 0-431.5 m (incomplete)

360.0 m	P 1187 (C-26325)	*B. granulosus* Zone
342.5 m	P 1130 (C-26326)	*B. granulosus* Zone
341.5 m	P 1127 (C-26327)	*B. granulosus* Zone
333.5 m	P 1090 (C-26328)	*B. granulosus* Zone
16.5 m	P 55 (C-26341)	Whiterockian

SECTION Q. WHITTAKER RANGE

62°28'N, 124°48'W, measured 7 km west of Trench Lake. Collected by J.F. Conrad and D.G. Perry.

WHITTAKER FORMATION - 0-221.0 m (incomplete)

160.5 m	Q 530	*W. planatus* Zone
130.0 m	Q 430	*C. mackenziensis* Zone
39.0 m	Q 130	*C. necra* Zone

SECTION R. DUSKY RANGE

63°17'N, 125°21'W, measured 16 km west of Dahadinni River. Collected by R. Ludvigsen and D.L. Christie.

WHITTAKER FORMATION (Ordovician part) - 135.0-330.0 m

199.0 m	R 655	*W. planatus* Zone
190.0 m	R 625	*W. planatus* Zone

BROKEN SKULL FORMATION - 0-135.0 m (incomplete)

APPENDIX 2

DERIVATION OF NEW NAMES

anacantha	in reference to the absence of an occipital spine in this species (*a* + *acantho*, without a thorn, (Greek).
anna	affectionately dedicated to my mother, Anna Ludvigsen.
arctica	from the northern regions.
atacius	from non-isolated basal glabellar lobes of this species, atypical for *Sphaerexochus*, suggests its name (*atacio*, out of order, Greek).
blussoni	for S.L. Blusson of the Geological Survey of Canada, Vancouver.
brevispina	in reference to the short first pygidial spines of this species (*brevi* + *spinosus*, short spined, (Latin).
esbataottinensis	for Esbataottine Mountain, Sunblood Range.
gabrielsi	for H. Gabrielse of the Geological Survey of Canada, Vancouver, whose work in the northern Cordillera has contributed significantly to an understanding of the regional geology of this area.
goniopyga	in reference to the bent appearance of the pygidium of this species in lateral view (*gonia* + *pygon*, angled rump, Greek).
granulosus	in reference to the granulate ornament of this species (*granulosus*, grainy, Latin).
hirsuitus	in reference to the fine, hair-like spines that cover the dorsal surface of this species (*hirsuitus*, hairy, Latin).
longispina	in reference to the long first pygidial spines of this species (*longi* + *spinosus*, long spined, Latin).
mackenziensis	for the Mackenzie Mountains.
maewestoides	descriptive name for the shape of the glabella of this species.
media	in reference to the occurrence of this species in the middle Estabaottine Formation (*medius*, middle, Latin).
necra	in reference to the type locality of this species in the Funeral Range, adjacent to the Headless Range, and just northwest of Deadman Valley -- names that serve to sustain the Legend of the Nahanni (Patterson, 1966), (*nekros*, a dead body, Greek).
platyparius	in reference to the broad and flat cephalic margin of this species (*platys* + *pareia*, flat cheek, Greek).
seriata	in reference to the closely aligned third pygidial spines of this species (*seriatus*, bound together, Latin).
serratus	in reference to the saw-toothed appearance of the second and third pygidial spines of this species (*serratus*, saw-toothed, Latin).
thor	for Thor, Norse god of thunder, who carried the hammer Miölnir, in reference to the hammer-shaped occipital spine of this species.
ulu	in reference to the shape of the dorsal part of the rostral plate of this species; identical to the outline of the Ulu - a knife used by the Inuit.

PLATES 1-21

All illustrated material, with the exception of Plate 6, figures 21-25 and Plate 19, figures 33-35, are isolated silicified specimens.

The silicified specimens were mounted on toothpicks, blackened with dilute India ink, and coated with ammonium chloride prior to photography against a black background. The photographs have not been retouched, but the toothpicks have been blacked out.

Photographs are by the author.

Five hundred and forty-four (544) specimens are assigned Geological Survey of Canada (GSC) type numbers and eighteen (18) are assigned University of Alberta (U.A.) type numbers.

PLATE 1

Bathyurus nevadensis Ross (Page 18)

Sunblood Formation, Mary Range. All from B 1100.

Figures 1-3. Cranidium, dorsal, lateral, and anterior views, GSC 57940, x3.5.
4, 5. Cranidium, dorsal and oblique lateral views, GSC 57941, x2.6.
6. Cranidium, dorsal view, GSC 57942, x2.6.
7. Cranidium, dorsal view, GSC 57943, x5.
8. Cranidium, dorsal view, GSC 57944, x3.8.
9. Cranidium, ventral view, GSC 57945, x2.6.
10, 11. Pygidium, lateral and dorsal views, GSC 57946, x3.4
12. Pygidium, dorsal view, GSC 57947, x2.
13. Cranidium, dorsal view, GSC 57948, x5.
14. Cranidium, dorsal view, GSC 57949, x5.
15, 16. Pygidium, ventral and anterior views, GSC 57950, x3.
17, 18. Pygidium, dorsal and lateral views, GSC 57951, x4.2
19. Pygidium, ventral view, GSC 57952, x3.6.
20. Pygidium, dorsal view, GSC 57953, x2.6.
21. Hypostome, ventral view, U.A. 1718, x5.
22. Hypostome, ventral view, GSC 57954, x5.
23. Hypostome, ventral view, GSC 57955, x4.
24-26. Hypostome, dorsal, oblique, and posterior views, GSC 57956, x5.8.
27. Rostral plate, ventral view, U.A. 1717, x6.3.
28-30. Thoracic segment, dorsal, posterior, and ventral views, U.A. 1716, x4.2 and 6.
31. Free cheek, dorsal view, GSC 57957, x3.
32. Free cheek, interior view, GSC 57958, x4.

Bathyurus cf. *ulu* n. sp. (Page 14)

Middle Esbataottine Formation, Sunblood Range. All from P 1685.

Figures 33-35. Cranidium, dorsal, anterior, and lateral views, GSC 40422, x3.8.
36. Rostral plate, ventral view, GSC 57959, x4.
37, 38. Cranidium, dorsal and anterior views, GSC 57960, x5.7.
39. Free cheek, dorsal view, GSC 57961, x5.5.
40. Pygidium, ventral view, GSC 57962, x4.5.
41, 42. Pygidium, dorsal and lateral views, GSC 40424, x4.
43. Hypostome, ventral view, GSC 40423, x5.7.

Bathyurus esbataottinensis n. sp. (Page 16)

Middle Esbataottine Formation, Whittaker Range. All from H 1020.

Figure 44. Cranidium, dorsal view, GSC 57963, x3.5.
45. Cranidium, dorsal view, GSC 57964, x2.1.
46. Hypostome, ventral view, GSC 57965, x3.8.
47. Pygidium, lateral view, GSC 57966, x2.1.

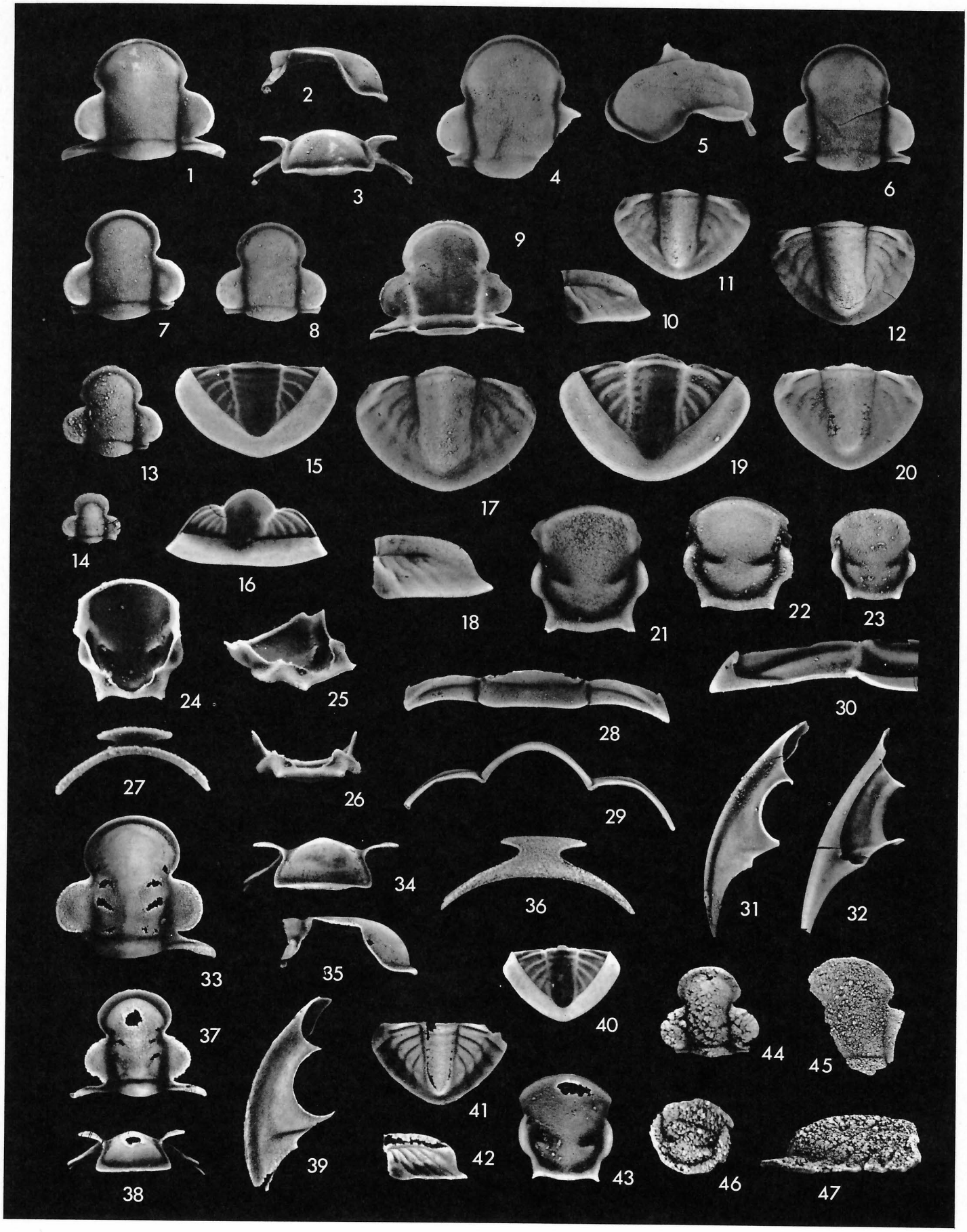
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PLATE 2

Bathyurus angustus Ross — Page 19

Sunblood Formation, Mary Range. All from B 795.

Figures 1-3. Cranidium, anterior, dorsal, and oblique lateral views, U.A. 1701, x5.
4. Cranidium, dorsal view, U.A. 1702, x5.
5. Cranidium, dorsal view, U.A. 1706, x5.
6, 7. Pygidium, lateral and dorsal views, U.A. 1703, x4.
8. Pygidium, ventral view, U.A. 1708, x4.4.
9. Rostral plate, dorsal view, U.A. 1711, x6.
10. Rostral plate, ventral view, U.A. 1712, x6.
11. Hypostome, ventral view, U.A. 1709, x5.5.
12, 13. Thoracic segment, dorsal and posterior views, U.A. 1713, x5.
14. Thoracic segment, ventral view, U.A. 1714, x7.3.
15. Free cheek, oblique view, U.A. 1715, x4.7.
16. Pygidium, ventral view, U.A. 1707, x4.4.
17. Pygidium, dorsal view, U.A. 1710, x4.4.
18. Cranidium, dorsal view, U.A. 1705, x5.
19. Cranidium, ventral view, U.A. 1704, x5.

Bathyurus platyparius n. sp. — Page 19

Sunblood and Esbataottine Formations, Mary Range, Sunblood Range, and Whittaker Range.

Figures 20, 21. Holotype cranidium, dorsal and anterior views, GSC 57967, x3.8, B 1450.
22. Cranidium, dorsal view, GSC 57968, x3.2, P 1625.
23. Cranidium, dorsal view, GSC 57969, x4.2, P 1625.
24. Pygidium, ventral view, GSC 57970, x4, B 1450.
25, 26. Pygidium, dorsal and lateral views, GSC 57971, x4, B 1450.
27. Rostral plate, dorsal view, GSC 57972, x6.3, B 1450.
28. Rostral plate, ventral view, GSC 57973, x5.7, P 1625.
29. Cranidium, ventral view, GSC 57974, x3.5, B 1450.
30. Cranidium, dorsal view, GSC 57975, x6.3, B 1450.
31. Pygidium, dorsal view, GSC 57976, x3.5, B 1450.
32. Free cheek, dorsal view, GSC 57977, x2.5, P 1625.
33, 34. Free cheek, dorsal and anterior views, GSC 57978, x3.5, B 1450.
35. Pygidium, dorsal view, GSC 57979, x3.3, P 1625.
36. Pygidium, ventral view, GSC 57980, x3.3, P 1625.
37, 38. Hypostome, oblique lateral and ventral views, GSC 57981, x4.7, B 1450.
39. Hypostome, ventral view, GSC 57982, x5.7, P 1625.
40. Hypostome, ventral view, GSC 57983, x3, H 1300.
41. Cranidium, dorsal view, GSC 57984, x3, H 1300.
42. Hypostome, ventral view, GSC 57985, x3.4, P 1625.
43. Hypostome, ventral view, GSC 57986, x4, B 1450.

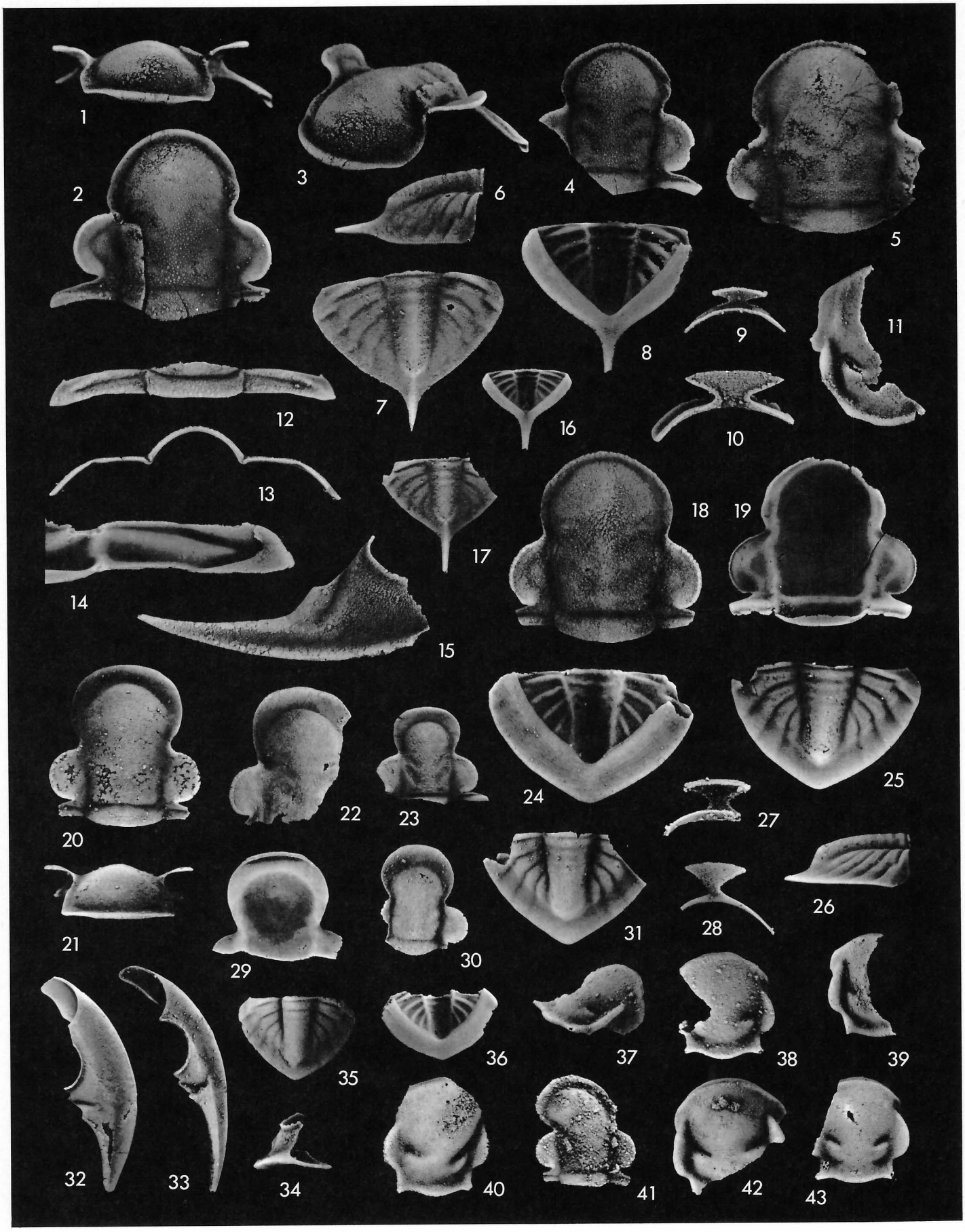
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PLATE 3

Bathyurus granulosus n. sp. (Page 18)

Upper Sunblood Formation, Mary Range and Sunblood Range.

Figures 1-3. Holotype cranidium, dorsal, lateral, and anterior views, GSC 40336, x3.8, P 1090.
4. Cranidium, dorsal view, GSC 43880, x3.8, P 1090.
5, 6. Cranidium, lateral and dorsal views, GSC 43881, x2.4, P 1090.
7, 8. Cranidium, lateral and dorsal views, GSC 43882, x4, B 1315.
9. Cranidium, dorsal view, GSC 40339, x3, B 1315.
10. Cranidium, ventral view, GSC 43883, x6.6, B 1315.
11. Cranidium, dorsal view, GSC 43884, x6.6, P 1090.
12, 14. Cranidium, anterior and dorsal views, GSC 43885, x3.6, B 1315.
13. Cranidium, dorsal view, GSC 43886, x5.5, B 1315.
15. Cranidium, ventral view, GSC 43887, x3, B 1265.
16, 17. Cranidium, anterior and dorsal views, GSC 43888, x3, B 1265.
18, 24. Pygidium, detail of axial region and dorsal view, GSC 43889, x8 and 2, B 1315.
19, 20. Pygidium, dorsal and lateral views, GSC 43890, x3.5, B 1315.
21. Pygidium, dorsal view, GSC 43891, x5.6, P 1090.
22, 23. Pygidium, dorsal and lateral views, GSC 40338, x3.6, P 1090.
25. Pygidium, ventral view, GSC 43892, x3, B 1315.
26. Pygidium, ventral view, GSC 43893, x4.1, B 1315.
27. Pygidium, dorsal view, GSC 43894, x4, P 1127.
28. Pygidium, ventral view, GSC 43895, x3.5, P 1090.
29. Pygidium, ventral view, GSC 43896, x5, P 1090.
30, 31. Pygidium, dorsal and lateral views, GSC 43897, x4, P 1127.
32. Pygidium, ventral view, GSC 43898, x4, P 1127.
33. Pygidium, dorsal view, GSC 43899, x3, B 1265.
34. Pygidium, ventral view, GSC 43901, x3, B 1265.
35. Hypostome, ventral view, GSC 43902, x3.3, B 1315.
36. Hypostome, ventral view, GSC 43903, x4, P 1127.
37. Hypostome, ventral view, GSC 40337 (specimen broken after photography, inadvertently assigned type number), x4, P 1090.
38. Hypostome, ventral view, GSC 43904, x3.1, B 1315.
39. Hypostome, ventral view, GSC 43905, x4.3, B 1315.
40. Hypostome, ventral view, GSC 43906, x3.8, P 1090.
41. Free cheek, dorsal view, GSC 43907, x2, B 1315.
42. Free cheek, interior view, GSC 43908, x3.6, P 1315.
43. Free cheek, interior view, GSC 43909, x3.7, P 1090.
44. Free cheek, lateral view, GSC 43910, x5.2, P 1090.
45, 46. Free cheek, lateral and dorsal views, GSC 43900, x3.7, P 1090.

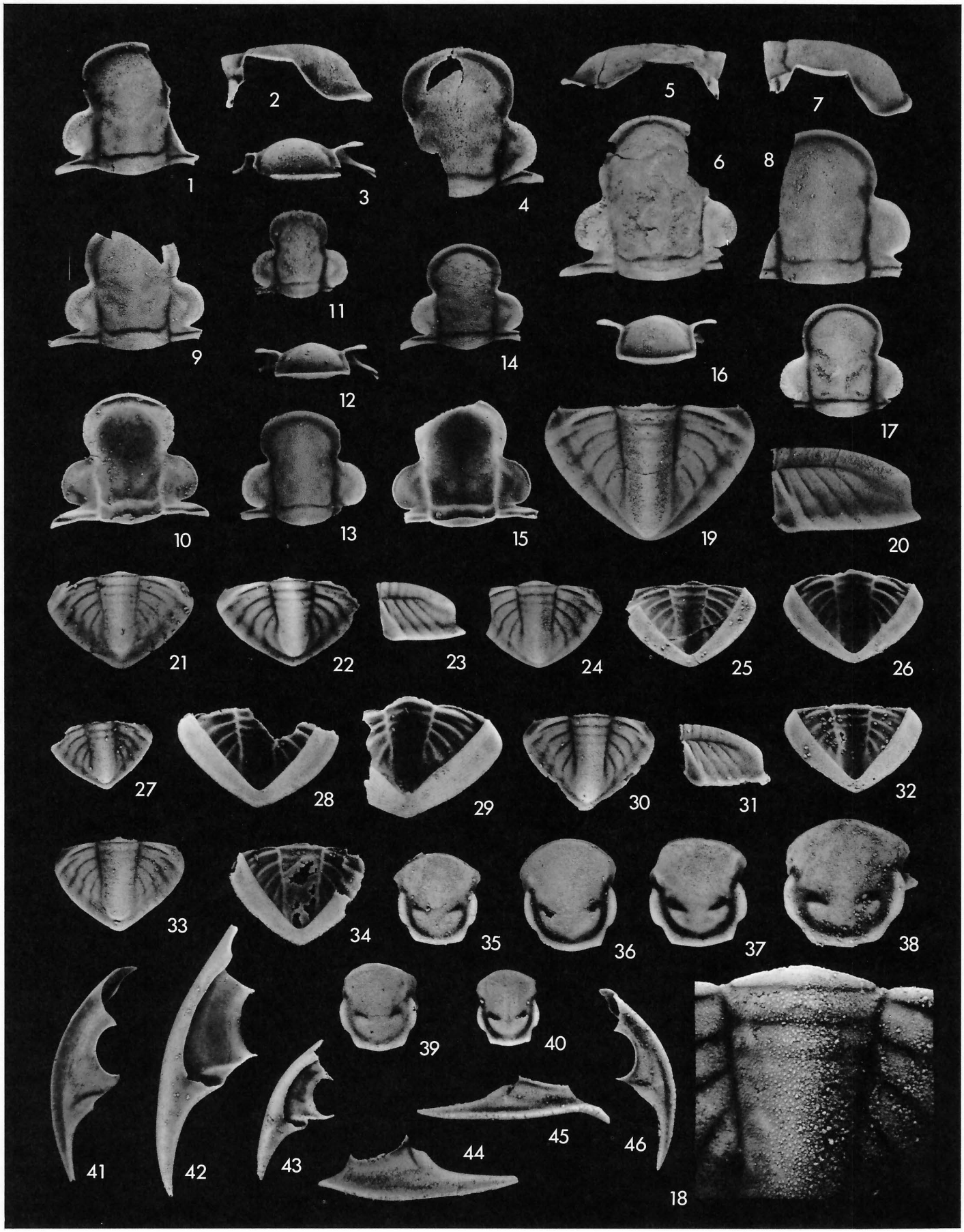
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PLATE 4

Bathyurus ulu n. sp. (Page 14)

Lower Esbataottine Formation, Sunblood Range. Figures 37-45 are from P 1595, the remainder are from A 220.

Figures 1-3. Holotype cranidium, dorsal, lateral, and anterior views, GSC 43911, x3.2
4, 5. Pygidium, dorsal and lateral views, GSC 43912, x3.
6. Cranidium, ventral view, GSC 43913, x3.2
7-9, 33. Pygidium, dorsal, lateral, and posterior views, GSC 43914, x3.3 and 6.8.
10, 11. Cranidium, dorsal and anterior views, GSC 43915, x5.
12, 13. Rostral plate, ventral and anterior views, GSC 43916, x4.
14. Cranidium, dorsal view, GSC 43917, x4.1.
15. Rostral plate, dorsal view, GSC 43918, x4.
16. Pygidium, dorsal view, GSC 43919, x4.
17. Pygidium (meraspid?), dorsal view, GSC 43920, x5.
18. Pygidium, ventral view, GSC 43921, x3.6.
19. Pygidium, ventral view, GSC 43922, x2.5
20, 21. Cranidium, oblique anterior and dorsal views, GSC 43923, x4.1.
22. Cranidium, dorsal view, GSC 43924, x5.
23. Cranidium, dorsal view, GSC 43925, x5.
24-26. Hypostome, lateral, posterior, and ventral views, GSC 43926, x4.4.
27. Hypostome, ventral view, GSC 43927, x5.7.
28-30. Hypostome, dorsal, anterior, and oblique lateral views, GSC 43928, x4.4.
31. Hypostome, ventral view, GSC 43929, x6.6.
32. Hypostome, ventral view, GSC 43930, x6.6.
34. Thoracic segments, dorsal view, GSC 43931, x5.7.
35, 36. Thoracic segments, ventral view, GSC 43932, x3.5 and 7.
37. Cranidium, dorsal view, GSC 43933, x4.
38. Cranidium, dorsal view, GSC 43934, x3.7.
39. Pygidium, dorsal view, GSC 43935, x3.7.
40. Pygidium, dorsal view, GSC 43936, x4.
41. Free cheek, dorsal view, GSC 43937, x4.
42. Free cheek, interior view, GSC 43938, x2.6.
43. Rostral plate, ventral view, GSC 43939, x3.7.
44. Hypostome, ventral view, GSC 43940, x3.7.
45. Hypostome, ventral view, GSC 43941, x4.
46, 52. Free cheek, lateral and dorsal views, GSC 43942, x3.3.
47, 50, 51. Free cheek, lateral, dorsal, and anterior views, GSC 43943, x2.8.
48. Free cheek, interior view, GSC 43944, x4.1.
49. Free cheek, interior view, GSC 43945, x3.
53. Thoracic segment, dorsal view, GSC 43946, x5.7.

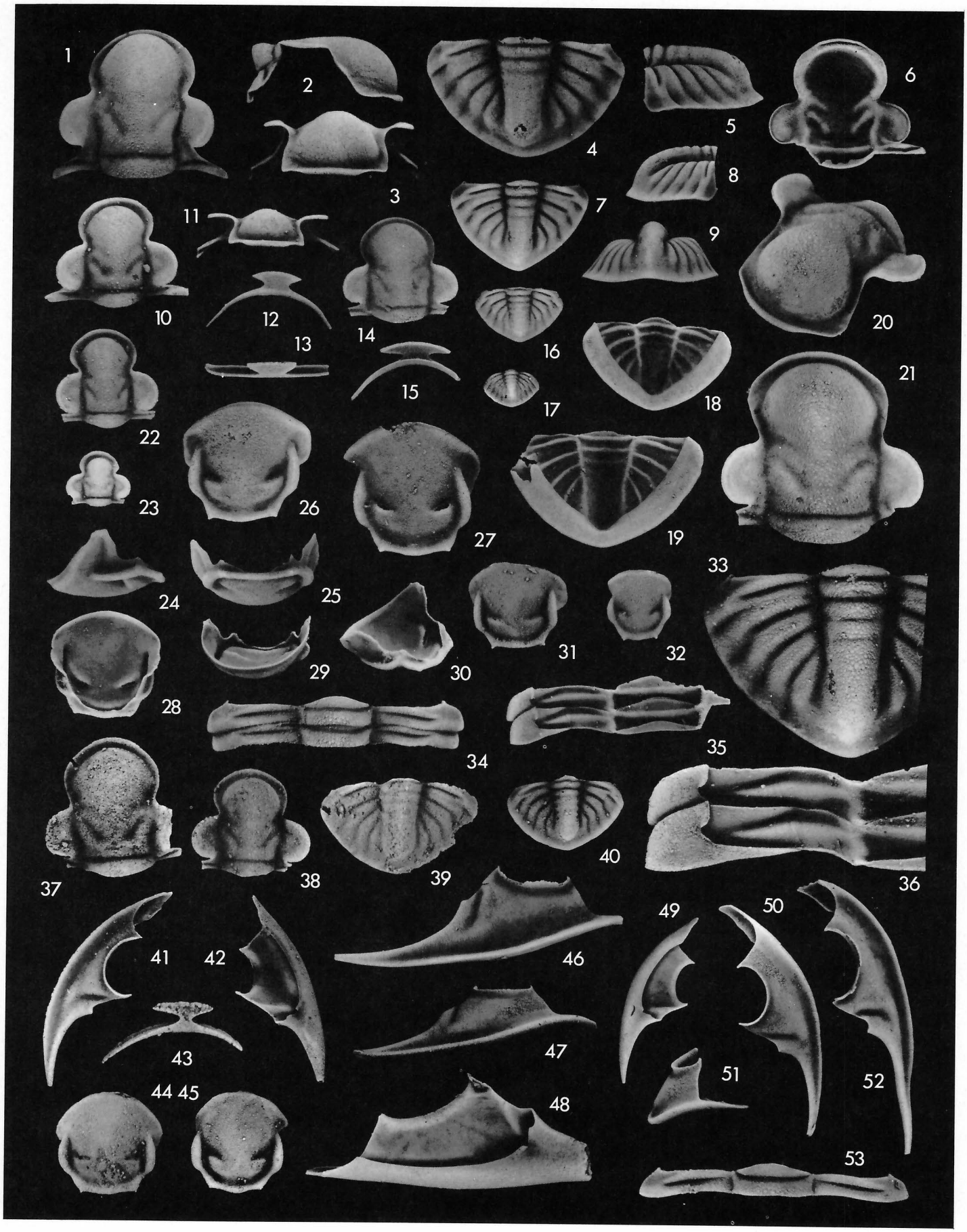
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PLATE 5

Bathyurus esbataottinensis n. sp. (Page 16)

Upper Esbataottine Formation, Sunblood Range. All from P 1931.

Figures 1-3. Holotype cranidium, dorsal, anterior, and lateral views, GSC 40431, x3.1.
4, 5. Cranidium, ventral view, GSC 43947, x3.1 and 6.2.
6. Cranidium, dorsal view, GSC 43948, x3.6.
7. Cranidium, dorsal view, GSC 43949, x3.4.
8. Pygidium, ventral view, GSC 43950, x2.7.
9. Pygidium, dorsal view, GSC 43951, x3.4.
10, 11. Pygidium and seven thoracic segments, lateral and dorsal views, GSC 43952, x2.7.
12. Cranidium, dorsal view, GSC 43953, x3.8.
13-15. Pygidium, dorsal, lateral, and posterior views, GSC 40432, x2.5.
16. Cranidium, dorsal view, GSC 43954, x3.8.
17. Cranidium, dorsal view, GSC 43955, x4.
18. Pygidium, dorsal view, GSC 43956, x3.1.
19. Pygidium, dorsal view, GSC 43957, x3.1.
20. Pygidium, dorsal view, GSC 43958, x1.3.
21. Cranidium, ventral view, GSC 43959, x3.6.
22. Rostral plate, dorsal view, GSC 43960, x2.6.
23-26. Rostral plate, anterior and ventral views, GSC 43961, x2.6 and 6.5.
27, 28. Hypostome, ventral and lateral views, GSC 43962, x3.6.
29, 30. Hypostome, ventral and lateral views, GSC 43963, x2.8.
31-35. Hypostome with attached rostral plate, oblique lateral, ventral, lateral, dorsal and anterior views, GSC 40434, x4.7.
36-39. Hypostome, oblique lateral, dorsal, anterior, and posterior views, GSC 43964, x4.5.
40. Free cheek, interior view, GSC 43965, x2.5
41, 42. Free cheek, dorsal and lateral views, GSC 43966, x5.5.
43, 44. Free cheek, dorsal and lateral views, GSC 40433, x3.
45, 46. Thoracic segment, ventral and posterior views, GSC 43967, x3.4.
47, 48. Thoracic segment, dorsal and anterior views, GSC 43968, x4.

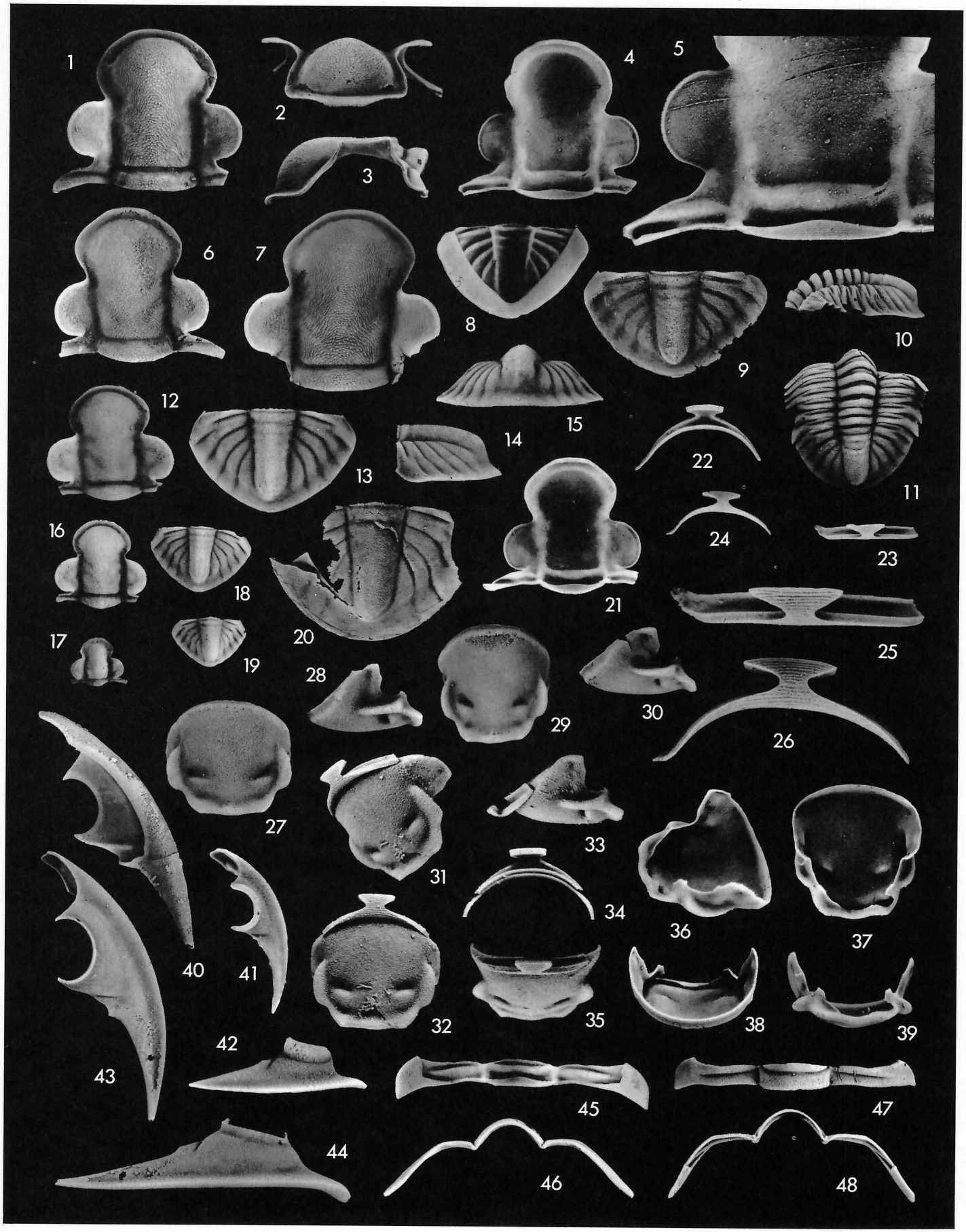
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PLATE 6

Bathyurus esbataottinensis n. sp. (Page 16)

Upper Esbataottine Formation, Sunblood Range and Whittaker Range and Sunblood Formation, Natla River.

Figure
1. Pygidium and seven thoracic segments, dorsal view, GSC 43952, x6.3 (see Pl. 5, figs. 10, 11), P 1931.
2. Holotype cranidium, dorsal view, GSC 40431, x5.3 (see Pl. 5, figs. 1-3), P 1931.
3. Hypostome with attached rostral plate, oblique lateral view, GSC 40434, x9.5 (see Pl. 5, figs. 31-35), P 1931.
4. Cranidium, dorsal view, GSC 43969, x3.6, I 780.
5. Hypostome, dorsal view, GSC 43970, x4.8, I 780.
6. Pygidium, dorsal view, GSC 43971, x4.8, I 780.
7. Cranidium, dorsal view, GSC 43972, x3.6, I 780.
8. Free cheek, interior view, GSC 43973, x4, I 780.
9. Hypostome, ventral view, GSC 43974, x4.8, I 780.
10. Free cheek, dorsal view, GSC 43975, x3.2, I 780.
11. Pygidium, dorsal view, GSC 43976, x4, P 1870.
12. Cranidium, dorsal view, GSC 43977, x3.3, P 1870.
13. Free cheek, dorsal view, GSC 43978, x3.2, P 1870.
14. Hypostome, ventral view, GSC 43979, x3.2, P 1870.
15. Cranidium, dorsal view, GSC 43980, x4.3, P 1870.
16. Pygidium, ventral view, GSC 43981, x4.8, I 780.
17. Cranidium, dorsal view, GSC 43982, x3.3, P 1945-1955.
18, 20. Pygidium, dorsal view and detail to show micro-ornament, GSC 43983, x2.2 and 6.6, P 1945-1955.
19. Pygidium, dorsal view, GSC 40432, x6.2 (see Pl. 5, figs. 13-15), P 1931.
21-25. Pygidium and four thoracic segments, lateral and dorsal views, GSC 43984, x1.6; details to show micro-ornament, x8. Upper Sunblood Formation, Natla River, GSC loc. 69001.
26. Pygidium, dorsal view, GSC 43985, x1.6. Upper Sunblood Formation, Natla River, GSC loc. 69001.

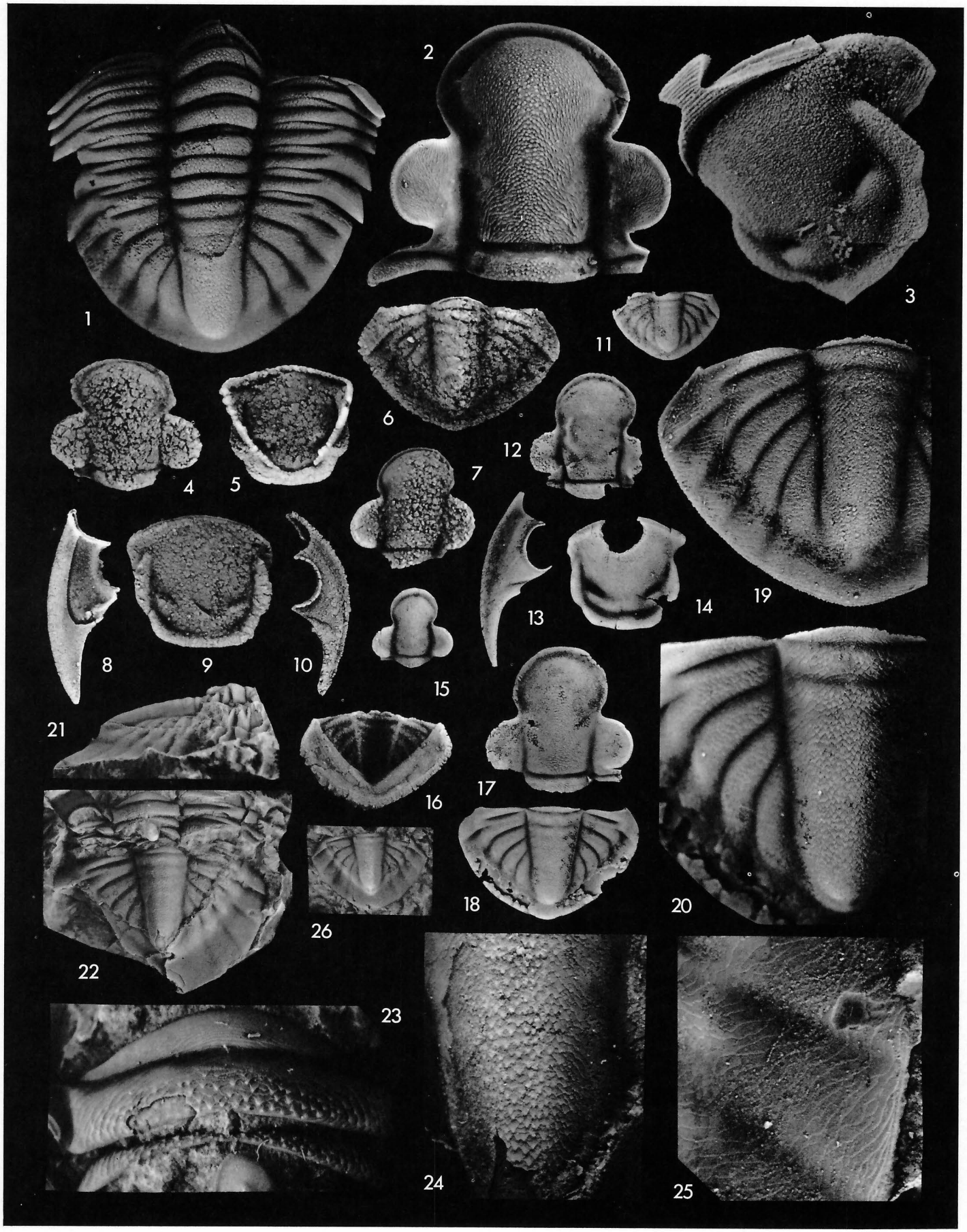
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PLATE 7

Ceraurinella nahanniensis Chatterton and Ludvigsen (Page 23)

Lower Esbataottine Formation, Sunblood Range. All from P 1440.

Figures 1-3, 19. Cranidium, dorsal, anterior, and lateral views, GSC 43986, x4 and 8.2.
4, 5. Cranidium, dorsal and oblique anterior views, GSC 43987, x4.2
6, 7. Cranidium, ventral and oblique anterior views, GSC 43988, x5.
8-10. Pygidium, dorsal, posterior, and oblique lateral views, GSC 43989, x5.
11. Pygidium, ventral view, GSC 43990, x4.5.
12, 13. Pygidium, dorsal and oblique lateral views, GSC 43991, x5.
14, 15. Hypostome, dorsal and oblique lateral views, GSC 43992, x4.7.
16-18. Hypostome, ventral, lateral, and posterior views, GSC 43993, x5.2
20. Free cheek, interior view, GSC 43994, x3.8.
21. Free cheek, dorsal view, GSC 43995, x4.5.

Ceraurinella seriata n. sp. (Page 23)

Lower Esbataottine Formation, Sunblood Range. All from P 1625.

Figures 22-24. Cranidium, dorsal, anterior, and lateral views, GSC 43996, x4.
25. Cranidium, dorsal view, GSC 43997, x4.7.
26, 27. Pygidium, dorsal and posterior views, GSC 43998, x5.2.
28, 29. Holotype pygidium, dorsal and posterior views, GSC 43999, x4.
30. Thoracic segment, dorsal view, GSC 44000, x4.
31, 32. Hypostome, oblique lateral and dorsal views, GSC 44001, x4.
33. Free cheek, interior view, GSC 44002, x4.
34. Free cheek, dorsal view, GSC 44003, x4.
35. Cranidium, oblique ventral view, GSC 44004, x3.5.
36. Pygidium, ventral view, GSC 44005, x5.
37. Pygidium, dorsal view, GSC 44006, x5.2.
38-41. Hypostome, ventral, lateral, posterior, and anterior views, GSC 44007, x4.
42. Cranidium, dorsal view, GSC 44008, x8.

Ceraurinella media n. sp. (Page 26)

Middle Esbataottine Formation, Sunblood Range. All from A 385.

Figures 43-45. Holotype cranidium, dorsal, anterior, and lateral views, GSC 44009, x3.1.
46, 47. Pygidium, dorsal and posterior views, GSC 44010, x2.7.
48. Free cheek, dorsal view, GSC 44011, x4.5.
49. Hypostome, ventral view, GSC 44012, x4.
50, 51. Hypostome, dorsal and oblique lateral views, GSC 44013, x4.
52. Cranidium, dorsal view, GSC 44014a, x3.5.
53. Cranidium, ventral view, GSC 44014b, x3.1.

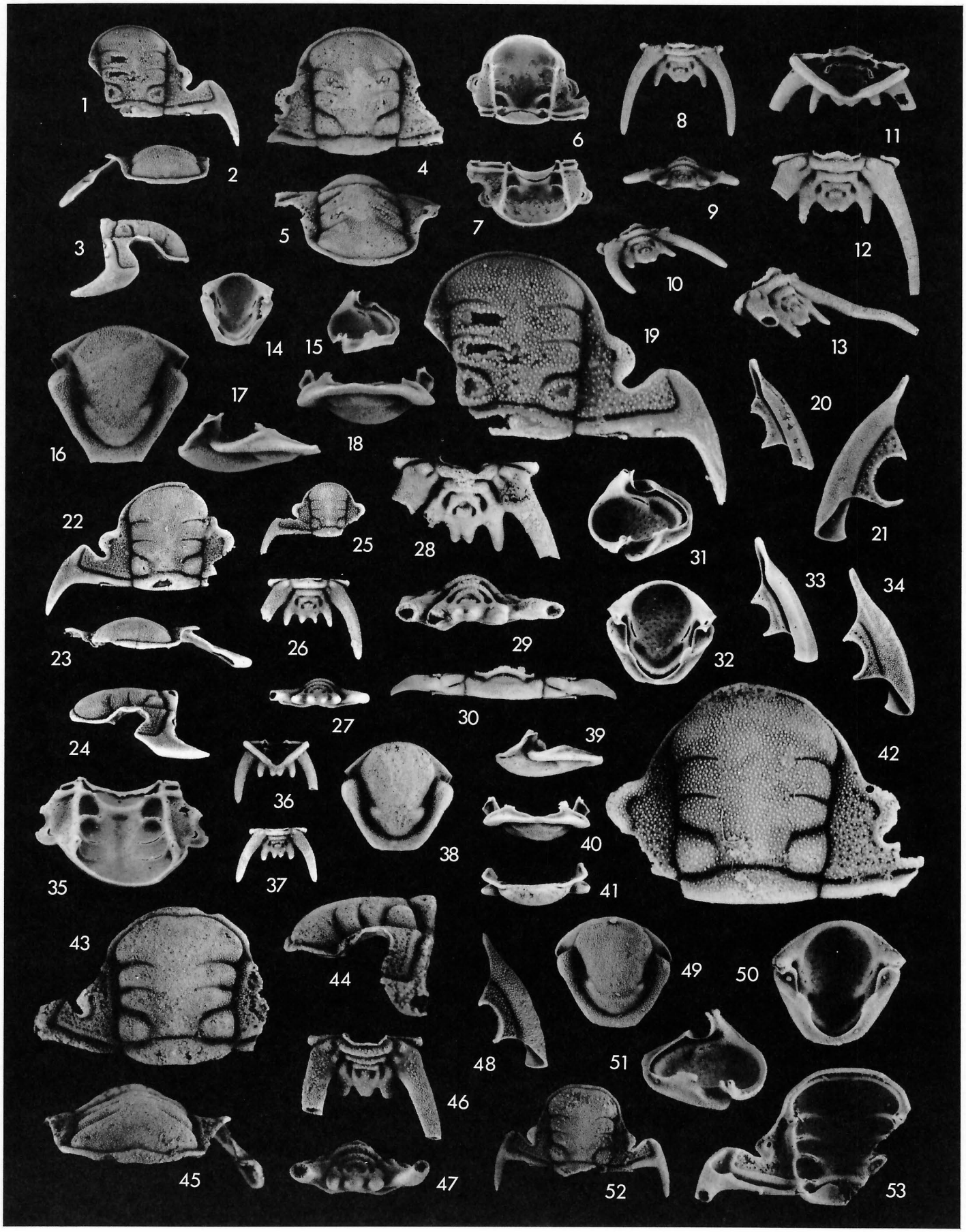
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PLATE 8

Ceraurinella longispina n. sp. (Page 25)

Upper Esbataottine Formation, Sunblood Range. All are from P 2038, except figures 5-8, 17, 18, and 20 which are from A 615.

Figures 1-4, 31. Holotype cranidium, dorsal, anterior, oblique posterior, and lateral views, GSC 44018, x4 and 6.6.
5, 6. Cranidium, dorsal and oblique interior views, GSC 44019, x5.2
7, 8. Cranidium, dorsal and anterior views, GSC 40413, x6.
9-11. Pygidium, posterior, dorsal, and lateral views, GSC 44021, x3.8.
12, 13. Pygidium, posterior and dorsal views, GSC 44022, x2.8.
14-16. Pygidium, dorsal, lateral, and posterior views, GSC 44023, x4.
17, 18. Pygidium, dorsal and posterior views, GSC 40414, x6.
19. Pygidium, ventral view, GSC 44024, x3.
20. Hypostome, ventral view, GSC 44025, x7.
21-23. Hypostome, oblique lateral, dorsal and posterior views, GSC 44026, x5.
24. Hypostome, lateral view, GSC 44027, x5.
25. Thoracic segment, ventral view, GSC 44028, x3.
26, 27. Pygidium, dorsal and posterior views, GSC 44029, x5.
28. Free cheek, dorsal view, GSC 44030, x5.
29. Free cheek, interior view, GSC 44031, x5.8.
30. Free cheek, dorsal view, GSC 44032, x5.

Ceraurinella media n. sp. (Page 26)

Upper Esbataottine Formation, Sunblood Range. All from P 2038.

Figure 32. Cranidium, dorsal view, GSC 44015, x5.
33-35. Cranidium, dorsal, oblique anterior, and lateral views, GSC 44016, x3.6.
36, 37. Cranidium, ventral and oblique anterior views, GSC 44017, x3.8.

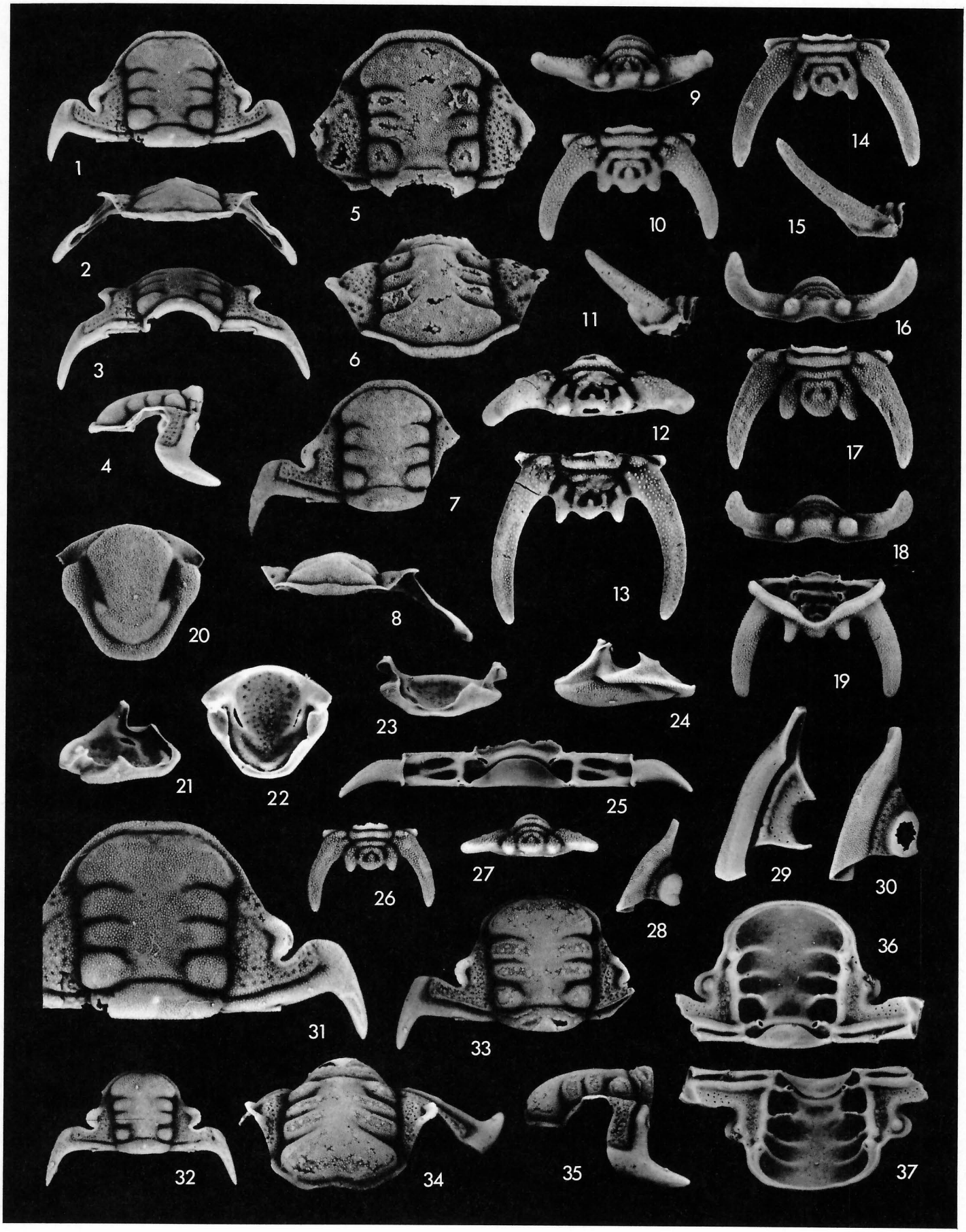
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PLATE 9

Ceraurinella arctica n. sp. (Page 24)

Upper Esbataottine Formation, Sunblood Range and Sunblood Formation, Mary Range. All from P 2050 except figures 10, 11, and 17-19 which are from B 1510-1520.

Figures 1-5, 31-34. Holotype cephalon, dorsal, ventral, oblique posterior, posterior, and oblique lateral views, GSC 44033, x3.8. 31, oblique posteroventral view showing attachement of hypostome. 32, ventral view showing lateral doublure. 33, oblique posteroventral view showing rostral, hypostomal, and connective sutures. 34, dorsal view showing course of facial suture, x6.4

6-9. Cranidium, dorsal, anterior, posterior, and lateral views, GSC 40419, x4.2.

10, 11. Cranidium, dorsal and anterior views, GSC 44035, x4.5.

12, 13. Thoracic segment, posterior and ventral views, GSC 44036, x2.6.

14-16. Pygidium, dorsal, posterior, and oblique lateral views, GSC 44037, x3.5

17-19. Pygidium, dorsal, lateral, and posterior views, GSC 44038, x3.5.

20, 21. Cranidium, oblique anterior and ventral views, GSC 44039, x2.8.

22, 23. Thoracic segment, dorsal and lateral views, GSC 44040, x2.8.

24. Pygidium, ventral view, GSC 44041, x4.2.

25. Hypostome, ventral view, GSC 44020, x3.5.

26, 27. Hypostome, ventral and oblique lateral views, GSC 44042, x4.7.

28. Free cheek, interior view, GSC 44043, x3.2.

29, 30. Nearly complete specimen, dorsal and ventral views, GSC 44034, x8.

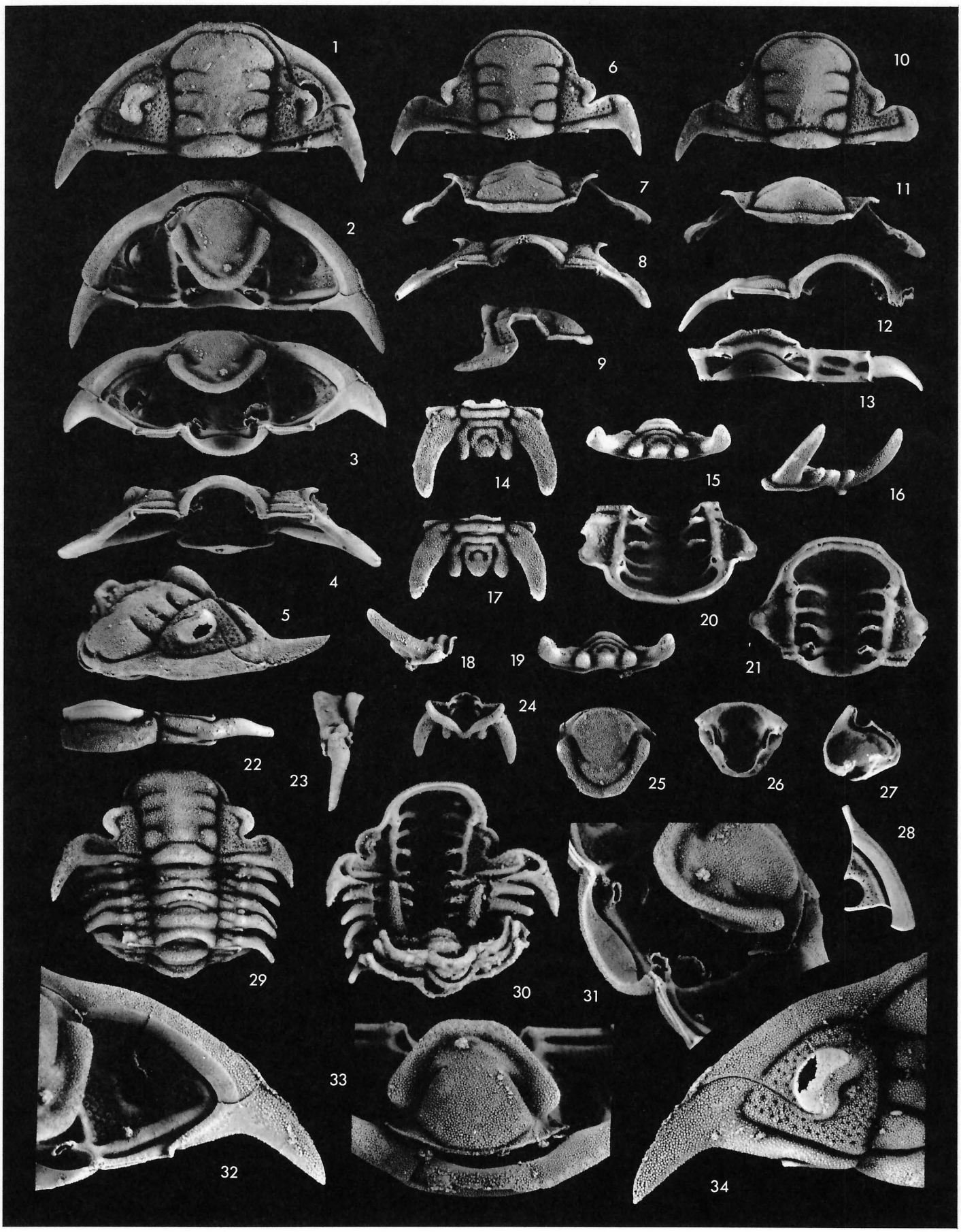
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PLATE 10

Ceraurinella necra n. sp. (Page 26)

Lower Whittaker Formation, Funeral Range and Whittaker Range.

Figures 1-3. Cranidium, dorsal, anterior, and lateral views, GSC 44045, x4.3, C 570-590.
4, 5, 30. Cranidium, dorsal and lateral views, GSC 44046, x4.5 and 8.6, C 570-590.
6-8. Cranidium, dorsal, anterior, and lateral views, GSC 44047, x4.5, I 1275.
9, 10. Pygidium, dorsal and posterior views, GSC 44048, x4.5, C 570-590.
11-13. Holotype pygidium, dorsal, posterior, and oblique lateral views, GSC 44044, x4.3, C 570-590.
14-16. Pygidium, dorsal, posterior, and lateral views, GSC 44049, x4.5, I 1275.
17. Cranidium, dorsal view, GSC 44050, x5, I 1275.
18, 19. Cranidium, ventral and oblique anterior views, GSC 44051, x4.7, C 570-590.
20. Pygidium, dorsal view, GSC 44052, x4.4, C 570-590.
21, 22. Pygidium, anterior and ventral views, GSC 44053, x4.5, C 570-590.
23. Free cheek, dorsal view, GSC 44054, x4.5, C 570-590.
24. Free cheek, interior view, GSC 44055, x4.5, C 570-590.
25, 26. Hypostome, lateral and ventral views, GSC 44056, x4.5, I 1275.
27. Hypostome, dorsal view, GSC 44057, x4.7, C 570-590.
28, 29. Hypostome, ventral and lateral views, GSC 44058, x4.3, C 570-590.

Ceraurinella brevispina n. sp. (Page 27)

Lower Whittaker Formation, Funeral Range and Whittaker Range.

Figures 31-33. Cranidium, dorsal, anterior, and lateral views, GSC 40453, x5, C 655.
34, 35. Pygidium, dorsal and lateral views, GSC 44060, x5, C 655.
36. Pygidium, ventral view, GSC 44061, x5, C 655.
37, 38. Pygidium, dorsal and posterior views, GSC 40454, x5, C 655.
39. Pygidium, dorsal view, GSC 44062, x5, I 1410.
40, 41. Holotype pygidium, posterior and dorsal views, GSC 44059, x5.1, I 1590.
42. Pygidium, ventral view, GSC 44063, x5.1, I 1590.
43, 44. Pygidium, dorsal and posterior views, GSC 44064, x5.6, Q 530.
45. Thoracic segment, ventral view, GSC 44065, x3.9, C 655.
46. Thoracic segment, dorsal view, GSC 44066, x3.9, C 655.
47, 48. Hypostome, ventral and lateral views, GSC 44067, x5, I 1410.
49, 50. Cranidium, anterior and dorsal views, GSC 44068, x5.1, I 1590.
51. Cranidium, dorsal view, GSC 44069, x5.5, C 655.
52. Cranidium, dorsal view, GSC 44070, x5, H 1920.
53, 54. Hypostome, ventral and lateral views, GSC 44071, x5, C 655.
55. Pygidium, dorsal view, GSC 44072, x4, H 1920.
56, 57. Thoracic segment, posterior and dorsal views, GSC 44073, x3.4, H 1920.

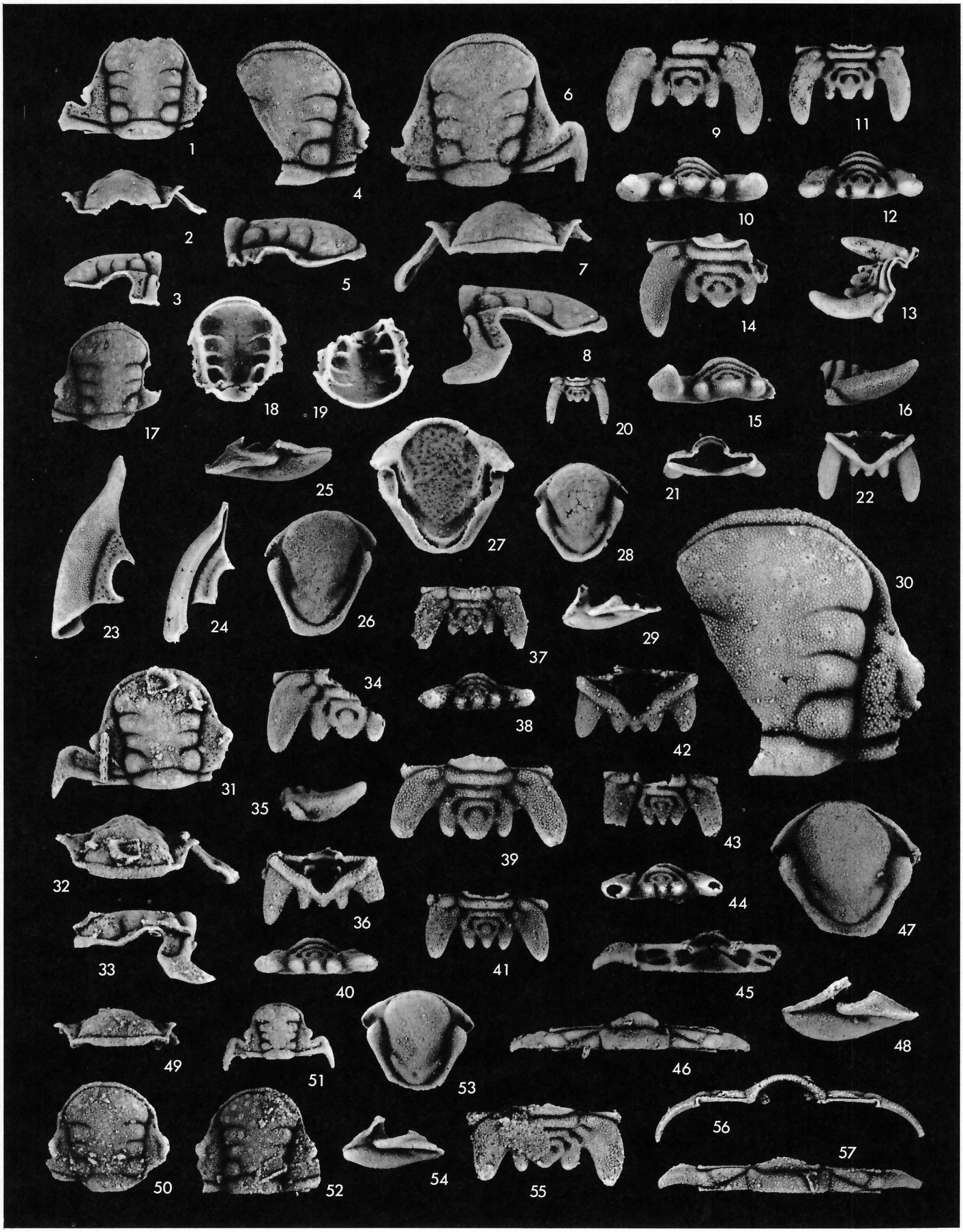
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PLATE 11

Ceraurus gabrielsi n. sp. (Page 29)

Middle and upper Esbataottine Formation, Sunblood Range. Figures 1-36 are from P 1685, figures 37-44 are from P 1931.

Figures

1-3. Cranidium, dorsal, anterior, and oblique anterior views, GSC 40425, x2.4 and 5.
4. Cranidium, dorsal view, GSC 44075, x5.4.
5. Cranidium, dorsal view, GSC 44076, x5.4.
6-8. Cranidium, dorsal, lateral, and anterior views, GSC 44077, x3.4.
9. Cranidium, ventral view, GSC 44078, x4.
10, 11. Pygidium, dorsal and posterior views, GSC 40426, x2.8.
12-15. Pygidium, dorsal, posterior, and lateral views, GSC 44079, x6.7 and 3.7.
16. Pygidium, ventral view, GSC 44080, x3.
17. Pygidium, dorsal view, GSC 44081, x5.4.
18. Pygidium, dorsal view, GSC 44082, x4.
19. Rostral plate, ventral view, GSC 44083, x5.4.
20. Rostral plate, interior view, GSC 44084, x4.
21, 22. Hypostome, ventral and lateral views, GSC 44085, x3.
23. Thoracic segment, ventral view, GSC 44086, x3.
24. Free cheek, dorsal view, GSC 44087, x3.5.
25, 34. Free cheek, dorsal and lateral views, GSC 44088, x3 and 7.
26. Free cheek, interior view, GSC 44089, x3.5.
27-29. Thoracic segment, dorsal, posterior, and lateral views, GSC 44090, x1.6 and 5.6.
30-33. Hypostome, posterior, oblique lateral, oblique anterior, and dorsal views, GSC 44091, x3.3.
35. Thoracic segment, ventral view, GSC 44092, x2.6.
36. Thoracic segment, dorsal view, GSC 44093, x3.5.
37. Cranidium, ventral view, GSC 44094, x2.7.
38-41. Cranidium, dorsal, anterior, lateral, and oblique anterior views, GSC 44095, x2.7 and 7.
42. Hypostome, ventral view, GSC 44096, x3.8.
43, 44. Pygidium, dorsal and posterior views, GSC 44097, x3.8.

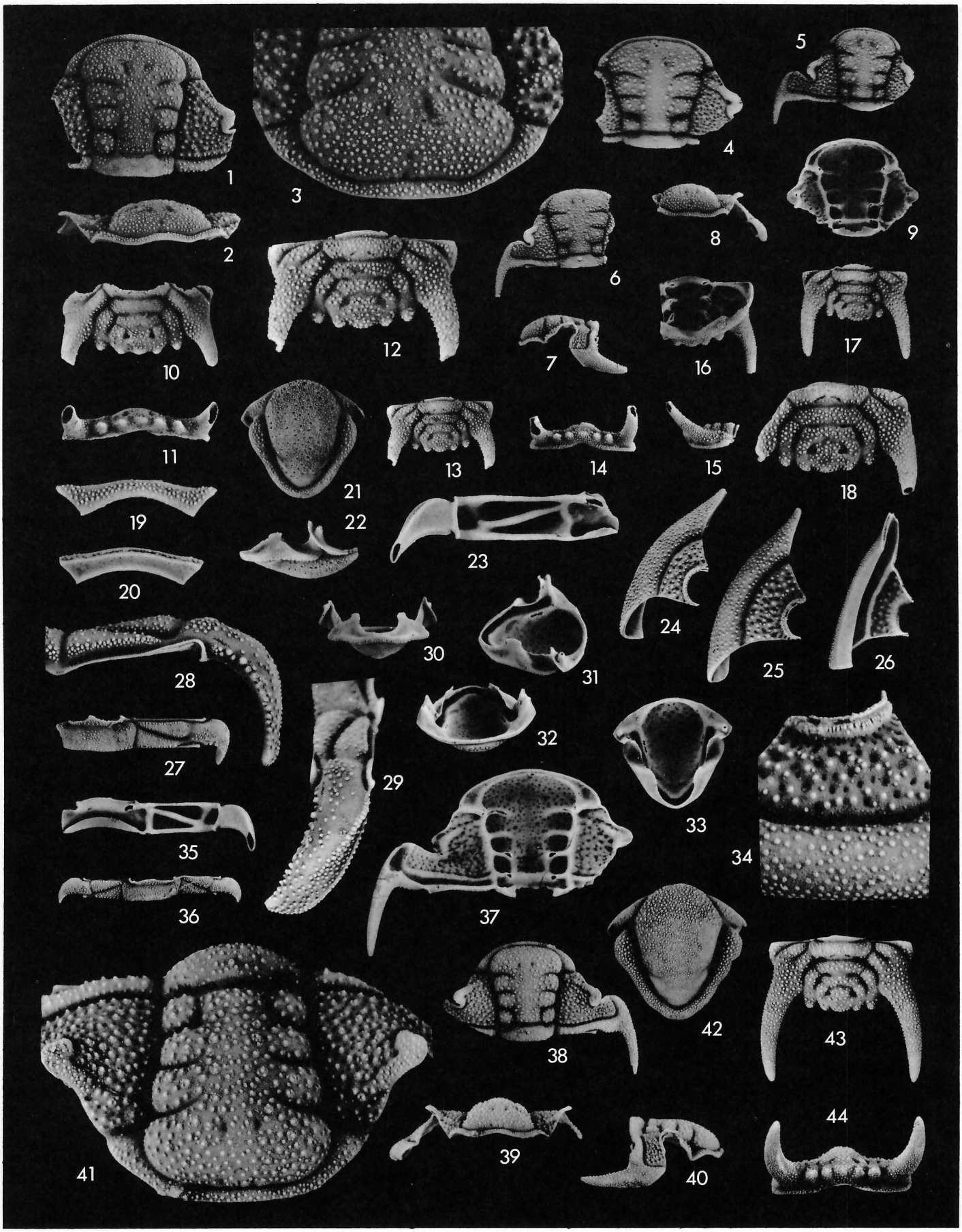
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PLATE 12

Ceraurus gabrielsi n. sp. (Page 29)

Upper Esbataottine Formation, Sunblood Range. All from P 1945-1955, except figures 22-24 which are from P 1931.

Figures
1-3. Holotype cranidium, dorsal, anterior, and lateral views, GSC 44074, x2.2.
4, 5. Cranidium, dorsal and anterior views, GSC 44098, x3.
6, 7. Cranidium, dorsal and anterior views, GSC 40435, x2.5.
8. Cranidium, dorsal view, GSC 44099, x3.2.
9. Cranidium, dorsal view, GSC 44100, x3.2.
10, 11. Cranidium, ventral and posterior views, GSC 44101, x3.
12. Cranidium, ventral view, GSC 44102, x2.3.
13. Pygidium, dorsal view, GSC 44103, x5.
14-16. Pygidium, dorsal, lateral, and posterior views, GSC 44104, x2.8.
17. Pygidium, dorsal view, GSC 44105, x4.
18, 19. Pygidium, dorsal and lateral views, GSC 40436, x4.
20, 21. Pygidium, dorsal and posterior views, GSC 44106, x4.
22-24. Pygidium, posterior and dorsal views, GSC 44107, x2.7 and 4.5.
25. Pygidium, dorsal view, GSC 44108, x4.
26, 27. Pygidium, ventral and anterior views, GSC 44109, x3.
28. Rostral plate, interior view, GSC 44110, x3.6.
29. Rostral plate, ventral view, GSC 44111, x3.6.
30. Free cheek, dorsal view, GSC 44112, x5.
31-34. Hypostome, ventral, anterior, posterior, and lateral views, GSC 44113, x2.8.
35, 36. Hypostome, ventral and posterior views, GSC 44114, x5.
37. Hypostome, ventral view, GSC 44115, x5.
38. Hypostome, ventral view, GSC 44116, x3.3.
39-41. Hypostome, dorsal, oblique exterior, and oblique interior views, GSC 44117, x3.7 and 6.1.
42. Thoracic segment, ventral view, GSC 44118, x4.
43. Thoracic segment, dorsal view, GSC 44119, x4.
44. Thoracic segment, dorsal view, GSC 44120, x2.9.
45. Thoracic segment, ventral view, GSC 44121, x2.9.
46. Thoracic segment, dorsal view, GSC 44122, x2.9.
47. Free cheek, interior view, GSC 44123, x4.1.
48. Free cheek, dorsal view, GSC 44124, x5.
49. Free cheek, dorsal view, GSC 44125, x4.1.

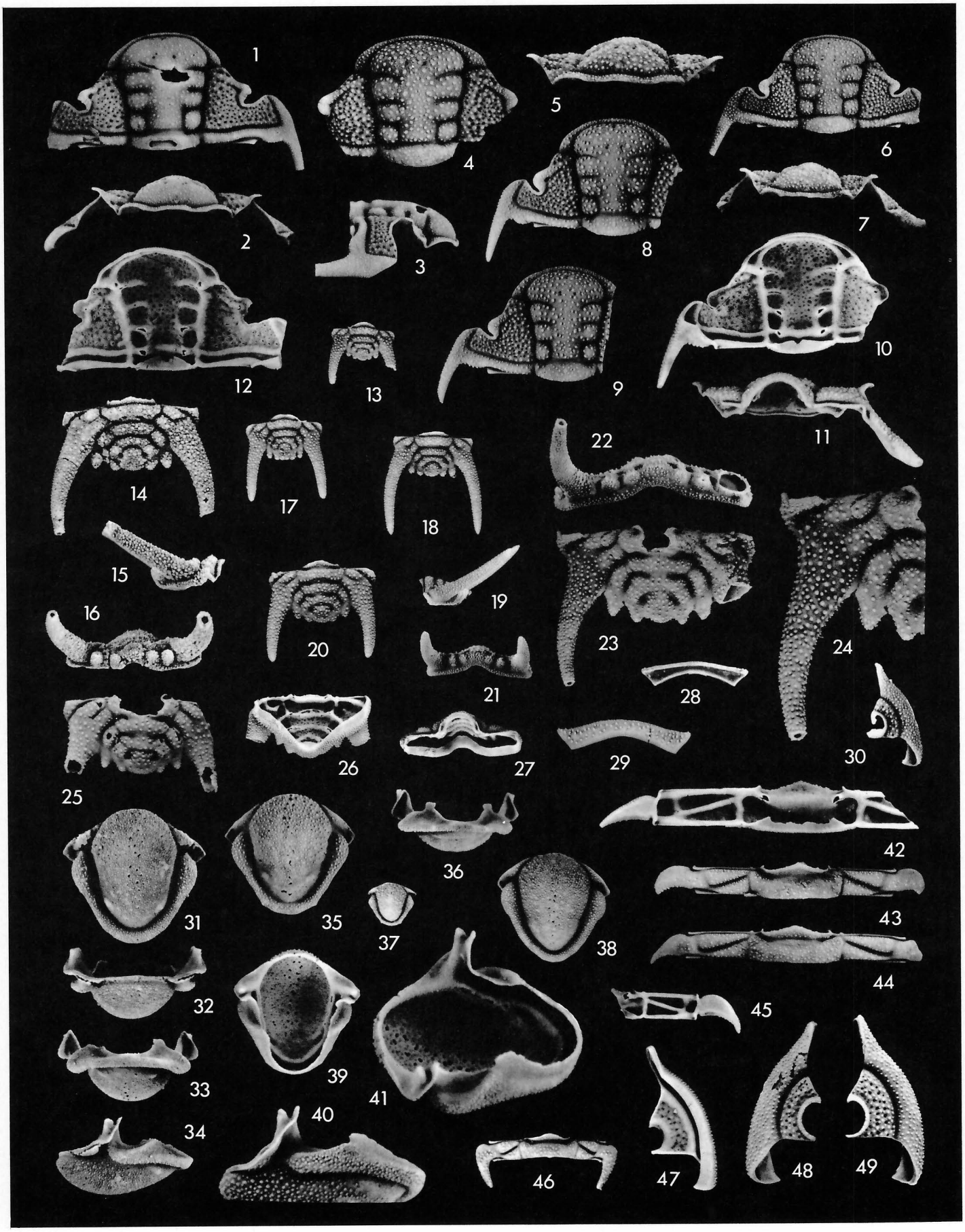
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PLATE 13

Ceraurus gabrielsi n. sp. (Page 29)

Upper Esbataottine Formation, Sunblood Range.

Figures 1, 2. Thoracic segment, dorsal and posterior views, GSC 44126, x3, P 1931.
3. Cranidium, oblique anterior view, GSC 44100, x7 (see Pl. 12, fig. 9), P 1945-1955.
4. Cranidium, oblique anterior view, GSC 44099, x7 (see Pl. 12, fig. 8), P 1945-1955.
5. Cranidium, dorsal view, GSC 44127, x4.8, P 1870.
6-8. Pygidium, lateral, posterior, and dorsal views, GSC 44128, x4.8, P 1870.

Ceraurus blussoni n. sp. (Page 32)

Upper Sunblood Formation, Mary Range. All from B 1450.

Figures 9-11, 29. Holotype cranidium, dorsal, anterior, and lateral views, GSC 44129, x2.1. Detail of cranidium, x5.7.
12, 13. Cranidium, dorsal and anterior views, GSC 44130, x3.
14. Cranidium, dorsal view, GSC 44131, x4.
15. Cranidium, dorsal view, GSC 44132, x4.3.
16, 17. Hypostome, ventral and lateral views, GSC 44133, x3.
18. Free cheek, dorsal view, GSC 44134, x3.
19, 20. Hypostome, ventral and lateral views, GSC 44135, x3.
21, 22. Pygidium, dorsal and posterior views, GSC 44136, x3.
23. Thoracic segment, dorsal view, GSC 44137, x2.7.
24. Pygidium, ventral view, GSC 44138, x2.3.
25, 26. Pygidium, dorsal and posterior views, GSC 44139, x3.1.
27. Pygidium, ventral view, GSC 44140, x2.7.
28. Free cheek, dorsal view, GSC 44141, x2.7.

Ceraurus maewestoides n. sp. (Page 36)

Lower Whittaker Formation, Dusky Range.

Figures 30-33. Holotype cranidium, oblique lateral, ventral, dorsal, and anterior views, GSC 44142, x5.1, R 625.

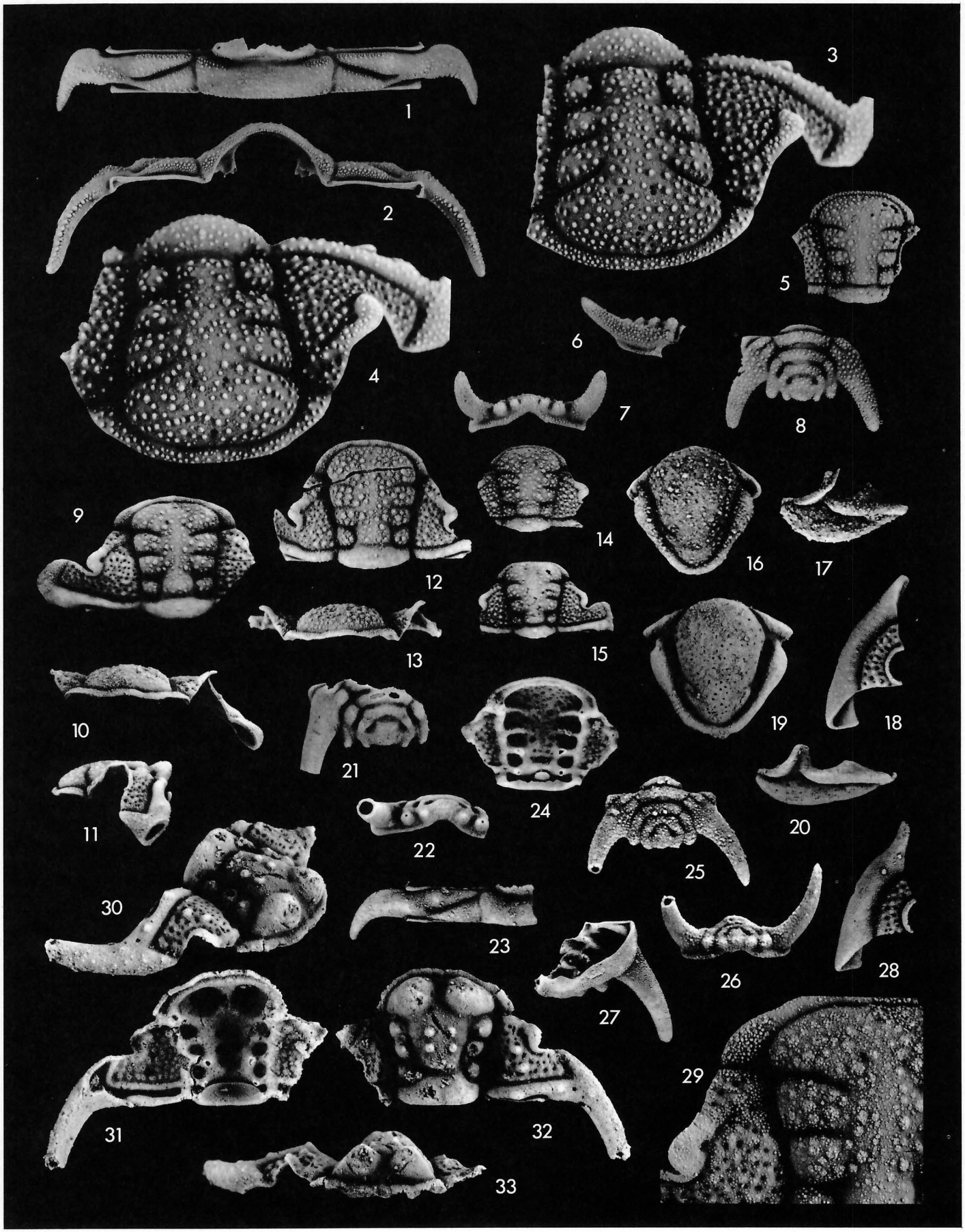
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PLATE 14

Ceraurus hirsuitus n. sp. (Page 32)

Upper Esbataottine Formation, Sunblood Range. All from P 2038.

Figures 1, 2. Holotype cranidium, dorsal and ventral views, GSC 40415, x4.
3, 4. Cranidium, dorsal and anterior views, GSC 44143, x2.
5, 6. Cranidium, oblique anterior and dorsal views, GSC 44144, x2.2.
7. Cranidium, dorsal view, GSC 44145, x2.2.
8, 9. Pygidium, dorsal and posterior views, GSC 40416, x2.
10. Cranidium, ventral view, GSC 44146, x2.2.
11. Pygidium, ventral view, GSC 44147, x2.2.
12, 25. Pygidium, dorsal view, GSC 44148, x2.2 and 3.7.
13, 20. Free cheek, dorsal and interior views, GSC 44149, x4.
14. Cranidium, ventral view, GSC 44150, x3.
15. Cranidial fragment overgrown by bryozoans, dorsal view, GSC 44151, x2.2.
16-19. Cranidium (note gall-like swelling at base of right genal spine), dorsal, posterior, ventral, and oblique interior views, GSC 44152, x3.2.
21. Thoracic segment, dorsal view, GSC 44153, x3.
22, 23. Thoracic segment, dorsal and anterior views, GSC 44154, x3.
24. Thoracic segment, lateral view, GSC 44155, x3.

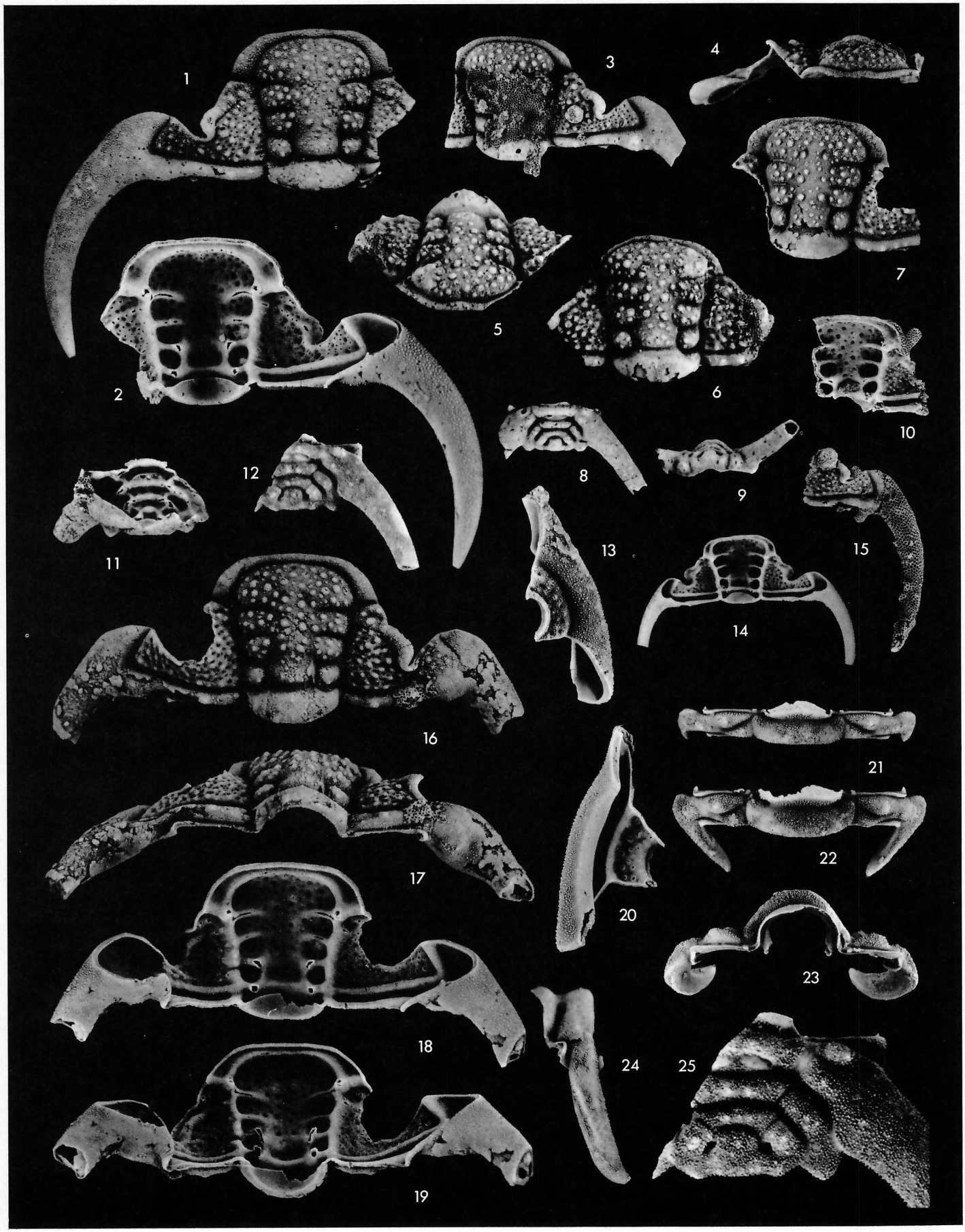
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PLATE 15

Ceraurus mackenziensis n. sp. (Page 34)

Lower Whittaker Formation, Funeral Range and Whittaker Range.

Figures 1-3. Holotype cranidium, dorsal, lateral, and anterior views, GSC 44156, x4.2, C 655.
4. Cranidium, dorsal view, GSC 44157, x5.4, H 1920.
5, 6. Cranidium, dorsal and anterior views, GSC 40447, x6, C 655.
7. Cranidium, dorsal view, GSC 44158, x6.6, C 655.
8, 9. Cranidium, dorsal and anterior views, GSC 44159, x6.6, C 655.
10. Cranidium, ventral view, GSC 44160, x4.3, C 655.
11. Cranidium, dorsal view, GSC 44161, x6.2, C 655.
12, 13. Cranidial fragment, dorsal and lateral views, GSC 44162, x3.1, C 655.
14. Cranidium, ventral view, GSC 44163, x3.4, H 1920.
15, 16. Cranidium, ventral and oblique posterior views, GSC 44164, x4.4, C 655.
17, 18. Pygidium, dorsal and posterior views, GSC 40448, x4.2, C 655.
19. Pygidium, dorsal view, GSC 44165, x6.6, C 655.
20. Pygidium, dorsal view, GSC 44166, x6.6, C 655.
21. Pygidium, ventral view, GSC 44167, x4.8, C 655.
22. Pygidium, ventral view, GSC 44168, x4.6, H 1920.
23-25. Pygidium, dorsal, posterior, and lateral views, GSC 44169, x3.6, J 220.
26, 27. Cranidium, dorsal and anterior views, GSC 44170, x4, J 220.
28, 29. Hypostome, ventral and lateral views, GSC 44171, x5.3, C 655.
30, 31. Hypostome, ventral and posterior views, GSC 44172, x5.4, H 1920.
32, 33. Pygidium, dorsal and posterior views, GSC 44173, x4.6, H 1920.
34, 35. Hypostome, ventral and lateral views, GSC 44174, x6, J 220.
36, 37. Hypostome, dorsal and posterior views, GSC 44175, x5.3, C 655.
38. Hypostome, dorsal view, GSC 44176, x6.6, C 655.
39. Hypostome, ventral view, GSC 44177, x6.2, C 655.
40. Hypostome, ventral view, GSC 44178, x6.6, C 655.
41. Free cheek, dorsal view, GSC 44179, x5.5, C 655.
42. Free cheek, dorsal view, GSC 44180, x3.5, C 655.
43. Free cheek, dorsal view, GSC 44181, x3.5, J 220.
44. Free cheek, interior view, GSC 44182, x3.4, C 655.

Ceraurus milleranus Miller and Gurley (Page 36)

Lower Whittaker Formation, Dusky Range. All from R 625.

Figures 45-48. Cranidium, ventral, dorsal, lateral, and anterior views, GSC 44183, x5.1 and 3.4.
49, 50. Hypostome, dorsal and oblique lateral views, GSC 44184, x5.
51, 52. Hypostome, ventral and lateral views, GSC 44185, x5.
53, 54. Pygidium, dorsal and posterior views, GSC 44186, x4.3.
55. Free cheek, dorsal view, GSC 44187, x4.
56, 57. Pygidium, posterior and dorsal views, GSC 44188, x3.2.

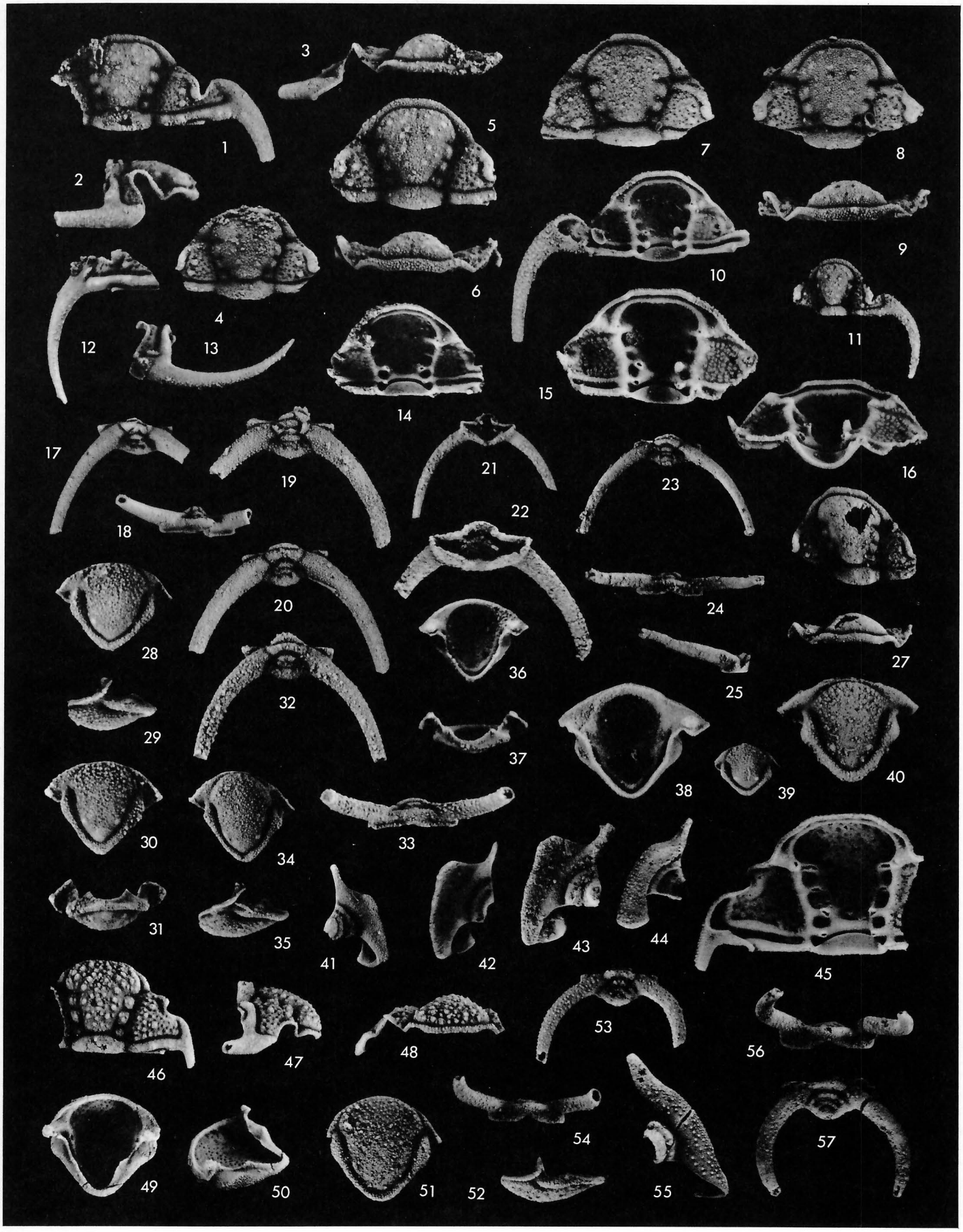
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PLATE 16

Whittakerites planatus Ludvigsen (Page 38)

Lower Whittaker Formation, Whittaker Range and Dusky Range.

Figures 1, 2. Cranidium, dorsal and anterior views, GSC 44189, x4.3, I 1590.
3. Cranidium, dorsal view, GSC 44190, x4.3, I 1590.
4, 5. Holotype cranidium, dorsal and ventral views, GSC 44191, x5, Q 530.
6, 7. Cranidium, dorsal and lateral views, GSC 44192, x4.3, I 1590.
8. Cranidium, dorsal view, GSC 44193, x3, Q 530.
9. Cranidium, dorsal view, GSC 44194, x5, Q 530.
10. Cranidium, dorsal view, GSC 44195, x5, Q 530.
11. Cranidium, dorsal view, GSC 44196, x4.3, I 1590.
12. Cranidium, dorsal view, GSC 41197, x5, Q 530.
13. Cranidium, dorsal view, GSC 44198, x4.3, I 1590.
14. Cranidium, dorsal view, GSC 44199, x4.3, I 1590.
15. Cranidium, ventral view, GSC 44200, x3.2, I 1590.
16. Cranidium, dorsal view, GSC 44201, x5.4, R 625.
17. Cranidium, dorsal view, GSC 44202, x5.4, R 625.
18-20. Pygidium, dorsal, posterior, and lateral views, GSC 44203, x4.3, I 1590.
21-23. Pygidium, dorsal, lateral, and posterior views, GSC 44204, x2.5, I 1590.
24. Pygidium, dorsal view, GSC 44205, x4.2, I 1590.
25. Pygidium, ventral view, GSC 44206, x5, Q 530.
26. Pygidium, dorsal view, GSC 44207, x4.3, I 1590.
27, 28. Pygidium, ventral and anterior views, GSC 44208, x3.8, I 1590.
29. Pygidium, dorsal view, GSC 44209, x5, Q 530.
30. Pygidium, dorsal view, GSC 44210, x4.3, I 1590.
31. Meraspid pygidium, dorsal view, GSC 44211, x5.6, I 1590.
32, 33. Hypostome, ventral and lateral views, GSC 44212, x4.7, I 1590.
34, 35. Hypostome, dorsal and oblique lateral views, GSC 44213, x4.7, I 1590.
36. Hypostome, ventral view, GSC 44214, x5, I 1590.
37. Hypostome, dorsal view, GSC 44215, x5, I 1590.
38. Hypostome, ventral view, GSC 44216, x6, Q 530.
39. Hypostome, dorsal view, GSC 44217, x6, Q 530.
40, 41. Free cheek, dorsal and lateral view, GSC 44218, x3, I 1590.
42. Free cheek, dorsal view, GSC 44219, x4.3, I 1590.
43. Free cheek, interior view, GSC 44220, x3, I 1590.
44, 45. Thoracic segment, lateral and dorsal views, GSC 44221, x3, I 1590.
46, 47. Thoracic segment, ventral and posterior views, GSC 44222, x3, I 1590.

Cheirurinid indet. n. gen. and n. sp. (Page 39)

Lower Whittaker Formation, Dusky Range. Both from R 625.

Figures 48-50. Pygidium, dorsal, posterior and lateral views, GSC 44223, x4.
51. Pygidium, ventral view, GSC 44224, x4.

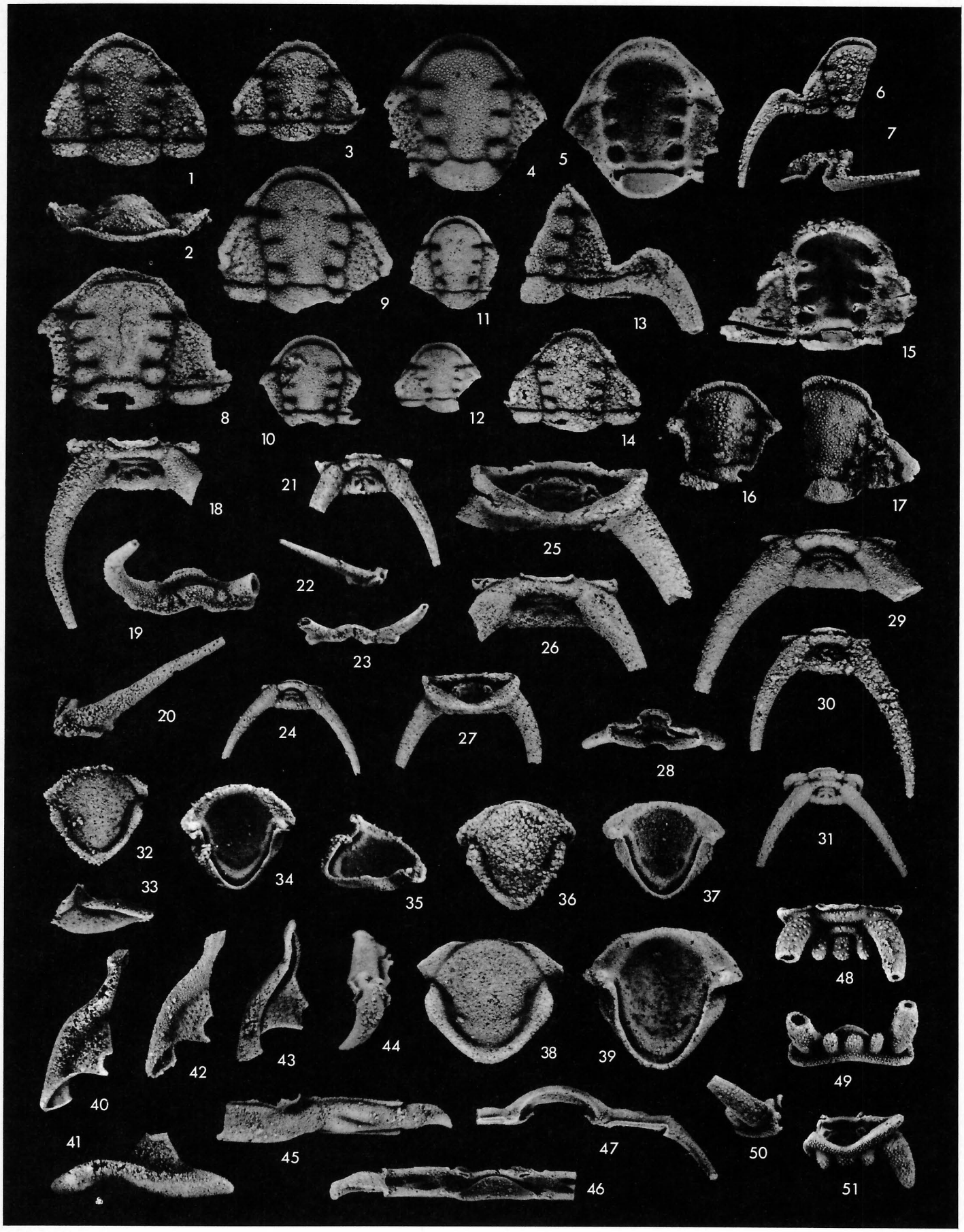
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PLATE 17

Borealaspis whittakerensis Ludvigsen (Page 39)

Lower Whittaker Formation, Funeral Range. All from C 655.

Figures 1-5. Holotype cranidium, dorsal, ventral, lateral, anterior, and oblique anterior views, GSC 40450, x8.4 and 10.5.
6, 7. Cranidium, lateral and dorsal views, GSC 44225, x5.1.
8. Pygidium, dorsal view, GSC 44226, x5.1.
9. Meraspid pygidium, dorsal view, GSC 44227, x6.3.
10. Meraspid pygidium, ventral view, GSC 44228, x6.3.
11, 12. Cranidium, anterior and dorsal views, GSC 44229, x5.

Borealaspis biformis Ludvigsen (Page 39)

Lower Whittaker Formation, Funeral Range and Whittaker Range. Figures 13-28 are from C 570-590, figures 29-35 are from H 1920.

Figures 13-16. Holotype cranidium, dorsal, lateral, anterior, and ventral views, GSC 44230, x9.3.
17, 18. Cranidium, dorsal and ventral views, GSC 44231, x9.3.
19. Cranidium, dorsal view, GSC 44232, x9.8.
20, 21. Cranidium, dorsal and lateral views, GSC 44233, x5.
22, 25, 26. Hypostome, oblique lateral, ventral, and lateral views, GSC 44234, x6.9 and 3.7.
23, 24. Hypostome, oblique lateral and dorsal views, GSC 44235, x4.5.
27. Pygidium, dorsal view, GSC 44236, x5.5.
28. Cranidium, dorsal view, GSC 44237, x9.8.
29-33. Cranidium, dorsal, ventral, anterior, posterior, and oblique lateral views, GSC 44238, x5.4.

Ceraurus cf. *maewestoides* n. sp. (Page 37)

Lower Whittaker Formation, Whittaker Range. From H 1920.

Figures 34, 35. Cranidium, anterior and dorsal views, GSC 44239, x6.

Ceraurus tuberosus Troedsson (Page 34)

Lower Whittaker Formation, Whittaker Range. All from I 1275.

Figures 36-38. Cranidium, dorsal, anterior, and lateral views, GSC 44240, x5.8.
39. Hypostome, ventral view, GSC 44241, x5.8.
40. Pygidium, dorsal view, GSC 44242, x5.8.
41. Cranidium, dorsal view, GSC 44243, x5.8.

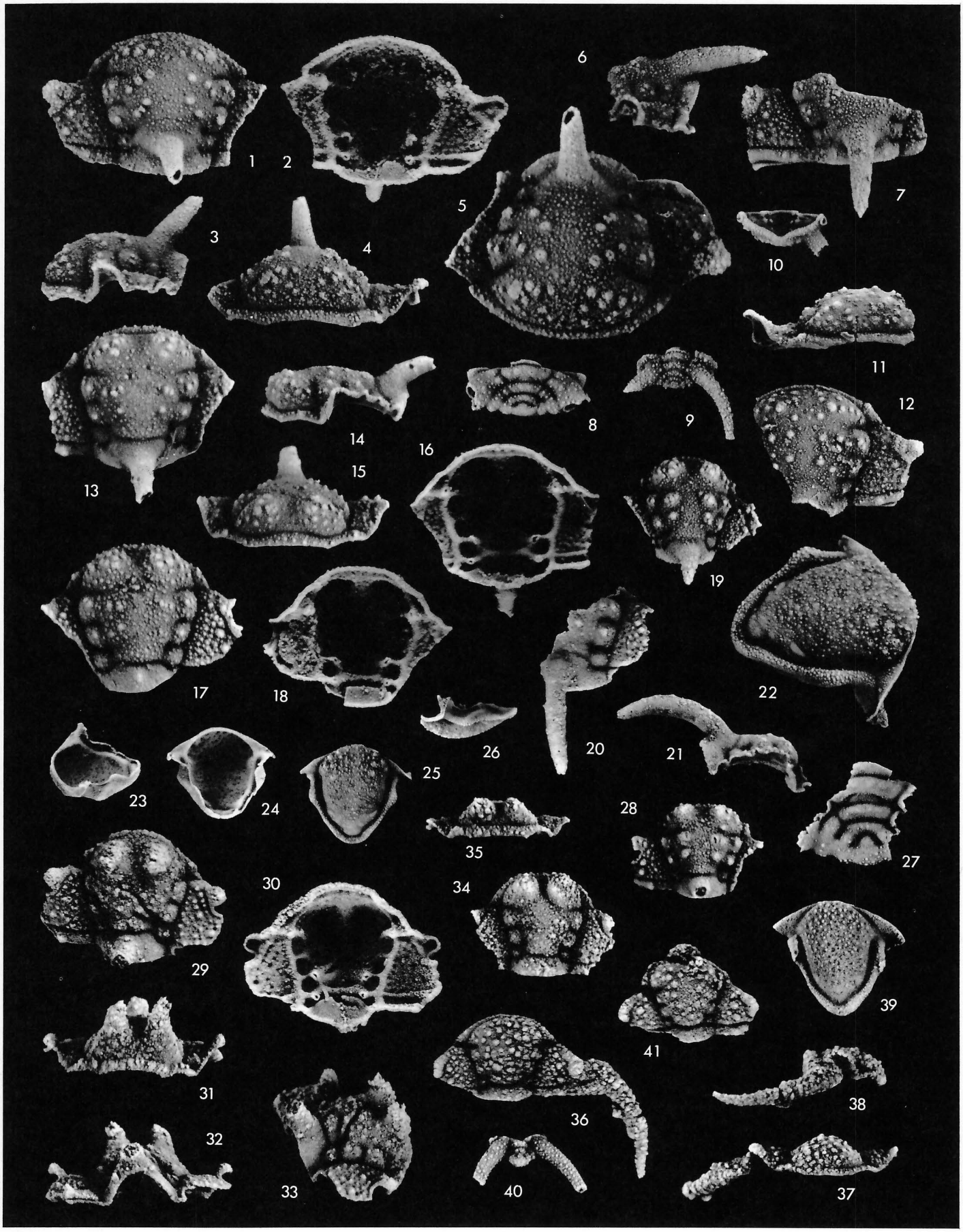
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PLATE 18

Ceraurinus serratus n. sp. (Page 37)

Lower Whittaker Formation, Whittaker Range and Funeral Range.

Figures 1-3. Cranidium, dorsal, lateral, and anterior views, GSC 40445, x3.1, I 1590.
4. Cranidium, ventral view, GSC 44244, x3.6, C 655.
5-7. Cranidium, dorsal, lateral, and anterior views, GSC 44245, x4.4, C 655.
8. Cranidium, dorsal view, GSC 44246, x3.8, C 655.
9. Cranidium, dorsal view, GSC 44247, x3.2, Q 530.
10, 11. Holotype pygidium, dorsal and posterior views, GSC 40446, x3.1, I 1590.
12, 13. Pygidium, dorsal and posterior views, GSC 44248, x2.8, C 655.
14. Pygidium, dorsal view, GSC 44249, x4, I 1590.
15. Pygidium, ventral view, GSC 44250, x3, C 655.
16. Pygidium, dorsal view, GSC 44251, x4, I 1590.
17. Pygidium, dorsal view, GSC 44252, x3.8, C 655.
18. Pygidium, ventral view, GSC 44253, x3, I 1590.
19. Pygidium, dorsal view, GSC 44254, x4.4, Q 530.
20. Hypostome, dorsal view, GSC 44255, x5, I 1590.
21, 22. Hypostome, ventral and lateral views, GSC 44256, x3, C 655.
23-25. Hypostome, lateral, posterior, and ventral views, GSC 44257, x5, Q 530.
26. Free cheek, dorsal view, GSC 44258, x3.5, Q 530.
27. Free cheek, interior view, GSC 44259, x3, I 1590.
28. Free cheek, dorsal view, GSC 44260, x3, I 1590.
29. Free cheek, dorsal view, GSC 44261, x3.6, C 655.
30. Thoracic segment, dorsal view, GSC 44262, x3.8, C 655.
31, 32. Thoracic segment, anterior and ventral views, GSC 44263, x2.2, C 655.

Sphaerocoryphe robustus Walcott (Page 44)

Lower Whittaker Formation, Whittaker Range and Funeral Range. All from C 655, except figures 49-53 which are from H 1920.

Figures 33-38. Cranidium, dorsal, anterior, oblique lateral, lateral, and ventral views, GSC 40451, x5 and 8.7.
39. Cranidium, ventral view, GSC 44264, x6.3.
40, 41. Pygidium, dorsal and posterior views, GSC 44265, x7.
42. Pygidium, ventral view, GSC 44266, x8.5.
43. Cranidium, dorsal view, GSC 44267, x8.5.
44, 45. Pygidium, dorsal and posterior views, GSC 44268, x5.6.
46. Hypostome, dorsal view, GSC 44269, x8.5.
47, 48. Hypostome, ventral and posterior views, GSC 44270, x8.5.
49-53. Pygidium, ventral, dorsal, posterior, lateral, and oblique dorsal views, GSC 40452, x4.6 and 7.

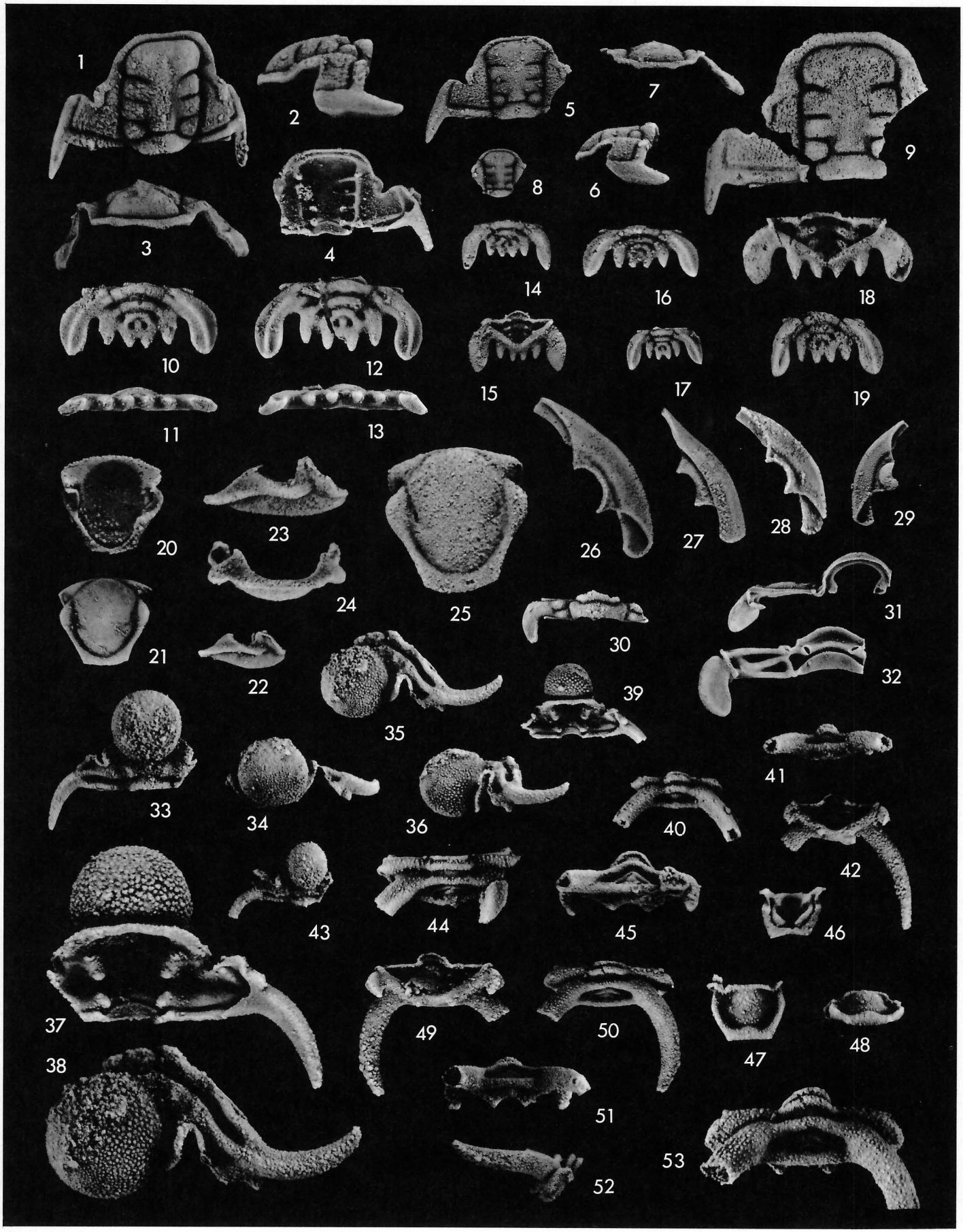
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PLATE 19

Acanthoparypha? goniopyga n. sp. (Page 40)

Lower Whittaker Formation, Funeral Range and Whittaker Range.

Figures 1-3. Cranidium, dorsal, anterior, and lateral views, GSC 44272, x4, H 1850.
4-6. Cranidium, dorsal, lateral, and anterior views, GSC 40449, x6, C 655.
7-9. Holotype pygidium, dorsal, posterior, and lateral views, GSC 44271, x8, I 1275.
10. Free cheek, dorsal view, GSC 44273, x8, I 1275.
11. Free cheek, dorsal view, GSC 44274, x4, H 1850.
12. Cranidium, dorsal view, GSC 44275, x8, I 1275.
13, 14. Pygidium, dorsal and posterior views, GSC 44276, x8, I 1275.
15. Cranidium, dorsal view, GSC 44277, x4.5, I 1410.
16-18. Pygidium, dorsal, posterior, and lateral views, GSC 44278, x6, C 655.
19. Thoracic segment, ventral view, GSC 44279, x4.5, I 1410.

Holia anacantha n. sp. (Page 41)

Lower Whittaker Formation, Funeral Range. All from C 570-590.

Figures 20. Cranidium, dorsal view, GSC 44281, x6.2.
21. Cranidium, dorsal view, GSC 44282, x7.2
22. Cranidium (crushed), dorsal view, GSC 44283, x5.3.
23. Cranidial fragment, GSC 44284, x6.
24, 25. Pygidium, posterior and ventral views, GSC 44285, x7.2
26. Free cheek, dorsal view, GSC 44286, x7.
27-29. Holotype pygidium, lateral, dorsal, and posterior views, GSC 44280, x6.2

Pandaspinapyga cf. *stubblefieldi* (Bancroft) (Page 41)

Upper Sunblood Formation, Sunblood Range. Both from P 1187.

Figures 30, 31. Pygidium, dorsal and posterior views, GSC 44287, x8.
32. Cranidial fragment, dorsal view, GSC 44288, x6.5.

Heliomera cf. *sol* (Billings) (Page 42)

Sunblood Formation, Mary Range. From B 145.

Figures 33-35. Cranidium, dorsal, anterior, and lateral views, GSC 40334, x4.8.

Sphaerexochus atacius n. sp. (Page 42)

Upper Esbataottine Formation, Sunblood Range. All from P 2038.

Figures 36-38, 58. Holotype cranidium, dorsal, lateral, and anterior views, GSC 40420, x5.1 and 8.6.
39. Cranidium, dorsal view, GSC 44289, x5.5.
40. Cranidium, dorsal view, GSC 44290, x6.2.
41. Cranidium, dorsal view, GSC 44291, x6.2.
42, 43. Pygidium, posterior and dorsal views, GSC 40421, x5.6.
44. Pygidium, dorsal view, GSC 44292, x5.6.
45. Pygidium, dorsal view, GSC 44293, x6.2.
46. Pygidium, ventral view, GSC 44294, x5.6.
47. Hypostome, ventral view, GSC 44294, x6.5.
48, 49. Hypostome, dorsal and posterior views, GSC 44296, x6.2.
50. Free cheek, oblique lateral view, GSC 44297, x7.
51. Free cheek, interior view, GSC 44298, x8.3.
52, 53. Thoracic segment, posterior and dorsal views, GSC 44299, x5.1.
54, 55. Thoracic segment, ventral and oblique lateral views, GSC 44300, x5.
56, 57. Cranidium, ventral and posterior views, GSC 44301, x5.

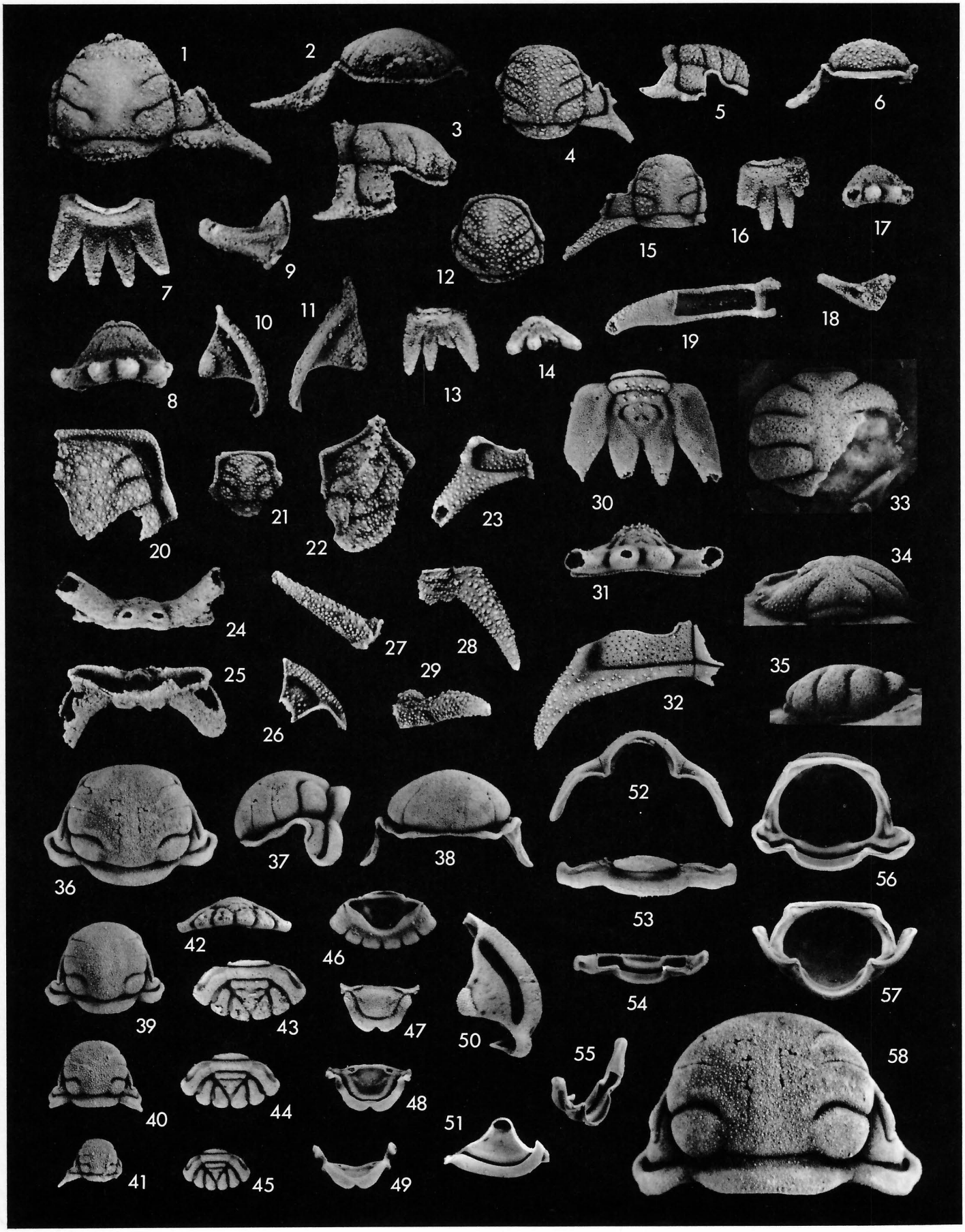
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PLATE 20

Cybellela? thor n. sp. (Page 47)

Sunblood Formation, southwest of South Nahanni River. All from GSC locality 58678.

Figures 1-3. Holotype cranidium, dorsal, lateral, and ventral views, GSC 44302, x9.5.
4, 5. Cranidium, dorsal and anterior views, GSC 44303, x9.5.
6. Cranidium, dorsal view, GSC 44304, x10.6.
7, 8. Cranidium, ventral and dorsal views, GSC 44305, x9.5.
9-11. Pygidium, posterior, lateral, and dorsal views, GSC 44306, x8.1.
12. Pygidium, oblique dorsal view, GSC 44307, x8.6.
13, 14. Free cheek, lateral views, GSC 44308, x7.

Cybeloides anna n. sp. (Page 46)

Upper Sunblood Formation, Sunblood Range. All from P 1187.

Figures 15, 16, 28. Holotype cranidium, anterior and dorsal views, GSC 44309, x4.1 and 11.
17-19. Pygidium, posterior, dorsal, and lateral views, GSC 44310, x5.
20. Pygidium, interior view, GSC 44311, x5.2.
21. Free cheek, oblique dorsal view, GSC 44312, x5.1.
22, 23. Hypostome, ventral and lateral views, GSC 44313, x6.
24. Thoracic segment (macropleura), dorsal view, GSC 44314, x5.
25. Thoracic segment, ventral view, GSC 44315, x5.
26, 27. Cranidium, dorsal and lateral views, GSC 44316, x4.1.
29. Pygidium, oblique dorsal view, GSC 44317, x6.6.
30. Rostral plate, exterior view, GSC 44318, x6.3.
31, 32, 36. Cranidium, ventral and oblique posterior views, GSC 44319, x4.1 and 7.3.
33, 34. Hypostome, dorsal and oblique anterior views, GSC 44320, x6.
35. Free cheek, interior view, GSC 44321, x5.

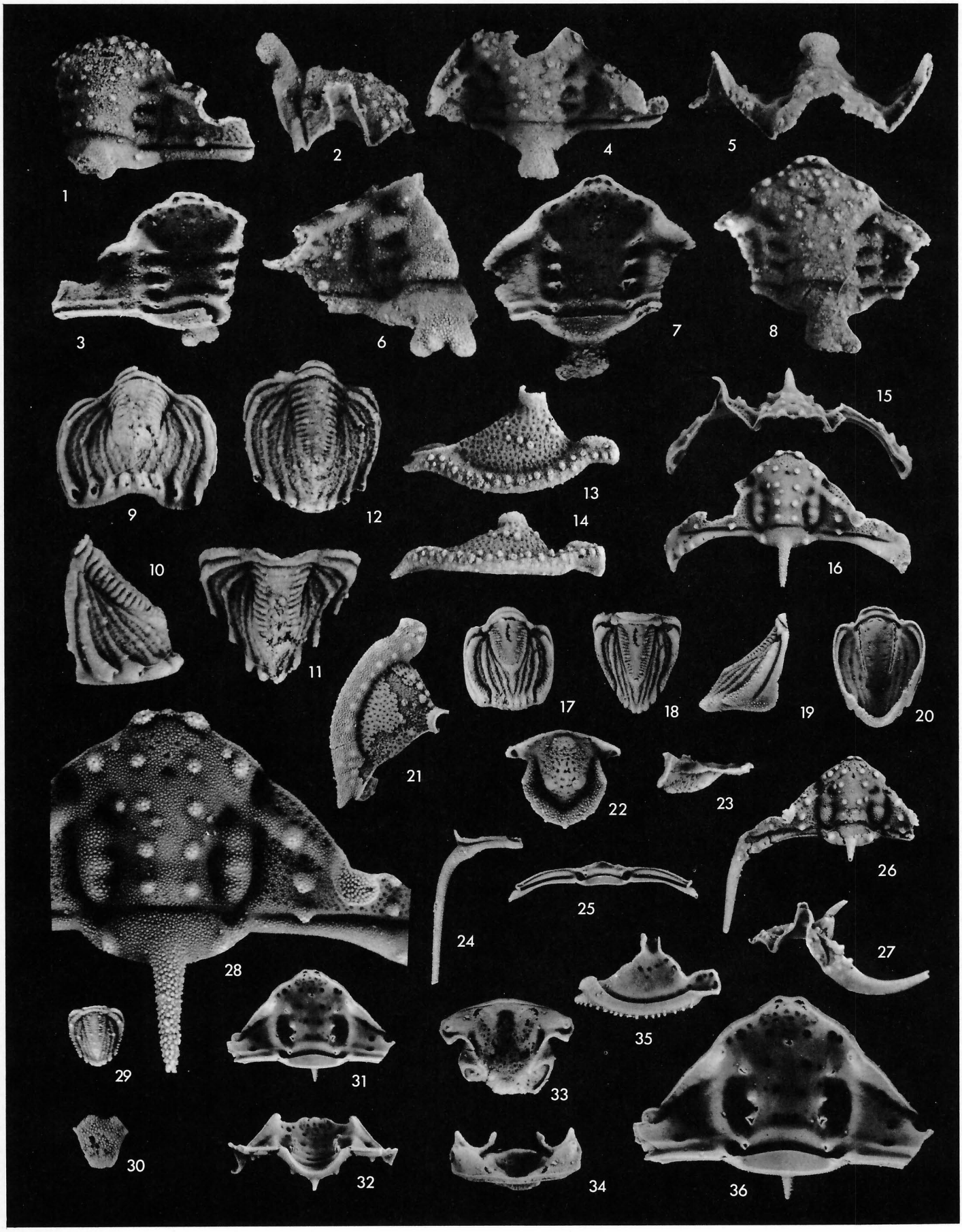
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PLATE 21

Cybeloides cimelia Chatterton and Ludvigsen (Page 46)

Esbataottine Formation, Sunblood Range and Flood Creek.

Figures 1-3. Cranidium, anterior, dorsal, and lateral views, GSC 40417, x3.3, P 2038.
4, 5. Cranidium, ventral and oblique posterior views, GSC 44322, x3.1, P 2038.
6. Cranidium, dorsal view, GSC 44323, x3.3, P 2038.
7, 8. Cranidium, dorsal and oblique anterior views, GSC 44324, x7.2, P 2038.
9-11. Pygidium, lateral, posterior, and dorsal views, GSC 40418, x4.1, P 2038.
12. Free cheek, interior view, GSC 44325, x4, P 2038.
13, 14. Free cheek, dorsal and lateral views, GSC 44326, x4, P 2038.
15, 16. Thoracic segment, dorsal and posterior views, GSC 44327, x4.3, P 2038.
17-19. Thoracic segment, posterior, dorsal, and lateral views, GSC 44328, x4, P 2038.
20-22. Hypostome, ventral, lateral, and posterior views, GSC 44329, x5.6, P 2038.
23, 24. Hypostome, dorsal and oblique anterior views, GSC 44330, x5, P 2038.
25. Thoracic segment, lateral view, GSC 44331, x3.6, P 2038.
26. Cranidium, dorsal view, GSC 44332, x3, G 3195.
27, 28. Pygidium, dorsal and lateral views, GSC 44333, x5.3, G 3195.
29. Free cheek, dorsal view, GSC 44334, x6, G 3195.
30. Hypostome, ventral view, GSC 44335, x6, G 3195.
31. Cranidium, dorsal view, GSC 43546, x7, P 1485.
32. Cranidium, ventral view, GSC 44336, x8, P 1485.
33. Thoracic segment (macropleura), dorsal view, GSC 44337, x5, P 1485.
34. Free cheek, oblique view, GSC 44338, x7, P 1485.
35, 36. Pygidium, lateral and dorsal views, GSC 44339, x8, P 1485.
37. Thoracic segment, dorsal view, GSC 44340, x7, P 1485.
38. Cranidium, dorsal view, GSC 44341, x6.2, A 365.
39. Pygidium, oblique dorsal view, GSC 44342, x6.2, A 365.
40. Hypostome, ventral view, GSC 44343, x6.2, A 365.
41. Free cheek, oblique view, GSC 44344, x6.2, A 365.

Encrinuroides rarus (Walcott) (Page 45)

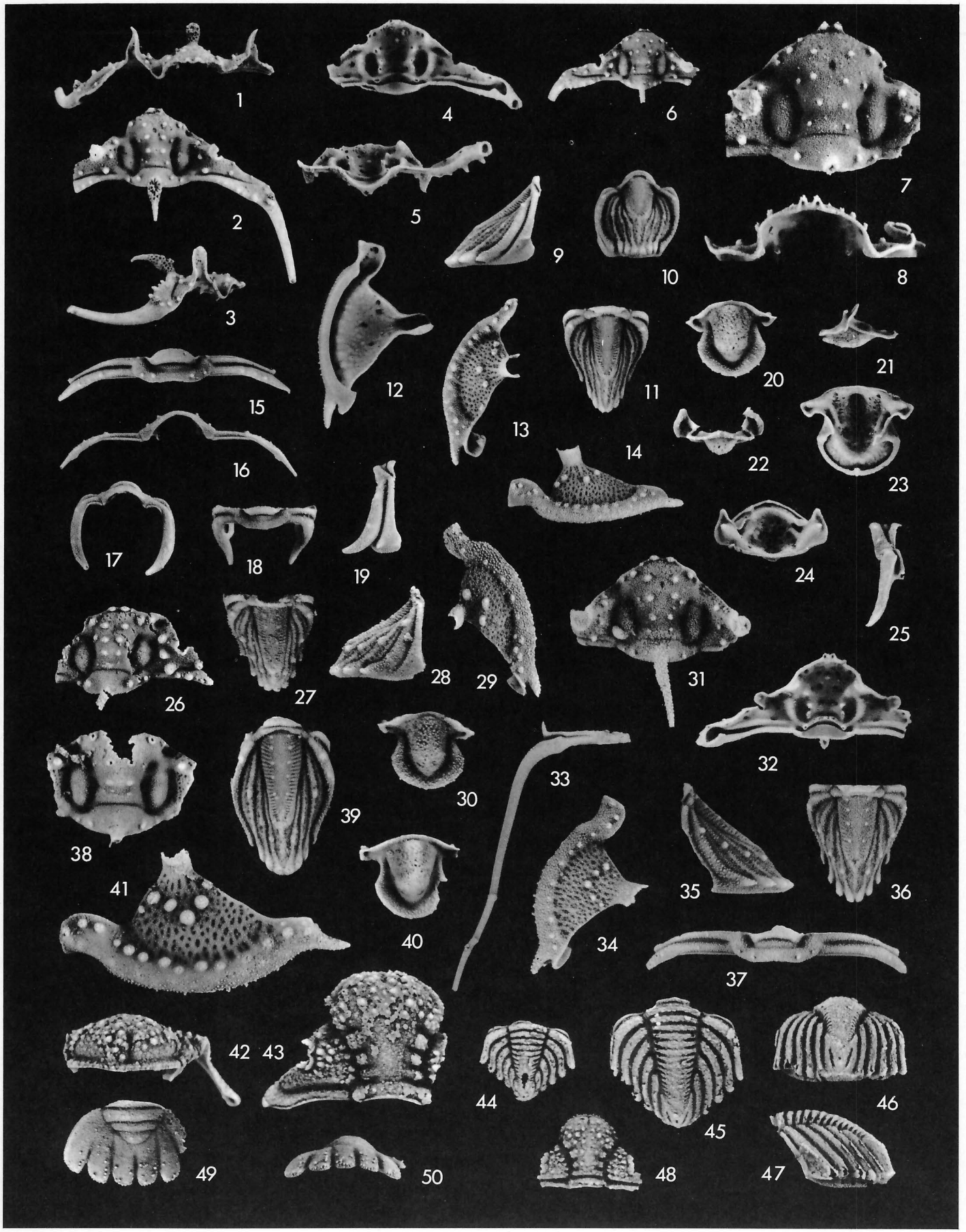
Upper Esbataottine Formation, Sunblood Range.

Figures 42, 43. Cranidium, anterior and dorsal views, GSC 44345, x5.5, A 385.
44. Pygidium, dorsal view, GSC 44346, x6, A 615.
45-47. Pygidium, dorsal, posterior, and lateral views, GSC 44347, x6, A 615.
48. Cranidium, dorsal view, GSC 44348, x6, A 615.

Kawina sp. (Page 43)

Sunblood Formation, Sunblood Range. From P 55.

Figures 49, 50. Pygidium, dorsal and posterior views, GSC 40335, x7.3.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