Distribution of the Middle Ordovician Copenhagen Formation and its Trilobites in Nevada

GEOLOGICAL SURVEY PROFESSIONAL PAPER 749

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By REUBEN JAMES ROSS, JR., *and* FREDERICK C. SHAW

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Descriptions of Middle Ordovician trilobites belonging to 21 genera contribute to correlations between similar strata in Nevada, California, and Oklahoma

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DISTRIBUTION OF THE MIDDLE ORDOVICIAN COPENHAGEN FORMATION AND ITS TRILOBITES IN NEVADA

By Reuben James Ross, Jr., and Frederick C. Shaw

ABSTRACT

The Copenhagen Formation of central Nevada is composed of a basal sandstone (member A) and two calcareous siltstone and silty limestone members (members B and C).

In areas north and south of Antelope Valley, member B of the formation is recognized, but the overlying member C is not recognized. To the east and southeast the supposedly older uppermost beds of the Antelope Valley Limestone are actually equivalent to the lower beds of member B. To the west in two thrust sequences of the Toquima Range, the Caesar Canyon Limestone of Kay and Crawford and an unnamed limestone are probably equivalent to the uppermost Copenhagen Formation.

Species of 21 genera of trilobites are described from members B and C. Four additional taxa have not been identified below familial rank. The most evident change in trilobite assemblages takes place about 100 feet below the top of member C in the type locality around Antelope Valley; these highest trilobites suggest correlation with the Viola Limestone of Oklahoma. The trilobites from lower in member C indicate a Wilderness-Barneveld age.

INTRODUCTION

The Middle Ordovician Copenhagen Formation was defined by Merriam in 1963 (p. 25–27) for highly fossiliferous arenaceous, argillaceous, and calcareous strata lying above the Antelope Valley Limestone and below the Eureka Quartzite in central Nevada. The formation is best developed on both sides of Antelope Valley (in the Monitor Range on the west and in the Antelope Range on the east, Horse Heaven Mountain quad.).

The formation or its lithologic equivalents can be recognized over a great distance from the Independence Mountains of northern Nevada to the northern Inyo Mountains of southern California (fig. 1).

It is the purpose of this report to describe the known trilobites of the Copenhagen Formation, to summarize the geographic extent of the formation, and to update information on the correlation of the formation. A few trilobites are described from units believed to be correlative with the Copenhagen beds.

The main responsibility for taxonomy rests with Shaw and for stratigraphy with Ross; in neither case is the responsibility exclusive.

PREVIOUS INVESTIGATIONS

The name Copenhagen Formation was first used by Nolan, Merriam, and Williams (1956, p. 28) without definition. Kirk (1933, p. 32–33) was the first to recognize the stratigraphic significance of beds later assigned to the formation and the first to imply that these strata were the lateral equivalents of the Eureka Quartzite. Cooper (1956, p. 127–128, chart 1) recognized strata of the formation and was probably responsible for calling attention to its members, the upper two of which he believed were separated by a considerable hiatus. Webb (1958, p. 2339–2345) used the name and discussed the extent and correlation of the Copenhagen Formation; his correlations were basically lithic, with some fossil control. He questioned the existence of a hiatus within the formation.

Ethington and Schumacher (1969, p. 440–443) have given a good review of the definition of the Copenhagen Formation, of early interpretations of the formation, and of the stratigraphic problems the unit poses. They discovered that the uppermost beds of the underlying Antelope Valley Limestone contained significant elements of the conodont fauna of members A and B of the Copenhagen. This discovery parallels that of Ross (1964, p. C78; 1970, p. 31) concerning brachiopods and trilobites and indicates that the major unconformity proposed by Cooper (1956, chart 1) beneath the basal sandstone of the Copenhagen Formation in its type locality does not exist.

ACKNOWLEDGMENTS

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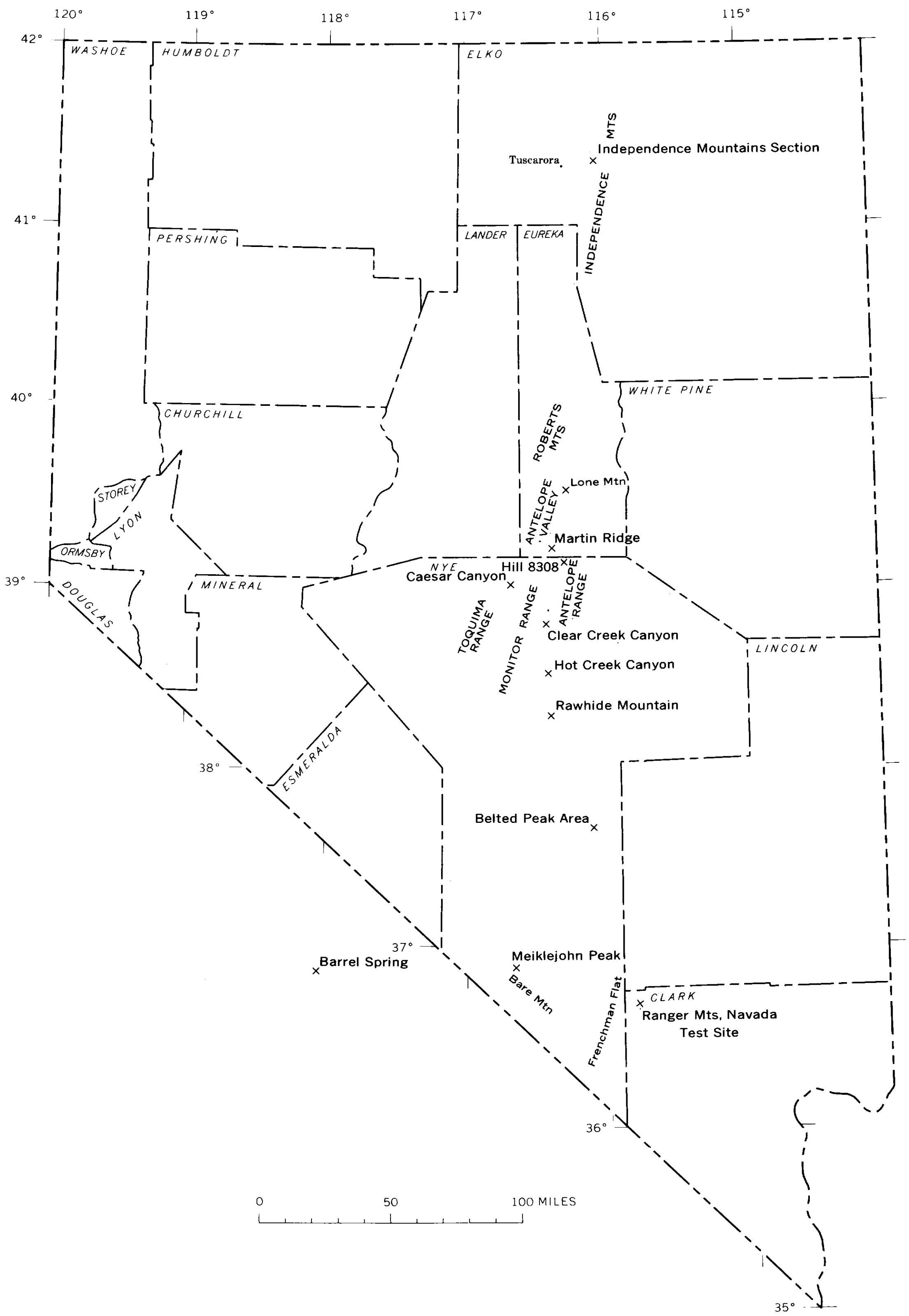

FIGURE 1. — Index map showing location of stratigraphic sections in which the Copenhagen Formation or its equivalents have been recognized in Nevada and California.

C. P. Hughes and R. B. Rickards arranged for the loan of the lectotype and other specimens of *Toernquistia nicholsoni* Reed from the Sedgwick Museum, Cambridge University.

GEOGRAPHIC OCCURRENCES OF THE COPENHAGEN FORMATION AND ITS EQUIVALENTS

The Copenhagen Formation is best developed on either side of Antelope Valley. In addition it seems to be recognizable in somewhat modified form as far north as the Independence Mountains and south and southwest to the northern Inyo Mountains of California and to Meiklejohn Peak, Bare Mountain quadrangle, Nevada.

Northeast of the type locality its equivalents are found as dolomitic or calcareous phases of the Eureka Quartzite. To the south in the Ranger Mountains, south of Frenchman Flat on the Nevada Test Site, a limy sandstone in the lower half of the Eureka Quartzite and the topmost limestone strata of the Antelope Valley Limestone are equivalent to the parts of member B of Merriam in the type area. Between Antelope Valley and the Test Site the lower part of the formation persists as calcareous shale, silty limestone, and calcareous sandstone. To the west both members B and C of Merriam are probably represented by silty limestones in the Toquima Range.

On following pages stratigraphic information is reviewed and fossil collections are listed for each of the areas wherein the Copenhagen or its equivalents are believed to be present.

STRATIGRAPHIC SECTIONS

ANTELOPE VALLEY, NEVADA

(Horse Heaven Mountain quadrangle)

There seems to be no entirely satisfactory stratigraphic section of the Copenhagen Formation. The type section designated by Merriam (1963, p. 26) is not completely exposed, as indicated by Ethington and Schumacher (1969, p. 441). Fossiliferous sections on the east side of Martin Ridge are cut by a half dozen faults (Merriam, 1963, pl. 2; Ethington and Schumacher, 1969, fig. 2), and much of the section in each fault block is covered. In a partly successful effort to find a more satisfactory section, Ross and L. A. Wilson measured the thickness of the Copenhagen on the west side of the Antelope Range (Ross, 1970, p. 29–31 and pl. 21) but found that the exact contact between members B and C was obscured. However, many of the collections on which this paper is based were made in that section.

Distribution of macrofossils in Ross's collections is shown in a previously published stratigraphic diagram (Ross, 1970, pl. 21). A much more complete list of brachiopods was published by Cooper (1956, p. 128) and quoted by Merriam (1963, p. 26–27), but in neither report was the precise occurrence of fossils referred to a measured section. The physical evidence for a major hiatus between members B and C of the formation is unimpressive; it would therefore be valuable to have better control on stratigraphic ranges of macrofossils within the Copenhagen than is now available. Ethington and Schumacher (1969) have gone to considerable pains to obtain the needed control for conodonts.

Most of the fossils collected from the Copenhagen Formation came from a section on the southeast side of hill 8308, south of Water Canyon, Antelope Range, (SW¼ sec. 24, T. 15 N., R. 50 E., Horse Heaven Mountain quad., Nevada), where the total thickness is about 490 feet.

The section measured at hill 8308 is fairly accurate except that the top 133 feet were masked on the line of section; this interval was pieced into the section by moving several hundred feet to the west.

Collections made by Shaw and H. B. Whittington in 1965 at this same section were designated SR, SR(−30), and SR-L. (See p. 14.)

In 1965 Shaw and Whittington also made collections from Martin Ridge, on the west side of Antelope Valley (S½NW¼ sec. 31, T. 16 N., R. 50 E., Horse Heaven Mountain quad., Nevada). These are designated MR-U for the upper member of the Copenhagen (member C of Merriam, 1963) or MR-L for the middle member (member B of Merriam, 1963). No section was measured.

FOSSILS FROM HILL 8308

USGS colln. D1880 CO, Copenhagen Formation, upper 50 ft of formation. Also USGS colln. D1912 CO and loc. SR.
- Trilobites:
  - *Triarthrus* sp.
  - *Cryptolithoides fittsi* Ulrich and Whittington
  - *Cryptolithoides reticulatus* n. sp.
  - *Anataphrus martinensis* n. sp.
  - *Robergia deckeri* B. N. Cooper
  - *Remopleurides* sp.
  - *Robergiella* sp.
  - *Raymondella nevadensis* n. sp.
  - *Ceraurinella* sp.

USGS colln. D1913 CO, Copenhagen Formation, high in member C of Merriam, about 50 ft below top of formation.
- Trilobite:
  - *Lonchodomas* sp.

Loc. SR(−30), Copenhagen Formation, member C, approximately 130 ft below top. About 360 ft above base of member B.
- Trilobites:
  - *Hypodicranotus* n. sp.
  - *Anataphrus martinensis* n. sp.

USGS colln. D1879 CO, Copenhagen Formation, member C, 341 ft above base of member B.
  Brachiopods:
    Sowerbyella merriami Cooper
    Resupinate plectambonitid?
  Trilobite:
    Isotelus sp.
USGS colln. D1878 CO, Copenhagen Formation, member C, 337 ft above base of member B.
  Brachiopod:
    Sowerbyella sp.
  Trilobite:
    Isotelus copenhagenensis n. sp.
USGS colln. D1877 CO, Copenhagen Formation, member C, 330 ft above base of member B.
  Brachiopods:
    Plectorthis obesa Cooper
    Sowerbyella merriami Cooper
    Cristiferina sp.
USGS colln. D1876 CO, Copenhagen Formation, member C, 303 ft above base of member B.
  Brachiopods:
    Oxoplecia nevadensis Cooper
    Sowerbyella sp. (large)
    Cristiferina sp.
    Strophomena sp.
    New genus and species resembling *Saukrodyctia*
  Trilobites:
    Calyptaulax sp.
    Lichid, very large, fragmentary
    Ceraurinid genus, indet.
USGS colln. D1875 CO, Copenhagen Formation, member C, 301 ft above base of member B.
  Brachiopods:
    Sowerbyella sp.
    Strophomena? sp.
    Cristiferina sp.
  Trilobite:
    Anataphrus martinensis, n. sp.
  Sponge:
    Receptaculites sp.
  Ostracodes, abundant
USGS colln. D1874 CO, Copenhagen Formation, member C, 277 ft above base of member B.
  Brachiopods:
    Strophomena sp.
    Sowerbyella sp.
  Trilobites:
    Amphilichas aff. *A. minganensis* (Billings)
    Anataphrus martinensis n. sp.
    Cybeloides sp.
    Calyptaulax sp.
    Sphaerocoryphe sp.
    Hypodicranotus n. sp.
    Isotelus copenhagenensis n. sp.
  Ostracodes, abundant
  Graptolite:
    Climacograptus cf. *C. phyllophorus* Gurley
USGS colln. D1873 CO, Copenhagen Formation, low in member C, 272 ft above base of member B. Rock in place.
  Brachiopods:
    Hesperorthis? sp.
    Sowerbyella sp.
    Leptellina? sp. (small species)
USGS colln. D1873 CO — Continued
  Trilobites:
    Hypodicranotus n. sp.
    Isotelus copenhagenensis n. sp.
    Anataphrus martinensis n. sp.
    Calyptaulax sp.
USGS colln. D1872 CO, Copenhagen Formation, float at 259–268 ft above base of member B. Almost all of this material probably comes from considerably higher in the section and is mixed stratigraphically.
  Brachiopods:
    Oxoplecia nevadensis Cooper
    Plectorthis sp.
    Cristiferina sp.
    Bilobia sp.
    Strophomena sp.
  Trilobites:
    Calyptaulax sp.
    Anataphrus martinensis n. sp.
    Isotelus copenhagenensis n. sp.
    Cryptolithoides sp.
USGS colln. D1871 CO, Copenhagen Formation, float, 225 ft above base of member B.
  Brachiopods:
    Orthid, indet.
    Cristiferina cristifera Cooper
    Eoplectodonta alternata (Botts)
    Skenidioides? sp.
    Sowerbyella? sp.
    Bimuria? sp.
Loc. SR-L, Copenhagen Formation, member B.
  Trilobites:
    Calyptaulax cf. *C. callirachis* B. N. Cooper
    Nileus? sp.
USGS colln. D1870 CO, Copenhagen Formation, 193 ft above base of member B.
  Brachiopods:
    Valcourea plana Cooper
    Plectambonitid, probably *Sowerbyella*
  Trilobites:
    Isotelus copenhagenensis n. sp.
    Calyptaulax sp.
USGS colln. D1869 CO, Copenhagen Formation, 151–156 ft above base of member B.
  Brachiopods:
    Valcourea cf. *V. plana* Cooper
    Valcourea transversa Cooper, large variety
    Multicostella? sp., possibly *Plectorthis*
    Strongly geniculate strophomenoid
  Cephalopod:
    Siphuncle, indet.
Fossils from this collection are reminiscent of those from the Mountain Lake Member (of Cooper, 1956) of the Bromide Formation.
USGS colln. D1868 CO, Copenhagen Formation, 119 ft above base of member B.
  Trilobite, unidentified
USGS colln. 6790 CO, Copenhagen Formation, approx. 50–70 ft above top of basal sandstone member A, from float.
  Bryozoans (identified by O. L. Karklins, written commun., Oct. 8, 1969):
    Chazydictya sp. (2 specimens)
  This form is similar to *Chazydictya chazyensis* Ross (1963, Geol. Soc. America Bull., v. 74, p. 587) described

USGS colln. 6790 CO, bryozoans — Continued

from the Chazy Limestone in New York. These are the first specimens, if my identification is reasonably correct, that show relationships with the species in the standard Chazyan Series of New York and Vermont. Another species of *Chazydictya* or of a related new genus with somewhat different morphologic features occurs in the collections which R. S. Boardman obtained in 1965 from the lower Copenhagen member B of Merriam (1963) or its equivalents at the following localities: Mill Canyon (*Bimuria* zone, uppermost Pogonip, below *Cryptolithoides* zone); east side, Martin Ridge, Horse Heaven Mountain quadrangle (member B of Merriam, 1963); and at Meiklejohn Peak (Copenhagen? Formation (Ross, 1967a, pl. 11)). The specimens from Meiklejohn Peak seem to differ slightly from those at Mill Canyon and Martin Ridge. Whether these differences are due to the preservation or to morphologic structure is difficult to determine because the material is fragmentary.

Phyllodictya cf. *P. crystallaria* Hinds (2 specimens)

The same form occurs in USGS colln. D680 CO (from the lower part of the Eureka Quartzite in the Ranger Mountains (Ross, 1967, pl. 11)).

Stictoporella? sp. form a (2 specimens)

The generic assignment of this form is tentative; it may belong to a new genus. This species appears to have a relatively large, explanate zoarium.

Stictoporellid(?) sp. (3 specimens)

The specimens are very fragmentary but appear to differ from those assigned to *Stictoporella*? sp.

Pachydictyid? sp. (1 specimen)

This specimen is somewhat similar to a pachydictyid(?) form which occurs in USGS colln. D1499 CO from Belted Peak.

Ottoseetaxis sp. (2 specimens)

According to Helen Duncan, this as a form of *Ottoseetaxis* Bassler, 1952. The type species of this genus, *O. bipartitus* Bassler, 1952, occurs in the Benbolt Formation of Cooper (1956) near Knoxville, Tenn. However, the material in this collection is too fragmentary for making further comparisons with the type.

Constellaria sp. (1 specimen)

The specimen is too fragmentary for comparison with those in other collections.

Anolotichia sp. (1 specimen)

Similar forms occur in USGS colln. D1905 CO from Clear Creek Canyon. This appears to be a generalized form and may not be significant in correlation.

Monticuliporid sp. (1 specimen)

This is an incomplete fragment and cannot be used for comparison with those in other collections.

Trepostome sp. (1 specimen)

The material is poorly preserved and it is not diagnostic.

This is an interesting assemblage of cryptostome bifoliates from USGS colln. 6790 CO. All of them are relatively well preserved and developed. As to the age of these rocks, the bifoliates indicate that the strata are of the same age as the McLish formation in Oklahoma or younger. However, the single fragment of a monticuliporid species suggests that the rocks probably are of the Bromide age, because the monticuliporids appear for the first time in the lowest Bromide shales and limestones of Oklahoma (R. S. Boardman, oral commun., 1965).

USGS colln. D1867 CO, Copenhagen Formation, float at 44 ft above base of member B.

Trilobite:

Anataphrus sp.

USGS colln. D1866 CO, Copenhagen Formation, 35–39 ft above base of member B.

Brachiopods:

Valcourea sp.

Plectambonitid

Trilobite:

Isotelus? sp.

USGS colln. D1865 CO, Copenhagen Formation, 29 ft above base of member B.

Brachiopod:

Sowerbyella? sp.

USGS colln. D1614 CO, Copenhagen Formation, 24–30 ft above base of member B.

Brachiopod:

Strophomenoid indet.

Trilobite:

Illaenid? indet.

USGS colln. D1864 CO, Copenhagen Formation, 6–17 ft above base of member B.

Brachiopod:

Valcourea sp.

Trilobite:

Illaenus sp.

USGS colln. D1863 CO, Copenhagen Formation, 1 ft above base of member B. (Same as USGS colln. 6792 CO.)

Bryozoans (identified by O. L. Karklins, written commun., Oct. 8, 1969)

Trepostome sp. (2 specimens)

These specimens are not diagnostic.

USGS colln. D1862 CO, Antelope Valley Limestone, approximately 35 ft below basal sand of Copenhagen Formation, on southeast side of hill 8308, NE¼SW¼ sec. 24, T. 15 N., R. 50 E., Antelope Range, Horse Heaven Mountain quad., Nevada.

Brachiopods:

Leptellina cf. *L. occidentalis* Ulrich and Cooper

Large plectambonitid?

Small asaphid pygidium

FOSSILS FROM EAST SIDE MARTIN RIDGE

Loc. MR–U, Copenhagen Formation, member C of Merriam.

Trilobites:

Anataphrus martinensis n. sp.

Illaenid sp. 1

Illaenid sp. 2

Calyptaulax cf. *C. callirachis* (Cooper)

USGS colln. D249a CO, Copenhagen Formation, float from member C of Merriam.

Trilobites:

Lonchodomas sp.

Harpid genus indeterminate

Amphilichas aff. *A. minganensis* (Billings)

USGS colln. D286 CO, Copenhagen Formation, float from member C of Merriam.

Trilobites:

Isotelus copenhagenensis n. sp.

Calyptaulax cf. *C. callirachis* (Cooper)

Primaspis sp.

460-196 O - 72 - 2

Loc. MR–L, Copenhagen Formation, member B of Merriam (1963).
Trilobite:
Calyptaulax cf. *C. callirachis* (Cooper)
USGS colln. D249c CO, Copenhagen Formation, float derived from member B of Merriam (1963).
Trilobite:
Isotelus copenhagenensis n. sp.

CLEAR CREEK CANYON, NEVADA
(T. 11 N., R. 48 E., Tonopah 2° quadrangle)

The Copenhagen Formation in Clear Creek Canyon is about 70 feet thick, including the basal sandstone member, which is 30 feet thick. These figures do not agree with those of Lowell (1965, table 1), who considered that the basal 30-foot sandstone was overlain by about 105 feet of strata representing both members B and C of Merriam (1963).

Fossil collections were made from the Copenhagen Formation on the north side of the creek and from the highest Antelope Valley Limestone on the south side.

USGS colln. D1903 CO, Copenhagen Formation, 38 ft above base of member B, topmost exposure beneath Eureka Quartzite.
Brachiopods:
Valcourea sp.
Multicostella? sp.
Macrocoelia sp.
Bryozoans (identified by O. L. Karklins, written commun., Sept. 26, 1969):
Homotrypid sp. (1 specimen)
This is an incomplete fragment and cannot be compared with those forms in other collections.
Amplexoporid sp. (1 specimen)
This is also an incomplete fragment, but it appears to be vaguely similar to some undescribed forms which occur in the Bromide Formation of Oklahoma.
Conodonts (identified by J. W. Huddle, written commun., April 13, 1970):

	Specimens
Belodina monitorensis Ethington and Schumacher	4
Cyrtoniodus flexuosus (Branson and Mehl)	2
Dichognathus typica Branson and Mehl	5
Drepanodus suberectus (Branson and Mehl)	3
Ozarkodina cf. *O. tenuis* Branson and Mehl	2
Phragmodus undatus Branson and Mehl	2
Sagittodontus robustus? Rhodes	1
Trichonodella cf. *T. barbara* (Stauffer)	2

USGS colln. D1904 CO, Copenhagen Formation, from float 37 ft above base of member B.
Brachiopod:
Valcourea sp.
Trilobite fragments, including problematical piece of frill of cryptolithid.
Bryozoans (identified by O. L. Karklins, written commun., Sept. 26, 1969):
Amplexoporid sp. (1 specimen)
Probably the same species as that which occurs in collection D1903 CO.

USGS colln. D1905 CO, Copenhagen Formation, from ledges in place 37 ft above base of member B.
Brachiopods:
Macrocoelia sp.
Valcourea sp.
Trilobites:
Nanillaenus sp.
Isotelus copenhagenensis n. sp.
Bryozoans (identified by O. L. Karklins, written commun., Sept. 26, 1969):
Anolotichia sp. (1 specimen)
Similar forms occur in the following collections: D1614 CO (reported as trepostomes from the Copenhagen Formation, 24–30 ft above the top of basal sandstone (member A of Merriam, 1963), Antelope Range); 6790 CO, 60 ft above the base of member B in Antelope Range; in the material obtained by R. S. Boardman in 1965 from member B on the east side of Martin Ridge, Horse Heaven Mountain quadrangle, Nevada, and D1466 CO, Saturday Mountain Formation, Idaho.
Ostracodes (identified by Jean Berdan, written commun., July 12, 1968):
Hypochilarina? sp.
Severella? sp.
Cryptophyllus sp.
Punctaparchites sp.
Ostracodes, indet.
This is an interesting association of ostracodes, but not particularly helpful as far as age determinations are concerned. *Hyperchilarina*? and *Cryptophyllus* both occur in the upper part of the Antelope Valley and apparently range upward. *Punctaparchites* occur in the Decorah and Bromide Formations, and has also been reported in the Leray Formation of Pauquette Rapids, Canada. It could range either higher or lower. *Severella* is a Baltic genus, but the identification is queried because only one tecnomorphic specimen was found, and the generic characters are based on the heteromorph.
Conodonts (identified by J. W. Huddle, written commun., April 13, 1970):

	Specimens
Acontiodus alveolaris Stauffer	2
Belodina monitorensis Ethington and Schumacher	4
Cyrtoniodus flexuosus? (Branson and Mehl)	1
Dichognathus sp	7
Distacodus sp	1
Drepanodus suberectus (Branson and Mehl)	1
Oistodus sp	1

Collections D1903 CO and D1905 CO contain part of the fauna described from the Copenhagen Formation by Ethington and Schumacher (1969). There is nothing that is very definitive, but a correlation with the Ashby-Porterfield is reasonable.

USGS colln. D1906 CO, Copenhagen Formation, 27 ft above base of member B.
Brachiopods:
Multicostella sp.
Valcourea sp.
Sowerbyites sp.
Macrocoelia sp.
Trilobite:
Isotelus sp.

USGS colln. D1907 CO, Copenhagen Formation, from float near base of member B.

Trilobite:

Calyptaulax sp.

USGS colln. D1909 CO, Antelope Valley Limestone, 127 ft below basal sandstone of Copenhagen Formation.

Brachiopods:

Anomalorthis cf. *A. oklahomensis*

Orthambonites sp.

Conodonts (identified by J. W. Huddle, written commun., April 13, 1970):

	Specimens
Acodus sp	2
Acontiodus sp	1
Drepanodus suberectus (Branson and Mehl)	3
Paltodus sp	1
Paltodus sp	1
Oistodus contractus Lindström	2
Scolopodus n. sp	3

USGS colln. D1910 CO, Antelope Valley Limestone, from float 129 ft below basal sandstone of Copenhagen Formation.

Brachiopods:

Anomalorthis cf. *A. oklahomensis* Ulrich and Cooper

Desmorthis cf. *D. crassus* Ross

Ostracodes (identified by Jean Berdan, written commun., July 12, 1968):

Eoleperditia bivia?

Hyperchilarina? sp.

The *Eoleperditia* in this collection is fragmentary and cannot be compared with those from other collections.

Conodonts (identified by J. W. Huddle, written commun., April 13, 1970):

	Specimens
Acodus cf. *A. auritus* Harris and Harris	3
Acodus sp	1
Drepanodus suberectus (Branson and Mehl)	6
Drepanodus subarcuatus Furnish	1
Oistodus cf. *O. lanceolatus* Pander	2
Oulodus sp	1
Scandodus n. sp	3
Scolopodus n. sp	1

USGS colln. D1908 CO, Antelope Valley Limestone, float 170 ft below basal sandstone of Copenhagen Formation.

Brachiopod:

Anomalorthis cf. *A. oklahomensis*

Trilobites:

Illaenus sp.

Ostracodes (identified by Jean Berdan, written commun., July 12, 1968):

Eoleperditia sp. cf. *E. bivia* (White)

Small, smooth ostracodes, indet.

The ostracodes in this collection are not well preserved and are difficult to work out of the matrix. The *Eoleperditia* appears to be similar to the kind that occurs in the upper part of the Kanosh Shale in the Ibex area, but I cannot be certain of this because the specimens are so poor. One of the smaller ostracodes seems to be new, but there is only one specimen, which is not enough to work with.

Conodonts (identified by J. W. Huddle, written commun., April 13, 1970):

USGS colln. D1908 CO, conodonts — Continued	Specimens
Eofalodus brevis Harris	1
Dichognathus n. sp	3
Distacodus symmetricus Mound	1
Drepanodus subarcuatus Furnish	2
Drepanodus suberectus (Branson and Mehl)	4
Oulodus sp	2
"Tetraprioniodus" costatus Mound	3
Synprioniodina? sp	3
Trichonodella sp	1
New genus	1

CORRELATION OF FOSSILS AT CLEAR CREEK CANYON

With exception of a fragment of a problematical cryptolithid trilobite in collection D1904 CO, every fossil collected from the Copenhagen Formation allies it with member B of Merriam. Ross is of the opinion that this fragment is harpid. It is difficult to understand where Lowell discovered *Reuschella*, unless specimens of *Valcourea* could have been mistaken for that genus. The thickness of member B measured by Ross is so different (by 100 ft) from that published by Lowell (1965, table 1) that we fear we have overlooked some nearby section that is more complete than the one in the valley of Clear Creek proper. It seems possible, if not likely, that figures for Hot Creek and Clear Creek were reversed in publication (Lowell, 1965, table 1). Concerning conodonts from the Antelope Valley Limestone in this section, J. W. Huddle (written commun., April 13, 1970) commented,

> Collections D1908–D1910 CO are all Middle Ordovician in age and are apparently early Middle Ordovician, as they contain species characteristic of the Joins Formation. I have not seen some of these species in the previous collections from the Antelope Valley.

HOT CREEK CANYON, NEVADA

(T. 8 N., R. 50 E., Tonopah 2° quadrangle)

Lowell (1965, p. 263 and table 1) indicated that the Copenhagen Formation was only 20–30 feet thick at Hot Creek; on the basis of a very limited number of fossils he concluded that the entire formation had been compressed into this thickness, which is in contrast to the far greater thickness in the northern Monitor Range.

Ross (1970, p. 17–19 and pls. 20, 21) has shown that the Copenhagen Formation at Hot Creek is about 90 feet thick and that the fossils are indicative of the lower member (member B of Merriam, 1963). The upper member (member C of Merriam, 1963) is either absent or represented by some part of the Eureka Quartzite. The Eureka is at least three times as thick at Hot Creek as in the northern Monitor Range.

Trilobites found in USGS colln. D1860 CO include: *Carrickia* sp., *Remopleurides* sp. 2, *Anataphrus martinensis* n. sp., and *Ceraurus*? sp. (possibly a cybelid).

RAWHIDE MOUNTAIN, NEVADA

(Ross, 1964, p. C64–C66, C68)

Although not so recognized previously, the unnamed black shale and underlying 25 feet of dolomitic sandstone beneath the Eureka Quartzite should probably be considered as the Copenhagen Formation at Rawhide Mountain (Ross, 1964, p. C66). The contained fossils, particularly the ostracodes (Ross, 1964, p. C68), seem to indicate that the lower part (member B of Merriam, 1963) of the formation is represented.

BELTED PEAK AREA, NEVADA

The Copenhagen(?) Formation near Belted Peak seems to be about 277 feet thick. In 1964 Ross and L. A. Wilson measured the thickness of an overturned section of Ordovician rocks stratigraphically below the Eureka Quartzite on the west side of hill 7089, 2.85 miles southwest of Belted Peak (Ekren and others, 1971) (Nevada coord., central zone: E. 659,650 ft, N. 1,017,300 ft). This section, which is at an altitude of approximately 7,040 feet, was revisited in 1966.

A unit of thin-bedded fossiliferous limestone containing a high percentage of interbedded siltstone is poorly exposed 41–44 feet beneath the Eureka Quartzite; this unit in turn is underlain by interbeds of shale, dolomitic sandstone, quartzose sandstone and siltstone, and thin silty dolomite. The section follows:

	Feet
Eureka Quartzite.	
Copenhagen(?) Formation:	
Interval completely masked by quartzite rubble	21
Siltstone, dark-yellowish-orange, limy; shows relicts of fossils	1
Shale, fissile, medium-gray; weathers yellowish orange to olive gray. Interbeds of calcareous siltstone	19
Limestone, calcarenitic silty, in thin irregular beds. Fossiliferous. Bryozoans abundant. USGS colln. D1499 CO from this interval	3
Slope masked by float. In lower 40 ft much shale, silty calcarenite, and thin quartzite chips in float	96
Float, composed of siltstone chips weathering grayish yellow	12
Limestone and dolomite; weather medium gray to light olive gray; form resistant ledge	3
Siltstone, platy, gray; weathers yellowish gray to yellowish orange	21
Argillite, grayish red	1
Slope covered by float. All float in this interval is yellowish orange to grayish orange	15
Float composed largely of yellowish-gray (5*Y* 8/1) very fine quartzite and sandstone in thin chips derived from very thin bedded rock. Much grayish-red sandstone in lower half	55
Copenhagen(?) Formation — Continued	
Siltstone and very thinly laminated sandstone; weathers pale yellowish orange	30
Total thickness of Copenhagen(?) Formation	277
Pogonip Group:	
Antelope Valley Limestone:	
Dolomite, light-gray; thin bedded in beds 2–3 ft thick. Some intraformational conglomerate	31
Not recorded below this unit.	

Fossils from this entire interval are limited to USGS colln. D1499 CO but include a considerable variety.

USGS colln. D1499 CO, Copenhagen(?) Formation, 41–44 ft below base of Eureka Quartzite.

Brachiopods:

Multicostella(?) sp.
Valcourea sp. (large)
Valcourea sp. (small)
Sowerbyella sp.

Trilobite:

Anataphrus cf. *A. spurius* (Phleger)

Conodonts (identified by J. W. Huddle, written commun., Mar. 3, 1965):

	Specimens
Belodina cf. *B. ornata* (Branson and Mehl)	1
Cordylodus sp	1
Dichognathus n. sp	7
n. sp	8
Distacodus sp	1
Drepanodus sp	1
sp	1
sp	1
Phragmodus undatus Branson and Mehl	4
Prioniodina? sp	1
Trichonodella sp	1
Zygognathus sp	1

"This fauna is probably Middle Ordovician in age. In New York *Phragmodus undatus* and *Dichognathus* appear in the Rockland Formation of Raymond (1914) and continue into the Late Ordovician," Huddle noted.

Bryozoans (identified by O. L. Karklins, written commun., Feb. 23, 1965):

About 11 zoaria were thin-sectioned. Four of these zoaria are well enough preserved for identification, but they belong to undescribed taxa. In the other sectioned material the distinguishing features of the wall structures appear to be recrystallized.

Pachydictyid(?) (2 specimens)

This is a form of a new cryptostome bifoliate genus of the family Rhinidictyidae.

Trepostome (1 specimen)

This form, probably a new genus, is vaguely similar to the diplotrypids.

Monticuliporid (1 specimen)

This form shows parts of well developed cystiphragms. The rest of the wall structures appear to be recrystallized.

"According to the information made available to me (R. S. Boardman, oral commun., 1965) in regard to the Simpson Group of Oklahoma, the cryptostome bifoliates, including pachydictyid-like forms, appear for the first

USGS colln. D1499 CO, bryozoans — Continued
time at the base of the lowest McLish shales and limestones, and the monticuliporids appear for the first time at the lowest Bromide shales and limestones," Karklins stated.

Subsequently Karklins (written commun., Sept. 26, 1969) commented on homotrypid bryozoans from colln. D1861 CO, Copenhagen Formation at Hot Creek (Ross, 1970, p. 18) and noted, "Vaguely similar forms appear to be present also in colln. D1499 CO, reported on Feb. 23, 1965, as a monticuliporid species. These forms suggest that the strata are of Bromide age or younger but probably not older than McLish Formation in Oklahoma."

Most of the fossils indicate equivalence with members A and B of Merriam (1963) of the Copenhagen Formation, though they are limited to the upper 45 feet of the 277-foot unit here assigned to the formation.

MEIKLEJOHN PEAK, NEVADA

(Ross, 1964, p. C25, C27, C29, C30; 1967a, pl. 11)

In two sections at Meiklejohn Peak, Ross (1964, p. C25, C29) included 31 feet and 51 feet of sandy limestone in a transitional interval in the top of the Antelope Valley Limestone and below the Eureka Quartzite. Fossils from this interval ally it to member B of the Copenhagen Formation, which it probably represents (Ross, 1967a, pl. 11). These fossils (Ross, 1964, p. C27, colln. D820 CO; p. C30, colln. D824 CO; 1967a, pl. 11, colln. D1601 CO) include:

Eofletcheria sp.
Glyptorthis sp.
Valcourea sp.
Sowerbyites sp.
Sowerbyella cf. *S. perplexa* Cooper
Leptellina sp.
Macrocoelia sp.
Protozyga? sp.
Oxoplecia monitorensis Cooper
Laticrura cf. *L. heteropleura* Cooper
Illaenus cf. *I. utahensis*

This interval is correlative with at least the upper 20 feet of the Antelope Valley Limestone and lower 90 feet of the Eureka Quartzite in the Ranger Mountains of the Nevada Test Site (Ross, 1967a, pl. 11).

NORTHERN INYO MOUNTAINS, CALIFORNIA

(Independence quadrangle)

The Barrel Spring Formation of the northern Inyo Mountains (Ross, R. J., 1964, p. C37, C40; 1967a, pl. 11; Ross, D. C., 1966) is surely correlative with member B of the Copenhagen Formation. The detrital nature of its constituents also relates this unit to the Copenhagen, but the resemblance is closer to the beds at Rawhide Mountain and Hot Creek Canyon than at the type section.

TOQUIMA RANGE, NEVADA

(Wildcat Peak quadrangle)

The Caesar Canyon Limestone described and mapped by Kay and Crawford (1964, p. 432–433, pl. 1) in the Toquima Range is actually considerably more than a limestone. As noted by Kay and Crawford, the lower contact at the type locality of the Caesar Canyon may be a gradational one with the underlying Antelope Valley Limestone. But in addition to the calcarenitic and phosphatic limestone that yields *Cryptolithoides* and graptolites there is a considerable thickness of shale and siltstone enclosing a varied trilobite assemblage in the middle of the formation. In fact most of the trilobites listed by Kay and Crawford (1964, p. 433) came from these argillaceous beds. The trilobites indicate equivalence to member C of the Copenhagen Formation.

Kay and Crawford (1964, p. 432) reported *Bimuria* from the lower silty limestone of their Caesar Canyon Formation, and this occurrence has been duplicated by Ross. However, it is virtually impossible to distinguish lithologically between strata that Kay and Crawford assign to the top of the Antelope Valley Limestone and the lower limestone of the Caesar Canyon Limestone in their August Canyon sequence. It seems probable that the lower and the middle members of the Copenhagen are represented in the Toquima Range by Antelope Valley or very similar lithology.

In the Mill Canyon sequence (Kay and Crawford, 1964, pl. 1) at Ikes Canyon (Ross, 1970, p. 21–23, pls. 20, 21) an unnamed Ordovician limestone unit overlies the Antelope Valley and underlies the Roberts Mountains Formation (Masket Shale of Kay and Crawford, 1964); that unit is probably equivalent to part of the Copenhagen Formation.

INDEPENDENCE MOUNTAINS, NEVADA

(Tuscarora quadrangle)

In the Independence Mountains north of Taylor Canyon, Kerr (1962, pl. 1) mapped three stratigraphic sequences of lower Paleozoic rocks separated by thrust faults. In the Burns Creek sequence he described the Eureka Quartzite as composed of three units (Kerr, 1962, p. 445). The upper unit is 440 feet of vitreous quartzite. The middle unit is a less resistant impure dolomite 90 feet thick; this unit is fossiliferous. The bottom unit is 25 feet of resistant, bench-forming crossbedded sandstone.

Kerr (1962, p. 445) reported the following fossils from the dolomite unit: *Receptaculites* sp., *Calyptaulax strasburgensis* (Ulrich and Delo), *Ampyx* sp., *Maclurites* sp., *Sowerbyella* sp., and an orthid brachiopod.

Kerr's locality is at an approximate altitude of 8,080 feet on the ridge west of hill 8422 in the SW¼NE¼ sec. 20, T. 40 N., R. 53 E., Tuscarora quadrangle. A collection made by Ross in 1967 (USGS colln. D2173 CO) from this locality includes two species of *Valcourea, Strophomena, Sowerbyella* sp., and a coarse ribbed orthid brachiopod. Combined with those on Kerr's list, these fossils suggest that the dolomite is equivalent to member B of Merriam of the Copenhagen Formation.

The Eureka Quartzite in this area is overlain by the Hanson Creek Formation, in which *Cryptolithoides* and *Anataphrus* are present with *Climacograptus hastatus* (USGS colln. D2175 CO); *C. hastatus* is abundant in the beds over the Eureka in the northern Monitor Range and in the Antelope Range.

AGE OF TRILOBITE FAUNAS OF THE COPENHAGEN FORMATION AND ITS EQUIVALENTS

MEMBER A OF MERRIAM (1963)

In the Antelope Valley area, the lower sandstone member contains orthocone nautiloids. No trilobites from this unit are in the present collections.

MEMBER B OF MERRIAM (1963)

Member B of Merriam (1963) was termed the "yellow sandstone" by Cooper (1956, p. 128) and was thought to be correlative with Cooper's Arline Formation of the southern Appalachians. It contains *Sowerbyites* and *Macrocoelia,* which may also suggest correlation of this unit with beds at the top of the Bromide Formation, in the Mountain Lake Member of Cooper (1956), in Oklahoma.

Few trilobites have been collected from this member of the formation, and they are of little use in distinguishing between members B and C. *Calyptaulax* cf. *callirachis* (Cooper), *Anataphrus martinensis* n. sp., and *Isotelus copenhagenensis* range from one member into the other. *Anataphrus* occurs in the topmost Antelope Valley Limestone at the Nevada Test Site in USGS colln. D710 CO (Ross, 1964, p. C19; 1970, pl. 13, figs. 3, 5, 7, 10) and is very common in the type section of the Hanson Creek Formation. *Illaenus* seems to range from the lower into the upper member.

If any change in trilobite assemblages takes place between members B and C, we have yet to find the evidence. On the other hand, there is a pronounced change within 100 feet of the top of member C.

MEMBER C OF MERRIAM (1963)

Member C of Merriam (1963) carries brachiopods thought by Cooper (1956) to be similar to those of his Oranda Formation of Virginia. The trilobites from this upper unit can be divided into two distinct assemblages.

The lower assemblage ranges upward through collections D1879 CO and D1913 CO on the east side of Antelope Valley and through similar levels at Martin Ridge.

It includes *Isotelus copenhagenensis, Anataphrus martinensis,* and *Calyptaulax callirachis,* which range upward from the underlying member. *A. martinensis* ranges higher. *Amphilichas* aff. *A. minganensis* and *Hypodicranotus* n. sp. are two of the more distinctive members of this assemblage; the former suggests an early Middle Ordovician age while the latter is known from strata of Wilderness (DeMott, 1963) or Barneveld (Whittington, 1952) age in North America. It should be noted that *Hypodicranotus* occurs in southwestern Scotland (Tripp, 1965, p. 601–602) in strata correlated with the Porterfield-Wilderness Edinburg Formation of Cooper and Cooper (1946) of the Appalachians.

The trilobites found in the uppermost 50 feet — in the upper assemblage — of the Copenhagen Formation on the east side of Antelope Valley include *Triarthrus, Robergia, Robergiella, Remopleurides, Cryptolithoides, Raymondella,* and *Ceraurinella.*

Cryptolithoides, accompanied by *Robergia,* is known from the lower part of the Viola Limestone of Oklahoma. The other genera are typical of the Edinburg Formation of the southern Appalachians (Whittington, 1959, p. 384–387), presumably an older unit (Cooper, 1956).

In eastern North America, *Cryptolithus,* rather than *Cryptolithoides,* appears at about this stratigraphic level, together with calymenids. Graptolites of the zone of *Orthograptus truncatus intermedius* (Berry, 1960) appear in New York and Oklahoma at approximately this level and, as discussed below, also appear with these trilobites in the Caesar Canyon Limestone of the Toquima Range, Nev. Shaw assumes that cryptolithinids and graptolites of zone of *O. truncatus intermedius* are indicative of the start of Barneveld time over much of North America, although Fisher (1962) showed that the Barneveld is entirely within that zone.

The simultaneous arrival of older eastern genera — for example, *Triarthrus, Raymondella,* and the others — at this same time in the west may well demonstrate facies or faunal province control over these latter genera.

CAESAR CANYON LIMESTONE

Kay (1962) and Kay and Crawford (1964) proposed the Caesar Canyon Limestone for supposed Copenhagen equivalents in the northern Toquima

Range. No accurate sections have been measured, because of structural complications and cover (Marshall Kay, oral commun., 1969). Locality GK ("Gatecliff") appears to be stratigraphically lower than locality CC, which has yielded *Cryptolithoides*. Scattered collections have been made by the present writers and by Kay (Kay and Crawford, 1964, table 1). Most of the trilobite genera known from the uppermost part of member C of the Copenhagen Formation are present in the Caesar Canyon Limestone. They show that the Caesar Canyon correlates with the topmost strata of the upper member of the Copenhagen. The appearance of *Cryptolithoides*, a calymenid, and *Primaspis* in the Caesar Canyon suggests that the age of this fauna is early Barneveld (Fisher, 1962; Whittington, 1959).

Graptolites from three collections from the Caesar Canyon Limestone have been examined by W. B. N. Berry, whose identifications follow:

USGS colln. D1901 CO. Caesar Canyon Limestone.
- *Climacograptus typicalis*
- *Diplograptus*? sp.
- *Orthograptus truncatus* var. *strigosus*
- *Orthograptus truncatus* cf. var. *intermedius*
- *Orthograptus truncatus* var. *pertenuis*?

Age: late Middle Ordovician (about Trenton-Eden), *Orthograptus truncatus intermedius* zone (zone 13).

USGS colln. D1917 CO. Caesar Canyon Limestone.
- *Climacograptus typicalis*
- *Orthograptus* sp. (of the *O. truncatus* type) (possibly *O. truncatus intermedius*)

Age: late middle Ordovician, *O. truncatus intermedius* zone (zone 13).

USGS colln. D2182 CO. Caesar Canyon Limestone.
- *Climacograptus* sp. (of the *C. typicalis* type)
- *Orthograptus* sp. (of the *O. truncatus* group; possibly both varieties *O. truncatus intermedius* and *O. truncatus strigosus* are present)

Age: late Middle Ordovician, *O. truncatus intermedius* zone (zone 13).

AGE OF THE COPENHAGEN FORMATION AND ITS EQUIVALENTS

Most of the brachiopods of the formation were described by Cooper (1956), but the relative stratigraphic positions where they were collected were highly generalized. The abundant bryozoans have yet to be described. A valuable biostratigraphic study of the conodonts has been published by Ethington and Schumacher (1969).

On the basis of brachiopods, Cooper (1956, p. 128, chart 1) correlated the upper member of the Copenhagen with the Oranda Formation of Virginia (Cooper, 1956, p. 81) which he considered to be somewhat older than the Sherman Fall Formation of Kay, (1937). Cooper considered the middle member to correlate with his Arline and Effna Formations of Virginia. As a result, in Cooper's (1956, chart 1) scheme of Middle Ordovician stages the upper member was late Wilderness and the middle member was early Porterfield.

Ethington and Schumacher (1969, p. 448–449) showed that the conodonts supply much conflicting evidence, but in general the evidence is not in discord with Cooper's correlations. They warn, however, that no correlations in this part of the section can be reliable until conodonts from most of the more easterly sections are studied.

A number of fossils other than trilobites from the Copenhagen and its equivalents are identified in the preceding stratigraphic sections. Although many of the correlations are uncertain, the information from bryozoans, ostracodes, and conodonts suggests that member B of the Copenhagen can be correlated with parts of the Bromide Formation of Oklahoma. The Bromide has been assigned by Cooper (1956) to the Porterfield-Wilderness transition. Thus this scattered information seems to corroborate work by Ethington and Schumacher (1969) discussed above.

Work in progress by Shaw on Simpson Group trilobites shows general similarities between trilobites of the middle member of the Copenhagen and of the Bromide. The McLish of Oklahoma is hard to separate from the Bromide on the basis of trilobites. Clearly, however, the Joins and Oil Creek Formations are not demonstrably correlatable to member B of the Copenhagen.

Some of the trilobites described here are also known from the Edinburg Formation of Virginia, a unit of very long ranging age but basically believed also to correlate to the Bromide (Cooper, 1956). Shaw thus would argue that a good part of member B of the Copenhagen is Bromide or Edinburg age (late Porterfield to early Wilderness of Cooper, 1956).

The uppermost few feet of the Copenhagen in Antelope Valley is clearly, on the basis of trilobites, equivalent to the uppermost part of the Caesar Canyon Limestone of Kay and Crawford (1964). Again, many of these trilobites also appear in Oklahoma, in the Viola Limestone. Similar forms also appear in the Oranda Formation of Cooper (1956) in the southern Appalachians and in the Shoreham Member of the Sherman Fall Formation of Kay (1937) of New York. According to Berry (1960, p. 38), the lower part of the Viola Limestone has graptolites of the zone of *O. truncatus intermedius*, and some of the same forms are known from the "Trenton Limestone" at Trenton Falls, N. Y. Strata at this last occurrence are partly equivalent to the Trenton Stage of Cooper (1956). Ethington and Schumacher (1969, p. 448) noted a difference between Caesar Canyon conodonts and those from the Copenhagen Formation further east. However, it is unclear what part of the Caesar Canyon Limestone they were referring to, and no suggestion was given that the novel genera represent a later age.

Conodonts apparently are scarce in all of member C (Ethington and Schumacher, 1969) but do include *Polyplacognathus ramosa* Stauffer and *Sagittodontus robustus* Rhodes, forms known from the Trenton Group (Schopf, 1966) and the Galena Dolomite (Ethington, 1959), respectively. In summary, graptolites and trilobites from the uppermost Copenhagen and from the Caesar Canyon Formation appear to be equivalent to those in the Viola and thus Barneveld in age.

Churkin (1963, p. 424) called attention to the possible correlation of trilobites from the Caesar Canyon Limestone with those from the Saturday Mountain Formation in Idaho; graptolites from beds adjacent to the trilobite-bearing strata were dated by Ross and Berry (1963, p. 62–63 and table 1) as middle Caradoc, probably Trenton-Eden.

Most of the sections discussed in this paper deal with the Copenhagen Formation and its equivalents to the south and west of Antelope Valley. As noted by Ross (1970, p. 33–34) at Lone Mountain (west of Eureka, Nev.) and northward in the Roberts Mountains, the Eureka Quartzite is present, and the Copenhagen is difficult or impossible to identify lithologically. At Lone Mountain, Ethington and Schumacher (1969, fig. 3) showed that member B conodonts are present directly below the Eureka in beds considered by Ross (1970, p. 33–34 and pl. 21) to be basal Eureka. At the type section of the Hanson Creek Formation on Pete Hanson Creek in the Roberts Mountains, *Cryptolithoides* and *Anataphrus* appear in that formation above the Eureka. The two genera also occur in the Hanson Creek Formation in the Independence Mountains, east of Tuscarora. It seems probable that the Eureka Quartzite is older than at Lone Mountain and was being deposited in these more northerly areas at the same time as the Copenhagen Formation was being deposited farther south. The picture is far from clear in the absence of good fossil material.

COLLECTIONS AND LOCALITIES

(Collections made by Ross unless otherwise indicated)

USGS colln. D249a CO, Copenhagen Formation, float from member C of Merriam (1963). West side of Martin Ridge, 3,200 ft south-southwest of hill 8172, sec. 13, T. 15 N., R. 49 E., Horse Heaven Mountain quad., Nevada. Collected by C. W. Merriam and R. J. Ross, Jr., 1955.

USGS colln. D249b CO, Copenhagen Formation, mixed float from bottom of member C and top of member B of Merriam. West side of Martin Ridge, 3,200 ft south-southwest of hill 8172, sec. 13, T. 15 N., R. 49 E., Horse Heaven Mountain quad., Nevada. Collected by C. W. Merriam and R. J. Ross, Jr., 1955.

USGS colln. D249c CO, Copenhagen Formation, float near middle of member B of Merriam. West side of Martin Ridge, 3,200 ft south-southwest of hill 8172, sec. 13, T. 15 N., R. 49 E., Horse Heaven Mountain quad., Nevada. Collected by C. W. Merriam and R. J. Ross, Jr., 1955.

USGS colln. D249d CO, Copenhagen Formation, float from lower part of member B of Merriam. West side of Martin Ridge, 3,200 ft south-southwest of hill 8172, sec. 13, T. 15 N., R. 49 E., Horse Heaven Mountain quad., Nevada. Collected by C. W. Merriam and R. J. Ross, Jr., 1955.

USGS colln. D286 CO, Copenhagen Formation, lower part of member C of Merriam. East flank of Martin Ridge, approximately 8,000 ft south of mouth of Copenhagen Canyon, T. 16 N., R. 50 E., Horse Heaven Mountain quad., Nevada.

USGS colln. D1499 CO, Copenhagen Formation, 41–44 ft below base of Eureka Quartzite. On west side of hill 7089, 2.85 miles southwest of Belted Peak, Nevada coord., central zone: E. 695,650 ft; N. 1,017,300 ft, Belted Peak quad., Nevada.

USGS colln. D1614 CO, Copenhagen Formation, 24–30 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1860 CO, Copenhagen Formation, equivalent of member B of Merriam, 79 ft above base of and 22 ft below top of formation. North wall of Hot Creek Canyon, sec. 24, T. 8 N., R. 49 E., Tonopah 2° quad., Nevada.

USGS colln. D1863 CO, Copenhagen Formation, 1 ft above base of member B of Merriam, 1963. Southeast side of hill 8308, SW¼ sec. 24, T. 15 N., R. 50 E., Horse Heaven Mountain quad., Nevada.

USGS colln. D1864 CO, Copenhagen Formation, 6–17 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1865 CO, Copenhagen Formation, 29 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1866 CO, Copenhagen Formation, 35–39 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1867 CO, Copenhagen Formation, float at 44 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1868 CO, Copenhagen Formation, 119 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1869 CO, Copenhagen Formation, 151–156 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1870 CO, Copenhagen Formation, 193 ft above base of member B. Southeast side of hill 8308, SW¼ sec. 24, T. 15 N., R. 50 E., Horse Heaven Mountain quad., Nevada.

USGS colln. D1871 CO, Copenhagen Formation, float, collected 225 ft above base of member B. Much of this collection derived from member C. Locality same as for D1863 CO.

USGS colln. D1872 CO, Copenhagen Formation, from float 258–269 ft above base of member B. All this collection is probably derived from considerably higher in the formation and is mixed stratigraphically. Locality same as for D1863 CO.

USGS colln. D1873 CO, Copenhagen Formation, lower part of member C of Merriam, 272 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1874 CO, Copenhagen Formation, member C of Merriam, 277 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1875 CO, Copenhagen Formation, member C, 301 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1876 CO, Copenhagen Formation, member C of Merriam, 303 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1877 CO, Copenhagen Formation, member C, 330 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1878 CO, Copenhagen Formation, member C, 337 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1879 CO, Copenhagen Formation, member C, 341 ft above base of member B. Locality same as for D1863 CO.

USGS colln. D1880 CO, Copenhagen Formation, upper 30–50 ft of formation, member C of Merriam. Southwest side of hill due west of hill 8308, approximate altitude 8,000 ft, NW¼SE¼ sec. 23, T. 15 N., R. 50 E., Horse Heaven Mountain quad., Nevada.

USGS colln. D1901 CO, Caesar Canyon Limestone of Kay and Crawford (1964), about 3 in. to 1 ft thick, above Antelope Valley Limestone lithology. On west side of mouth of north tributary to Mill Canyon approximately 1,800 ft east-southeast of hill 8725. Nevada coord., central zone: E. 465,000 ft; N. 1,551,100 ft, Wildcat Peak quad., Nevada.

USGS colln. D1903 CO, Copenhagen Formation, 38 ft above base of member B; topmost exposure beneath the Eureka Quartzite. North side of Clear Creek Canyon (p. 6).

USGS colln. D1904 CO, Copenhagen Formation, from float 37 ft above base of member B. North side of Clear Creek Canyon (p. 6).

USGS colln. D1905 CO, Copenhagen Formation, 37 ft above base of member B of Merriam, north side of Clear Creek Canyon (p. 6).

USGS colln. D1906 CO, Copenhagen Formation, 27 ft above base of member B. North side of Clear Creek Canyon (p. 6).

USGS colln. D1907 CO, Copenhagen Formation, float near base of formation. North side of Clear Creek Canyon (p. 6, 7).

USGS colln. D1912 CO, Copenhagen Formation, upper 50 ft. Same locality as D1880 CO.

USGS colln. D1913 CO, Copenhagen Formation, from top of yellow-weathering limy siltstone just below upper dark shale, member C of Merriam. South-southwest side of hill in NE¼SE¼ sec. 23 and NW¼SW¼ sec. 24, T. 15 N., R. 50 E., Horse Heaven Mountain quad., Nevada.

USGS colln. D1914 CO, Caesar Canyon Limestone of Kay and Crawford, about 50 ft below top in shaly unit. East side of Caesar Canyon, approximate altitude 8,000 ft. Nevada coord., central zone: E. 470,200 ft; N. 1,548,400 ft, Wildcat Peak quad., Nevada.

USGS colln. D1915 CO, Caesar Canyon Limestone of Kay and Crawford, approximately 35 ft below top in shaly unit. East side of Caesar Canyon, approximate altitude 8,000 ft. Nevada coord., central zone: E. 470,200 ft; N. 1,548,400 ft, Wildcat Peak quad., Nevada.

USGS colln. D1916 CO, Saturday Mountain Formation, approximately 10 ft above quartzite and dolomitic quartzite ledge. About 200 yd south of mouth of Bruno Creek, altitude 5,940 ft, west side of Squaw Creek, NE¼SE¼ sec. 8, T. 11 N., R. 17 E. Idaho coord., E. 375,700 ft; N. 958,800 ft, Clayton 7½-min. quad., Idaho.

USGS colln. D1917 CO, Caesar Canyon Limestone of Kay and Crawford, upper part. East side of Caesar Canyon, approximate altitude 8,240 ft. Approximate Nevada coord., central zone: E. 470,000 ft; N. 1,548,600 ft, Wildcat Peak quad., Nevada.

USGS colln. D2182 CO, Caesar Canyon Limestone, type section. Approximate altitude 8,000 ft. North of Mill Canyon in tributary canyon. Ne-

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vada coord., central zone: E. 470,300 ft; N. 1,547,600 ft, Wildcat Peak quad., Nevada.

USGS colln. 6790 CO, Copenhagen Formation, float, 50–70 ft above base of member B. Same locality as USGS colln. D1863 CO.

CC, Caesar Canyon Limestone of Kay and Crawford, from phosphatic limestone. East side of Caesar Canyon. Essentially the same locality as USGS colln. D1915 CO. Collectors H. B. Whittington and F. C. Shaw, 1965, in company of Ross and others.

GK, Caesar Canyon Limestone from talus slope on north side of Mill Canyon, near gate between two cliffs. This place called "Gatecliff" by Kay and Crawford, (1964, pl. 1). Approximate Nevada coord., central zone: E. 469,300 ft, N. 1,548,000 ft, Tonopah 2° quad., Nevada. Collectors Marshall Kay and others (Kay and Crawford, 1964, pl. 1).

MR, Copenhagen Formation: L, member B of Merriam; U, member C of Merriam. East side of Martin Ridge, S½SW¼ sec. 31, T. 16 N., R. 50 E., Horse Heaven Mountain quad., Nevada. Collectors H. B. Whittington and F. C. Shaw, 1965, in company of Ross and others.

SR, Copenhagen Formation, 3 miles north-northeast of Segura Ranch. Same locality as USGS colln. D1880 CO. A few specimens labeled SR(−30) from 30 ft stratigraphically below D1880 CO. SR-L from 100 ft below USGS colln. D1880 CO. Collectors H. B. Whittington and F. C. Shaw, 1965, in company of Ross and others.

DESCRIPTIONS OF TRILOBITES

Family OLENIDAE Burmeister, 1843
Subfamily TRIARTHRINAE Ulrich, 1930

Genus TRIARTHRUS Green, 1832

Porterfieldia Cooper. Whittard, 1961, Ordovician trilobites of the Shelve Inlier, West Shropshire: Palaeontographical Soc. (London), Pt. 5, p. 189.

Triarthrus sp.

Plate 1, figure 1

Figured specimen.—USNM 169601.

Occurrence.—USGS colln. D1880 CO, Copenhagen Formation, member C; USGS colln. D1914 CO and loc. GK, Caesar Canyon Limestone.

Discussion.—Four *Triarthrus*-like cranidia from USGS collns. D1880 CO and D1914 CO and from locality GK are present. The largest Caesar Canyon specimen (pl. 1, fig. 1) appears to show a nearly complete cephalic border on the right side. No trace of an eye or of a dorsal facial suture is present. A furrow extends from the anterolateral corner of the glabella across the fixed cheek posterolaterally to the border furrow. These characteristics suggest relationship with *Triarthrus caecigenus* Raymond (Cooper, B. N., 1953, p. 8–9, pl. 2, figs. 7–10; pl. 19, fig. 4). The present material is inadequate for detailed description.

Triarthrus caecigenus has been reported by B. N. Cooper (1953, p. 9) from strata in Alabama and Virginia that have been referred to the Porterfield Stage by G. A. Cooper (1956, chart 1). A very similar species has been described by Whittard (1960, p. 190–191) from the Lower Llanvirn Hope Shales in West Shropshire, England.

Family KOMASPIDIDAE Kobayashi, 1935

Genus CARRICKIA Tripp, 1965

Carrickia Tripp, 1965, Palaeontology, v. 8, pt. 4, p. 579–580.
Goniophrys Whittington, 1965, Harvard Univ. Mus. Comp. Zoology Bull., v. 132, no. 4, p. 371.

Carrickia? sp.

Plate 1, figure 2

Figured specimen.—USNM 169602.

Occurrence.—USGS colln. D1860 CO, Copenhagen Formation, equivalent of member B, Hot Creek Canyon.

Discussion.—Only a single, partial cranidium was obtained. This specimen possesses a very short (sag.) preglabellar field, a long (exsag.) palpebral lobe, and a short (sag.), rounded glabella. The length of the glabella excluding the occipital ring seems to be eight-tenths its width. In specimens assigned to *Goniophrys breviceps*? (Billings) by Whittington (1965, pl. 38, figs. 10, 12) this proportion is 73/100–77/100. In *Carrickia pelagia* Tripp (1965, pl. 81, fig. 17a) it is 74/100. The same proportion in *Carrickia setoni* Shaw (1968, pl. 4, fig. 29) is 75/100. In *Goniophrys prima* Ross (1951, pl. 18, figs. 17, 27), the oldest closely related species, the glabellar length to width ratio is 111/100. In specimen referred to *Carrickia* sp. (Ross, 1972, pl. 10, fig. 19) from USGS colln. D1994 CO, *Orthidiella* zone at Meiklejohn Peak, the same proportion is 78/100.

It is possible that *Goniophrys* is restricted to Early Ordovician strata and is distinguished by its narrow glabella. If so, *Carrickia* probably ranges from the *Orthidiella* zone into beds of Porterfield age. The only species of *Carrickia* for which a pygidium is known is *C. pelagia* Tripp (1965, pl. 81, figs. 21a, b). That pygidium closely resembles the pygidium of *Goniophrys prima* Ross (1951, pl. 18, figs. 19, 20, 22) in outline, convexity, and number of axial rings; it differs in the failure of the axial furrows to delineate the terminus of the axis confluently. The pygidium assigned by Shaw (1968, pl. 4, figs. 27, 33) to *Carrickia setoni* is so small that it must represent the immature stage of some trilobite. In the opinion of Ross, this is more likely to be a hystricurus-like form than a komaspidid; regardless, it has little in common with the pygidium of *C. pelagia.*

Family REMOPLEURIDIDAE Hawle and Corda, 1847
Genus HYPODICRANOTUS Whittington, 1952

Hypodicranotus n. sp.
Plate 1, figures 3–7

This species is represented by two hypostomes, one partial cranidium, one complete cephalon with partial hypostome, one pygidium, and one free cheek.

Cranidium much like that of *Hypodicranotus striatulus* (Walcott) (Whittington, 1952, pl. 1), but glabella somewhat narrower between back ends of eyes. Free cheeks have short lateral spines in addition to genal spines; lateral spines extend backward about same distance as genal spines and are not much bigger than genal spines.

Hypostome much like that of *H. striatulus* but has fewer longitudinal ridges on ventral surface of forked prongs (compare pl. 1, fig. 7 with Whittington, 1952, pl. 1, fig. 7).

Pygidium composed of articulating half-ring, single axial ring with backward swept pleural spines, and semielliptical terminal piece. Pleural spines directed straight backward, their tips overlapping front seven-tenths of terminal piece. Bertillon markings pronounced on terminal piece, transverse with convex side forward.

Dimensions of pygidium.—(USNM 169603a)
Length (sag.) : 3.4 mm
Width (trans.) : 4.0 mm
Width without pleural spines: 3.1 mm
Length (sag.) axial ring: 0.7 mm
Length (sag.) terminal piece: 2.2 mm
Width (trans.) terminal piece: 2.7 mm

Figured specimens.—USNM 169603a, b; 169604; 169605.

Occurrence.—Copenhagen Formation, member C of Merriam, USGS colln. D1873 CO, 272 ft above base of formation, USGS colln. D1874 CO, 277 ft above base of formation. SR(−30), 30 ft below D1880 CO, or approximately 130 ft below top of formation.

Discussion.—Although the material available is hardly adequate for the description of a new species, it clearly does not represent any species that has been previously described. The great difference in size of the lateral spines on the cephalon immediately distinguishes the Copenhagen species from *Hypodicranotus striatulus,* in which the lateral spines extend back about half the length of the thorax.

The lateral spines in *H. missouriensis* (Bradley, 1930, pl. 30, figs. 4, 6, 8) are stouter than in the species described here, but smaller than in *H. striatulus.* The hypostome has fewer surface ridges than in *H. striatulus* and in that respect may resemble a specimen described by Roy (1941, p. 155, fig. 114) from Baffin Land.

The pygidium is better preserved than any previously reported for the genus.

The stratigraphic significance of the genus has been noted by Whittington (1952, p. 3, 8), who considers it of Trenton age; he further comments that he has collected from the Viola Limestone of Oklahoma *Hypodicranotus, Cryptolithoides,* and *Robergia,* an association duplicated here. The free cheek described by Tripp (1965, p. 582–583, pl. 80, fig. 16) from the Albany Mudstone (Girvan District, Ayrshire, Scotland) possesses a short lateral spine similar to that of the Copenhagen species; it is the oldest known representative of the genus — that is, of Porterfield age. A hypostome of *Hypodicranotus* has also been reported by Tripp from the Stinchar Limestones of the Girvan District (1967, p. 48, pl. 1, fig. 24).

Genus ROBERGIA Wiman, 1905

Robergia occurs over a considerable stratigraphic range in the Ordovician, according to Lenz and Churkin (1966, fig. 3), from basal Llanvirn to Ashgill. Two species are pre-Caradoc. One of these species is *R. micropthalmus* (Linnarson) from the *Ogygiocaris* shales of Sweden (Whittington, 1950, p. 543–544, pl. 71, figs. 1–8) of Late Llandeilo age; it is the type species of the genus. The other is *R. schlotheimi* (Billings) from the Middle Table Head Formation of Newfoundland (Whittington, 1965, p. 375–377, pl. 40, figs. 9–12, and pl. 41). Both species are characterized by exsagittally long palpebral rims, the front ends of which extend in front of the distal ends of lateral glabellar furrows 3*p*. In both species, glabellar furrows 2*p* extend laterally well within the arc of the palpebral rims.

In later species the palpebral rims are shorter, and the glabellar furrows are excluded from the field bounded by the palpebral rim and a chord through its ends. These differences may seem trivial, but they have stratigraphic significance. Furthermore, *Robergia yukonensis,* believed by Lenz and Churkin to be the youngest representative of the genus, seems to possess a shallow sagittal furrow on the glabella (Lenz and Churkin, 1966, p. 41, pl. 4, and pl. 5, figs.

1, 2, 4, 5), a feature not found in any other species. Although this furrow has obviously been accentuated by crushing in some specimens, as noted by Churkin (in Lenz and Churkin, 1966, p. 41), nothing like it appears in the Nevada specimens.

The relative age of the Nevada and Yukon species is of considerable interest. Lenz and Churkin placed their association of *Robergia yukonensis*, *Cryptolithoides* sp., and *Ampyxina salmoni* in the Ashgill on the basis of associated graptolites. There is some question concerning this dating, simply because the association of *Robergia*, *Cryptolithoides*, and *Ampyxina* is of Trenton age everywhere else that it has been found. Recently Toghill (1970, p. 10), working with Ingham in southern Scotland, has shown that the Ashgill-Caradoc boundary probably lies within the zone of *Dicellograptus anceps*, higher than previously believed. This may result in reassignment of the trilobite association to the Caradoc, but it does not solve the problem of its age relative to occurrences of the same association in Nevada and Oklahoma.

Robergia deckeri B. N. Cooper

Plate 1, figures 16–21

Robergia deckeri B. N. Cooper, 1953, Geol. Soc. America Mem. 55, p. 23–24, pl. 2, figs. 1–6; pl. 19, figs. 1, 2.

Only cranidia and pygidia known. Cranidial width (trans. at palpebral lobes) about five-sixths cranidial length (sag.); length (sag.) of tongue about equal to length (sag.) of median area; maximum width of tongue four-fifths maximum width of median area. Glabellar furrow 3*p* opposite anterior end of palpebral rim, proximal end curving posteriorly parallel to furrow 1*p*; furrow 2*p* longer and more transverse than furrows 1*p* and 3*p*. Basal glabellar lobe is formed by occipital furrow and furrow 1*p*, is slightly trapezoidal in outline, and possesses independent convexity. Occipital ring with typical swelling on lateral flank and median tubercle on anterior slope.

Pygidium distinctive, having length (exsag. through longest marginal spine) only two-thirds of maximum width (trans. at anterior end). Overall outline of pygidium subrectangular. Width (trans.) of axis at anterior end three-elevenths of total pygidial width, axis tapering posteriorly to end at two-thirds total pygidial length (sag.); maximum number of axial rings counted equals four plus triangular terminal nub. Pleural field essentially flat, crossed by two interpleural ridges which rise from the first and second axial furrows respectively; anterior ridge forms proximal edge of outer pygidial spine, posterior ridge joins margin proximal to second pygidial spine. Second marginal spine longest on pygidium; inner spine short and unassociated with interpleural ridge. Pleural area anterior to first interpleural furrow nearly forming an equilateral triangle. Doublure wide and covered with terrace lines; other details not known. (See pl. 1, fig. 9.) Entire exoskeletal surface smooth. Two immature pygidia from locality D1880 CO are assigned to *R. deckeri* because of the relative abundance of this species at the locality.

Figured specimens.—USNM 169607a–c; 169608a–c.

Occurrence.—USGS colln. D1880 CO, Copenhagen Formation, upper 100 ft of formation, member C of Merriam. Caesar Canyon Limestone at Caesar Canyon, loc. CC; Caesar Canyon Limestone, loc. GK.

Discussion.—*Robergia deckeri* has been noted by Decker and Cooper from the basal Viola Limestone near Sulphur and near Bromide, Okla. Similar pygidia are reported (Cooper, 1953) from the upper part of the Edinburg Formation near Harrisonburg, Va. Present material consists of three pygidia from the Caesar Canyon Limestone at Caesar Canyon, three cranidia from the same locality, and two cranidia and two juvenile pygidia from USGS colln. D1880 CO. Several cranidia from the Caesar Canyon at "Gatecliff" resemble this species but occur with pygidia evidently belonging to *R. major*, so they are assigned to that species.

The Nevada specimens are indistinguishable from those figured by Cooper (1953) from the Viola. The nonparallel nature of the 2*p* glabellar furrow and the short, broad pygidium with prominent interpleural ridges are the principal distinctive features of this species. Were it not for differences in the course of the 2*p* furrow, cranidia of *Robergia* would be notoriously difficult to separate. An instance of this confusion is given above and in the following discussion of *R. major*.

Robergia major Raymond, 1920

Plate 1, figures 8–15

Robergia major Raymond, 1925, Harvard Coll. Mus. Comp. Zoology Bull., v. 67, no. 1, p. 60–61, pl. 3, figs. 6–10.

Robergia major Raymond. Cooper, B. N., 1953, Geol. Soc. America Mem. 55, p. 22–23, pl. 8, figs. 7–11.

Robergia major Raymond. Whittington, 1959, Harvard Coll. Mus. Comp. Zoology Bull., v. 121, no. 8, p. 428–431, pl. 18, figs. 1–22, 25.

Cranidial features basically as in other species of *Robergia*. Three pairs lateral glabellar furrows parallel, particularly at their proximal ends; pair 2*p* the longest. Pairs 1*p* and 3*p* almost same length; but 3*p* tends to be slightly shorter. Palpebral rims extend as far forward as distal ends of glabellar furrows 3*p*. Free cheeks and thorax not found.

Pygidium subrectangular in outline. Maximum exsagittal length equal to or slightly greater than width. Axis composed of six rings and terminal piece. Axial length ¾–⅚ sagittal length of pygidium. Pleural field narrow (trans.), crossed by interpleural ridges trending nearly straight posteriorly at their distal ends.

Figured specimens.—USNM 169606; AMNH 29106–112 incl.

Occurrence.—Loc. GK ("Gatecliff"), Caesar Canyon Limestone of Kay and Crawford (1964). From talus slope on north side of Mill Canyon, Toquima Range. All specimens collected by Marshall Kay and associates. USGS colln. D1914 CO, Caesar Canyon Limestone of Kay and Crawford, about 50 ft below top of shaly unit, east side of Caesar Canyon.

Discussion.—Of the specimens described here, three cranidia and four pygidia came from the Caesar Canyon Limestone in Mill Canyon, about 20 yards east of the "Gatecliff" (Kay and Crawford, 1964, pl. 1). The pygidia, each with an axis composed of six rings plus terminal piece, indicate a close relationship with *Robergia major* Raymond as described and illustrated by Raymond (1925, p. 60–61, pl. 3, fig. 8). According to Whittington's (1959, p. 429) description of *R. major,* only five axial rings may be distinguished; Cooper (1953, p. 23) on the other hand stated that the pygidial axis was composed of "7 or 8 segments." The pygidium of *R. schlotheimi* (Billings) (Whittington, 1965, p. 376, pl. 41, figs. 9, 10) has a much shorter axis but is similar in outline. In *R. yukonensis* Lenz and Churkin the pygidium possesses an axis of five rings and an outline that is basically semicircular.

The present cranidia not only resemble those of *Robergia major* Raymond as described and illustrated by Cooper (1953, p. 23, pl. 8, figs. 8, 10, 11) and Whittington (1959, p. 429, pl. 18, figs. 3, 4, 5) but also those of *Robergia schlotheimi* (Billings) (Whittington, 1965, pl. 41, figs. 5, 8). In *R. yukonensis,* glabellar furrows tend to be parallel, as they are in *R. major* and *R. schlotheimi,* but all three are about equal in length.

As noted under the discussion of *R. deckeri,* cranidia in different species of *Robergia* are nearly impossible to differentiate. A single cranidium of the *R. deckeri* type occurs at "Gatecliff" associated with cranidia assigned to *R. major.* Possibly these two species could be considered sexual dimorphs differing only in the width of pygidia, but the present material is inadequate to solve the problem.

R. major occurs somewhat lower than *R. deckeri* in the Appalachian section. This may also be the case in Nevada, as the material from Caesar Canyon is from the uppermost part of the formation of the same name, except for one pygidium.

Genus REMOPLEURIDES Portlock, 1843

Remopleurides sp. 1

Plate 1, figure 23

A single cranidium is the basis for this description. Cranidial length (sag.) equal to width (max. trans. across palpebral lobes); tongue width two-thirds width of median area. Palpebral rim length (exsag.) two-thirds total cranidial length (sag.). Occipital ring length (sag.) about one-sixth total cranidial length (sag.). Entire cranidial surface covered with fine granules.

Figured specimen.—USNM 169609.

Occurrence.—Float from member B of Copenhagen Formation; near USGS colln. D1880 CO.

Discussion.—Because this specimen has a relatively narrow (trans.) tongue, it probably does not belong to *Hypodicranotus.*

Remopleurides sp. 2

Plate 1, figures 22, 24, 25

This description is based on a single complete cephalon. Greatest width (trans.) of cranidium located opposite cranidial midlength; width (trans.) slightly greater than length (sag.) of cranidium. Convexity of glabella in lateral view strong; in anterior view, moderate. Anterior tongue of glabella markedly convex in transverse profile, so that glabella protrudes well ahead of front ends of eyes. Width of glabella (trans.) between eye lobes 1.15 times its length (sag.) exclusive of occipital ring, 1.6 times its width at anterior tongue, and 1.5 times width (trans.) of occipital ring. Arc of palpebral rims evenly curved. Glabellar furrows $1p$ and $2p$ indicated by smooth lines in otherwise granular surface. Genal spines short, based toward rear of free cheeks.

Figured specimen.—USNM 169610.

Occurrence.—USGS colln. D1860 CO, Copenhagen Formation, 21–23 ft below base of Eureka Quartzite, Hot Creek Canyon, Nev.

Discussion.—Outline of cranidium and lateral convexity are not unlike those of *Remopleurides simulus* Whittington, but the anterior tongue is more narrowly convex. The free cheeks have genal spines based like those of *R. eximius* Whittington and lack the anterior spine of *R. simulus.*

Genus ROBERGIELLA Whittington, 1959

Robergiella sp.

Plate 2, figures 1, 2

Only cranidia known. Length (sag.) equal to total width (maximum at palpebral rim). Median area broad, length (sag.) to width (trans.) ratio three-fifths. Three pairs of glabellar furrows well developed on median glabellar area. Anterior pair of furrows, 3*p*, shallowest and at anterior edge of median area; others evenly spaced with respect to each other and occipital furrow. Furrows 1*p* curved and strongly convex. Palpebral rim broad; width (trans.) of each rim about one-tenth total maximum cranidial width. Tongue at maximum width (trans.) nearly as broad as median area; length (sag.) about one-third total cranidial length. Fossula present in axial furrow just anterior to maximum width of tongue. Preglabellar area and anterior area of fixed cheek very narrow and uniform in width. Occipital ring length (sag.) less than half of width (trans.); one enlarged median tubercle present on anterior slope of ring. Entire surface of cranidium (except furrows and palpebral rim) covered with small tubercles.

Figured specimens.—USNM 169611, 169612.

Occurrence.—USGS colln. D1880 CO, Copenhagen Formation, upper 100 ft, member C of Merriam, east side of Antelope Valley. Collection CC, Caesar Canyon Limestone of Kay and Crawford, top of type section in Caesar Canyon, Toquima Range.

Discussion.—Two cranidia were obtained from member C of the Copenhagen and three from the highest strata of the Caesar Canyon Limestone. This appears to be the first record of *Robergiella* in the Ordovician of the Great Basin. Absence of parts other than the cranidium prevents specific assignment; but on the basis of the general size and character of the glabellar furrows, these forms closely resemble *R. sagittalis* Whittington from the Edinburg Formation (of Cooper and Cooper, 1946) of Virginia. The Nevada material differs in having a granulate or tuberculate surface ornament.

Family ASAPHIDAE Burmeister, 1843

Genus ISOTELUS Dekay, 1824

Isotelid fragments are known from member B and from the lower and middle parts of member C of the Copenhagen Formation at a number of localities. Most of the material appears assignable to a single species and is described below as such. Generic assignment is more difficult, because this species possesses characteristics intermediate between those of at least *Isotelus* and *Isoteloides* and perhaps other genera as well. A qualitative comparison of these genera is given in table 1.

Jaanusson (1953; 1959, in Moore, p. O339–O350) and Whittington (1965) have discussed the classification of isotelid genera at length. Nearly every exoskeletal detail has been utilized for systematic subdivision of the group. Nevertheless, as Whittington (1965) and Shaw (1968) have noted, discrimination of the genera involved is difficult at best.

Isotelus copenhagenensis n. sp.

Plate 2, figures 3–11; plate 3, figures 1–3; text figure 2

Cephalon probably subtriangular in outline; length (sag.) estimated to be one-half width (trans.) across genal angles. "Glabella" low and indistinct; occupies posterior 0.80 length (sag.) of cranidium. Estimated width (trans.) of glabella at posterior margin about 0.32 total cephalic width (trans.) across genal angles. Preglabellar field a broad (trans. and sag.) flat area without well-defined border. Glabella narrows between eye lobes, so that width is 0.50 glabellar length. Anterior width (trans.) of glabella exceeds 0.75 glabellar length (sag.), but width (trans.) at posterior cephalic border is less than 0.75 glabellar length (sag.). Anterior of glabella bluntly (135°–140°) pointed.

Eyes positioned entirely behind transverse line through glabellar midpoint.

Eye lobes erect, nearly one-half of total height of each free cheek in lateral view (pl. 3, fig. 2), and short (exsag.); located three-tenths sagittal cranidial length from posterior cephalic margin. Width (trans.) of cranidium at palpebral lobes 0.80–0.85 cranidial length (sag.). Posterior part of each fixed cheek slightly wider (trans.) than posterior width of glabella, crossed by shallow posterior border furrow. Anterior branch of facial suture diverging only

TABLE 1. — *Characteristics of isoteloid genera, based on type species*

	Posterior cephalic border furrow	Axis	Hypostome	Cephalic border	Eye location	Pygidium doublure	Pygidium border
Isoteloides	Fixed cheek.	Narrow	Rounded	Well defined, flat.	Mid-length	?	Flat.
Isotelus	None	Broad	Parallel sided.	Poorly defined, flat.	Posterior	Simple V	Almost absent.
Nevada sp.	Fixed cheek.	Intermediate.	do	do	do	do	Do.
Megalaspides	None	Narrow	Distinctive	Well defined, flat.	About mid-length.	Similar to above.	Do.
Lannacus	Like *Megalaspides* but approaching *Isoteloides*-type pygidium.					?	Flat.
Stegnopsis	Fixed cheek and occipital ring.	Narrow	Distinctive	Well defined, flat.	Posterior	Similar to Nevada species.	Do.

slightly anterolaterally, so that sides of cranidium are nearly parallel, sutures joining anteriorly at angle of 100°–110°. Free cheek with rounded genal angle; no border furrow or flattened borderlike area present except where adjacent to flat preglabellar field. Surface ornament of fine pits. Posterior notch of hypostome occupying one-half of total sagittal length; anterior part of notch nearly round, posterior margins of notch diverging at about 20°–25°. Terrace lines present parallel to margin on hypostome surface.

At least eight segments present; axial width (trans.) about one-third total segment width. Pleural furrow well incised almost to axial furrow.

Pygidial outline subtriangular; length (sag.) 0.70 to 0.8 maximum anterior width (trans.). Axis raised

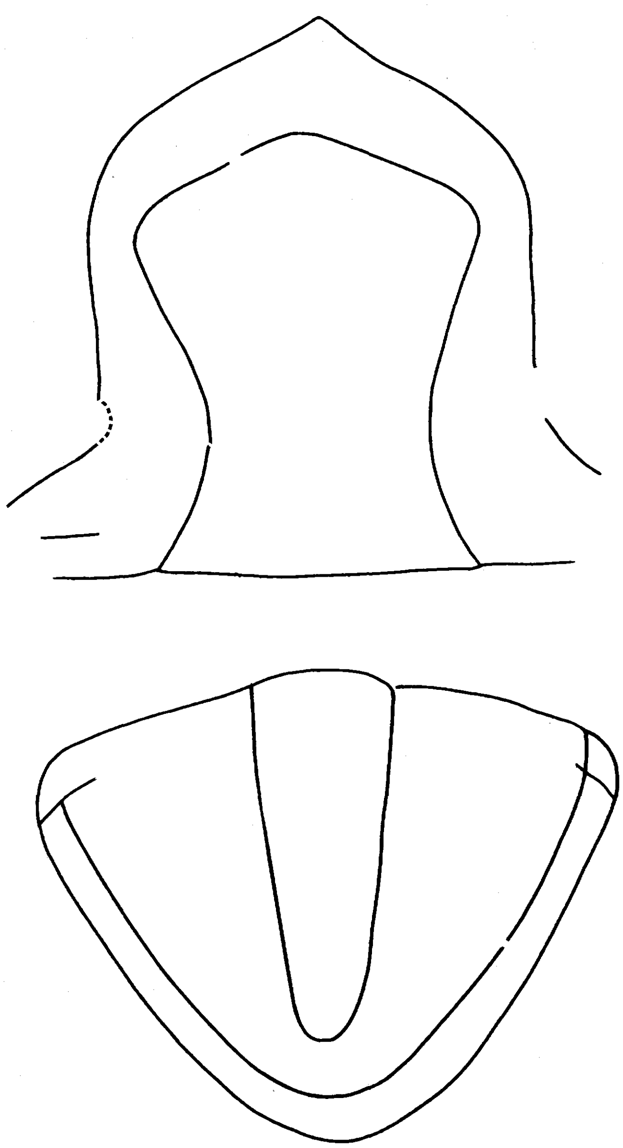

FIGURE 2. — Outline sketches of cranidium and pygidium of *Isotelus copenhagenensis* based on plate 2, figures 4, 7.

above pleural field; width (trans.) at anterior end 0.25 to 0.30 total pygidial width, tapering posteriorly, ending in blunt point; axial length (sag.) 0.75–0.80 pygidial length (sag.). Slight segmentation on axis on some immature specimens. Pleural field smooth, very slightly flattened along posterior margin. Doublure of uniform width, occupying distal one-fourth of pygidium, carrying typical asaphid ventral bulge, proximal edge a simple rounded "V" posterior to axis (pl. 2, fig. 6).

Holotype.—USNM 169614.

Paratypes.—USNM 169613; 169615a, b; 169616a, b, c, d; 169617; 169618a, b; 169619; 169620.

Occurrence.—Copenhagen Formation, USGS colln. D249c CO, float, member C; D286 CO, member C; D1870 CO, member B; D1872 CO, float; D1874 CO, member C; D1878 CO, member C; D1905 CO, member B, Clear Creek Canyon. Caesar Canyon Limestone, USGS colln. D1914 CO, shaly unit.

Discussion.—This species differs from others of *Isotelus* (table 1) only in the possession of a border furrow along the posterior of the cephalon on either side of the glabella, and in this single regard it resembles *Isoteloides.*

Isotelus copenhagenensis differs from *I. gigas* Hall, as described by Ross (1967b, p. B3, B5; text fig. 3; pl. 1, figs. 1–11; pl. 2, figs. 1–4), in having less divergent anterior facial sutures, a better defined glabella and posterior cephalic border furrow, a narrower indentation of the hypostome, and a somewhat narrower pygidial axis. The outline of the cephalon and pygidium seems to be about the same, as are features of the pygidial doublure.

I. copenhagenensis differs markedly from *I. harrisi* Raymond (Shaw, 1968, p. 57–58; pl. 21, figs. 13–16; pl. 22, figs. 1–9) in having a different course of the anterior facial suture, poorer development of maculae on the hypostome, a narrower posterior indentation, a more triangular outline of the pygidium, and more prominently erect eyes. Eyes are farther apart than in Raymond's species.

Genus ANATAPHRUS Whittington, 1954

Anataphrus Whittington, 1954, Geol. Soc. America Mem. 62, p. 141.

Homotelus Raymond. Esker, 1964, Oklahoma Geol. Notes, v. 24, no. 9, p. 195–209.

Isotelus Dekay. Ross, 1967, U.S. Geol. Survey Prof. Paper 523–D, p. D12.

Isotelus Dekay. Ross, 1970, U.S. Geol. Survey Prof. Paper 639, p. 78.

Whittington (1954, p. 141) erected *Anataphrus* for forms possessing no visible axial furrows, low eyes, and a narrow ventrally directed rim on the cephalic border. Here we include in *Anataphrus*

Whittington several highly convex asaphids with narrow nonconcave borders. Some of these have very faint, incomplete axial furrows.

Anataphrus seems to range from the Porterfield to the Barneveld Stage of Fisher (1962). The type species, *A. borraeus* Whittington, from Baffin Island, may be younger but is probably of Barneveld age. *A. bromidensis* Esker from the Pooleville Member of Cooper (1956) in the Bromide Formation in Oklahoma is of Wilderness age, as is the new species *A. martinensis* from the Copenhagen Formation. *A. martinensis* may also be represented in the type section of the Hanson Creek Formation. *Anataphrus vigilans* Meek and Worthen and *A. gigas* Raymond from the Maquoketa Shale are probably of Maysville age. Probably the oldest species recorded is *A. spurius* (Phleger) from the Barrel Spring Formation of the northern Inyo Mountains, Calif.; *A. spurius* is also recorded from the lower part of the Eureka Quartzite and uppermost Antelope Valley Limestone in the Ranger Mountains (Ross, 1967a, p. D12, pl. 4, figs. 6–9; 1970, p. 78, pl. 13, figs. 3, 5, 7, 10). These last occurrences are probably of Porterfield age but could be somewhat older.

Raymond (1920, 1925) proposed *Homotelus* to include several similar forms. *Homotelus* Raymond, as pointed out by Whittington (1950, p. 552), is based on a type species with relatively prominent concave cephalic and pygidial borders and thus does not fulfill the original concept of the genus; Raymond, himself (1920, p. 286), did not consider it "a good genus" for that reason.

Esker (1964) retained the use of *Homotelus* for isoteloid trilobites displaying two pairs of glabellar furrows and differentiated species within the genus on the basis of furrow position. Because furrows or corresponding pits are very difficult to see on most such specimens, it seems more practical to return to use of characteristics of the border originally used by Raymond (1920, p. 286) and elaborated further by Whittington. We would follow Whittington (1950, p. 552) in restricting *Homotelus* to the type species, *H. ulrichi,* and reassign *H. bromidensis* Esker to *Anataphrus* as suggested by Ross (1970, p. 78). Specimens of *A. bromidensis* (Esker) collected by Shaw in the Criner Hills, Okla., display barely distinguishable glabellar furrows — including one set opposite the midpoint of the eye lobe — counter to Esker's original description. As the trilobite cephalon probably bore as many as six pairs of appendages, and because the attachment points on some specimens are very poorly defined (Whittington, 1950, fig. 5), variable development of glabellar furrows in asaphids appears to have been common, even within a species.

Whittington (1954, p. 141) objected to the use of *Vogdesia* for these relatively featureless forms because the type species, *V. bearsi,* from the Chazy Group of New York, possessed eye stalks, broad shallow axial furrows, and a concave border on the pygidium, and it supposedly lacked a border on the free cheek. Shaw (1968, p. 59–60) discussed *V. bearsi,* noting that a pygidium with a concave border had been incorrectly assigned to the species by Raymond. The characteristics of the eye, degree of development of the cranidial axial furrows, and details of the border of the free cheek thus remain the only characteristics separating *Vogdesia* from this group of smooth convex asaphids.

In Shaw's opinion, these characteristics are obviously gradational with those of such species as *Vogdesia? obtusus* (Hall) from the Chazy Group of New York (Shaw, 1968). Shaw believes that *Nileoides perkinsi* (Raymond) (Shaw, 1968, p. 59, pl. 19, figs. 8–11) represents the ultimate in this trend towards a smooth exoskeleton. Thus, Shaw chose to restrict *Vogdesia* to species lacking an obvious narrow border — that is, the Chazy Group species *V. bearsi* (Raymond) and *V.? obtusus* (Hall) (Shaw, 1968, p. 59–62) — and to restrict *Nileoides* to extremely smooth forms.

In the opinion of Ross, *Vogdesia* differs from *Anataphrus* in having larger palpebral lobes and in better definition of the pygidial axis in decorticated specimens.

Anataphrus martinensis n. sp.
Plate 3, figures 4–16

Dorsal exoskeletal outline suboval; cephalon wider (trans. at genal angle) than pygidium by ratio of about four-thirds. Cephalon broadly semicircular in dorsal view, extreme border coarsely and concentrically striated along ventral edge; cephalic length (sag.) slightly over one-third of maximum width (trans.). Cranidium narrow (trans.), width at palpebral lobes three-halfs cranidial length (sag.); small median tubercle present just anterior to posterior margin; "axial furrow" present as shallow trough circling proximal base of eye lobe. Sagittal cephalic profile increases in convexity anterior to eye lobe. Palpebral lobe minute, located opposite cranidial midlength (sag., dorsal view). Anteriorly facial sutures diverge, curving distally to width equal to width of palpebral lobe, then recurve sharply to join cephalic margin at sagittal line; posteriorly, sutures run nearly straight posterolaterally, distal segment arcing to posterior cephalic border so that posterior cranidial width (trans.) is 1.6 width at palpebral lobes. Eye lobe stands above cephalon in lateral profile; visual surface extends almost completely around lobe, so that some facets are directed proximally; visual surface separated from rest of free cheek by shallow furrow which joins "axial furrow" on proximal side of eye lobe. Distal part of free cheek evenly convex, dropping steeply to margin; narrow rim constituting only border; genal angle broadly rounded.

Hypostome not known. Cranidial doublure folded under cranidium; rear edge cut away at hypostomal suture, which shows that anterior width (trans.) of hypostome 1.6–1.7 sagittal width of doublure. Sagittal width of doublure equals width (trans.) of cranidium between elevated palpebral lobes.

Number of thoracic segments eight; length of segment (sag.) about one-twelth width (trans.), tapering distally; articulating half-ring short (sag.), ring furrow broad (sag.) and shallow. Axial furrow absent on exterior surface of thorax, its theoretical position indicated on internal mold at about three-fourths distance (trans.) from sagittal line to pleural tips by axial processes and sockets.

Pygidial outline rounded subtriangular, length (sag.) three-fourths maximum width (trans.); dorsal exterior surface without trace of axis, smoothly convex in lateral and posterior view, lacking border or marginal rim. Doublure slightly concave dorsally, wide (sag.), extending under distal one-third of pygidium; outline of proximal margin broadly V-shaped in dorsal view.

Holotype.—USNM 169623.

Paratypes.—USNM 169621; 169622; 169624a, b.

Occurrence.—USGS colln. D1872 CO, Copenhagen Formation. Thirty feet below USGS colln. D1880 CO, Copenhagen Formation. MR-U, upper member (member C of Merriam) Copenhagen Formation, Martin Ridge. USGS colln. D1912 CO, upper 50 ft of Copenhagen Formation.

Discussion.—Whittington (1954, p. 141–142) has discussed many of the species of *Anataphrus* present in the Middle and Upper Ordovician of North America. The characteristic serving to distinguish *A. martinensis* n. sp. from these species and from *A. bromidensis* (Esker) is the high eye lobe with a visual surface nearly encircling the lobe. Probably the closest species to *A. martinensis* n. sp. is *A. vigilans* Meek and Worthen, 1870, from the Maquoketa Shale in Illinois. *A. spurius* (Phleger) (Ross, 1967a, p. D12) also possesses a smaller eye than *A. martinensis.* Additional collecting may provide some overlap between these two species.

Family NILEIDAE Angelin 1854
Genus NILEUS Dalman, 1827

Nileus? sp.
Plate 4, figure 1

A single partial cranidium may be assignable to *Nileus,* but in the absence of free cheeks, in particular, the assignment is questionable. In the absence of free cheeks and pygidium, a comparison at the species level is impossible. The cranidium is illustrated as a matter of record.

Figured specimen.—USNM 169625.

Occurrence.—Loc. SR-L, Copenhagen Formation.

Family ILLAENIDAE Hawle and Corda, 1847
Illaenid genus, indeterminate

Two illaenid cranidia are included in collection MR-U. One of these is very large but badly damaged. The other is small and fairly well preserved but is lacking one palpebral lobe. A pygidium thought at first to belong to one of these has proved to be assignable to *Anataphrus.* Possibly the two cranidia belong to the same species and represent different growth stages. Poor preservation of the larger specimen prohibits complete comparison with the smaller. Therefore the two are described separately.

Illaenid sp. 1
Plate 4, figures 2, 3

Cranidium decorticated, broken diagonally so that left, middle, and some of right posterior parts missing. Right palpebral lobe preserved. Right posterior fixed cheek crumpled beneath palpebral lobe. Anterior end of right axial furrow present, but none of left furrow preserved. Furrows seem to have been S-shaped and certainly were confined to posterior half of cranidium. Therefore, back of glabella missing, and any estimate of convexity largely conjectural. Right facial suture seems to run forward and downward straight for about 10 mm before curving evenly inward. Most of front of cranidium broken and frayed so that anterior configuration can be only crudely estimated. Circumferential sagittal length estimated at 60 mm.

This specimen shows some similarities to *Nanillaenus.*

Figured specimen.—USNM 169626.

Occurrence.—Collection MR-U, Copenhagen Formation, member C.

Illaenid sp. 2
Plate 4, figures 4, 5

Small cranidium about 5.5 mm in sagittal circumferential length. Greatest width (trans.) estimated 7.0 mm. Right palpebral lobe missing; width (trans.)

in front of palpebral lobes 5.7 mm. Width of glabella at posterior margin 3.0 mm. Axial furrows converge for exsagittal distance of 1.5 mm so that glabella is 2.0 mm wide; then axial furrows diverge and fade out about 2.5 mm from posterior margin.

As seen with glabella approximately horizontal, transverse convexity very slight. Sagittal convexity strong from back to defined front of glabella, decreasing only slightly toward front of cranidium. However, when glabella is approximately horizontal, front of cranidium slopes downward and backward so that anterior margin lies beneath glabella.

Exsagittal length (diameter) of palpebral lobe about 1.0 mm. Facial suture runs straight forward and downward about 1.5 mm before curving inward to margin. No distinct border on cranidium, but three or four coarse terrace lines spaced 0.25 mm apart roughly parallel margin.

Figured specimen.—USNM 169627.

Occurrence.—Collection MR-U, Copenhagen Formation, member C.

Discussion.—In the absence of any knowledge of the pygidium, this specimen would be extremely difficult to differentiate from many that are assigned to *Illaenus*. The glabella is narrow (trans.) for *Bumastoides,* and axial furrows are better developed than Whittington's (1954, p. 139) concept of that subgenus permits. Convexity of cranidium in lateral view is much like that of specimens of *Illaenus auriculatus* (Ross, 1967a, pl. 5, figs. 2, 4, 10) and other species.

Family DIMEROPYGIDAE Hupé, 1953
Genus TOERNQUISTIA Reed, 1896
Toernquistia? idahoensis Churkin

Plate 4, figures 6–9

Toernquistia idahoensis Churkin, 1963, Jour. Paleontology, v. 37, no. 2, p. 426–427, pl. 51, figs. 15–21.

Figured specimens.—USNM 169628; AMNH 29113–29115.

Occurrence.—Caesar Canyon Limestone, loc. GK and USGS colln. D1914 CO.

Discussion.—Churkin (1963, p. 427) noted that this species might be assigned to *Chomatopyge* Whittington and Evitt, rather than to *Toernquistia,* but the tapering glabellar outline and shallow furrows separating fixed cheeks from preglabellar field are typical of *Toernquistia.* Reed (1904, p. 86–87, pl. 12, figs. 3–7) described from the Balclatchie beds of Ayrshire, Scotland, three cranidia that he assigned to *Toernquistia* cf. *T. nicholsoni.* The Scottish specimens seem to have short (exsag.) palpebral lobes, shorter than those of *T. nicholsoni* from the Kiesley Limestone of England, of Churkin's Idaho specimens, or of ours from Nevada.

Family HARPIDAE Hawle and Corda, 1847
Harpid genus, indeterminate

Plate 4, figure 10

Figured specimen.—USNM 169629.

Occurrence.—USGS colln. D249a CO, Copenhagen Formation, member C.

Discussion.—This specimen is figured as a matter of record. The relatively wide (trans.) brim and small disordered pits present are typical of both *Hibbertia* Jones and Woodward and *Paraharpes* Whittington.

Family TRINUCLEIDAE Hawle and Corda, 1847
Subfamily CRYPTOLITHINAE Angelin, 1854
Genus CRYPTOLITHOIDES Whittington, 1941

Since Whittington's original description, little additional material of *Cryptolithoides* has been discussed. Some emendations of the generic description are proposed here. Originally, the distinctive generic features were given as: Absence of reticulate ornament on cephalon, expanded anterolateral corners of fringe, fringe pits with rows E1 and I1 concentric and partly radially arranged, pits I2–I4 (I5 present anteriorly in some specimens) radially arranged anterior to glabella; pits of I2–I4 positions randomly scattered posterolaterally to glabella. *Cryptolithus fittsi* Ulrich and Whittington (in Whittington, 1941) was excluded because it lacked prominent anterolateral extensions of the fringe and had reticulate ornament on the glabella and cheeks.

Reticulate ornament is probably a subsidiary characteristic for defining any trilobite genus, and much of the Nevada material possesses most of the above characteristics of *Cryptolithoides* as well as such ornament. The Nevada specimens (and, in fact, the original material of *Cryptolithus fittsi*) show numerous gradations between expanded anterolateral fringe margins and *Cryptolithus*-like fringe margins. To differentiate consistently between *Cryptolithus* and *Cryptolithoides,* one is thus brought to details of the fringe. The adventitious pits and disordered arrangement of pits proximal to E1 and I1 are the main bases for distinguishing the two genera and are used here.

In distinguishing between *Cryptolithus* and *Cryptolithoides,* primary emphasis is placed on interruptions in the radial arrangement of pits in the anterior part of the fringe. If obvious connections along radial lines are made in tracings of various cryptolithinids (fig. 3), the forms from Oklahoma and Nevada have far greater disorder than eastern representatives of *Cryptolithus* sensu stricto. The following forms thus are placed in *Cryptolithoides*: *C. carinatus* Whittington 1941; *C. convexus* Whittington 1941; *C. fittsi*

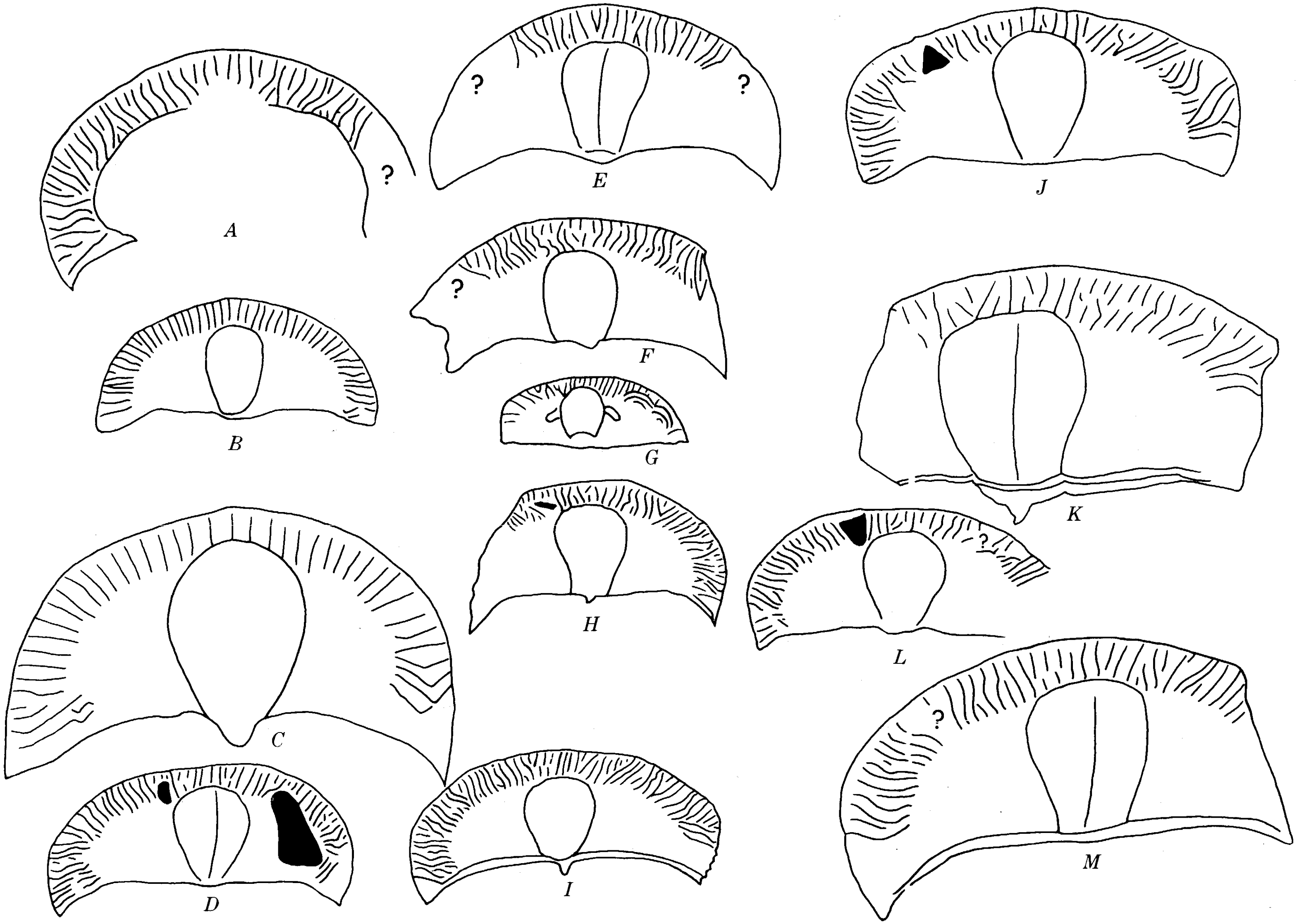

FIGURE 3. — Line tracings of cryptolithinid genera and species from North America. Arrangement of radial pit rows emphasized to contrast the genera *Cryptolithoides* and *Cryptolithus*. *A*, *Cryptolithoides* sp.; lower part of Viola Limestone; west of Highway 77, about 15 miles north of Ardmore, Okla. × 2.5. *B*, *Cryptolithus lorrettensis*; Montmorency Falls, Quebec (after Whittington, 1968). × 11.3. *C*, *Cryptolithus tesselatus*; Tribes Hill, N.Y. (after Whittington, 1968). × 4.5. *D*, *Cryptolithoides reticulatus* n. sp.; upper member of Copenhagen Formation, USGS colln. D1880 CO. × 2.5. *E*, *Cryptolithoides* sp. Same as *A*. × 5.6. *F*, Same as *D*. × 5.6. *G*, Same as *D*. × 6.8. *H*, Same as *D*. × 2.5. *I*, Same as *D*. × 2.5. *J*, *Cryptolithoides reticulatus* n. sp.; loc. 7106, × 2.5. *K*, *Cryptolithoides reticulatus* n. sp.; USGS colln. D1880 CO, × 5.6. *L*, *Cryptolithoides reticulatus* n. sp.; USGS colln. D1880 CO, × 2.5. *M*, *Cryptolithoides reticulatus* n. sp.; USGS colln. D1880 CO, × 5.6.

Ulrich and Whittington, 1941; *C. ulrichi* Whittington; *C. reticulatus* n. sp. The first four of these have all been reported from Oklahoma.

The first three of this group retain cephalic outlines similar to those of *Cryptolithus* and may well represent transitional forms between eastern species of *Cryptolithus* and members of *Cryptolithoides* with angulate margins and more pronounced pit disorders. Shaw has in progress a detailed stratigraphic study of Oklahoma cryptolithinids to clarify these relationships.

Cryptolithoides as here defined is known only from the central and Western United States, probably from British Columbia (B. S. Norford, oral commun., 1965) and from Yukon (Lenz and Churkin, 1966). *Cryptolithus* reportedly occurs with *Cryptolithoides* in the Viola Limestone of Oklahoma (Whittington, 1941); however, this report is based on only three cephala (Whittington, 1941, p. 37, pl. 6, fig. 15). *Cryptolithus,* to which *Cryptolithoides* obviously is closely related and from which it perhaps was derived, is common in rocks of Barneveld age of eastern North America (Whittington, 1968). The upper part of the Viola, member C of the Copenhagen, and Caesar Canyon Formations are probably Barneveld in age.

Cryptolithoides fittsi (Ulrich and Whittington), 1941

Plate 5, figures 18, 20, 21, 23

Cryptolithus fittsi Ulrich and Whittington. Whittington, 1941, Jour. Paleontology, v. 15, no. 1, p. 36–37, pl. 5, figs. 3, 5, 6, 10–12, 16, 20, 24.

Two cranidia, one from member C of the Copenhagen Formation northeast of Segura Ranch (USGS colln. D1880 CO) and one from the Caesar Canyon Limestone at Caesar Canyon, probably assignable to this species. Cephalic outline semicircular, ratio of length (sag.) to width (max. trans.) about two-fifths, glabellar outline expanding evenly anteriorly, maximum width (trans.) about five-sixths length; glabella slightly carinate, small median tubercle present. Occiput occupying posterior two-fifths of glabella, anterior end defined by 2*p* glabellar furrow; 1*p* furrow with small pit; occipital pit also present. Occipital ring not preserved. Cheek inflated, width (trans. opposite anterior end of occiput) equal to length (exsag.) along axial furrow. No eye ridge or eye lobe present. Anterior pit well developed. Surface of cheek and median area of glabella covered with reticulate raised lines. Arrangement of pits in fringe variable. One specimen from USGS colln. D1880 CO (pl. 5, fig. 21) shows only E1, I1, and I2, developed anterior to glabella with fair concentric and radial symmetry. At R5 an additional row is intercalated; this is maintained to about R17, where nearly complete disorder occurs in pit arrangement. E1 total 28 pits (one side). Distinctive feature of this specimen is presence of only three concentric rows of pits on anterior part of fringe. Specimen from Caesar Canyon has four well-developed concentric rows anterior to glabella and approximately same pit pattern as described above lateral to this. Whether this indicates a different species or intra-specific variation cannot be told from few specimens available.

Figured specimens.—USNM 169634, 169635.

Occurrence.—USGS colln. D1880 CO, Copenhagen Formation, top 100 ft; loc. CC, Caesar Canyon Limestone. This species previously reported by Whittington (1941, p. 37) from the Viola Limestone of Oklahoma and Pete Hanson Creek, Roberts Mountains, Nev. (Hanson Creek Formation).

Discussion.—The assignment of this species to *Cryptolithoides* has been discussed above. *C. fittsi* differs from *C. reticulatus* n. sp. in having a more semicircular cranidial outline, longer (exsag.) cheek areas, and fewer rows of pits anterior to the glabella and in row E1. Differences from Oklahoma species such as *C. carinatus* Whittington and *C. convexus* Whittington are less well defined, being chiefly the larger number of pits in row E1 of *C. fittsi.*

Cryptolithoides reticulatus n. sp.

Plate 4, figures 11–19; plate 5, figures 1–17, 19

This description is based on the following specimens: 18 cranidia from USGS colln. D1880 CO and four from Caesar Canyon (loc. CC), three pygidia from collection D1880 CO and five from Caesar Canyon (loc. CC), and partial specimens from these collections and USGS collns. D1901 CO and D1914 CO.

Cephalic outline nearly semicircular, length (sag.) slightly less than one-third width (max. trans. at anterolateral margin); anterolateral margin laterally expanded as in *C. ulrichi* Whittington. Glabella slightly carinate, expanding evenly anteriorly; median tubercle present at one-half length (sag.); maximum width (trans.) of glabella just posterior to anterior pits and equal to about one-fourth total cephalic width (trans.) at this point. Occiput not clearly defined; only one glabellar furrow clearly observed, and this accomplishes typical posterior constriction of glabella at posterior end; well-developed pit developed on lateral slope of this posterior bulge. Occipital ring very short (sag.), median part broken on all specimens. Cheeks more triangular in outline than in *C. fittsi,* width (trans. at widest point) slightly greater than length (exsag. along axial furrow); surface of cheek covered with reticulate ornament but (in larger holaspids) does not show eye ridges or eye lobes (pl. 5, fig. 4).

Pits E1 and I1 concentrically and radially arranged; E1 pits separated by prominent radial ridges average about 30 (one side). Four to five concentric rows of pits present anterior to glabella in all specimens; radial arrangement holding laterally to about E7 in larger individuals, farther around fringe in smaller specimens. Adventitious pits irregularly present even in front of glabella in some specimens. Vestiges of radial arrangement preserved as far as E20 in some specimens; these rows may have as many as eight pits; concentric and radial arrangement totally lacking posterior to this point. Lower fringe shows only one row of pits exterior to girder and long genal spine directed posterolaterally.

Pygidial outline subtriangular, length (sag.) slightly more than one-fourth of width (trans. max. anterior). Axial width (trans. anterior) about one-seventh total pygidial width (trans. anterior), axis tapering evenly posteriorly to rim of pleural field; nine to 11 axial rings visible; distal ends of axial ring furrow directed slightly posterolaterally. Average of seven pleural furrows cross pleural field, distal ends flexed posterolaterally.

Holotype.—USNM 169630.

Paratypes.—USNM 169631a–m; 169632a, b; 169633.

Occurrence.—USGS colln. D1880 CO, Copenhagen Formation. USGS colln. D1901 CO, Caesar Canyon Limestone, Mill Canyon sequence. USGS collns. D1914 CO and D1915 CO, Caesar Canyon Limestone, August Canyon sequence. Loc. CC, Caesar Canyon Limestone, August Canyon sequence.

Discussion.—From the shape of the anterolateral parts of the fringe and the general size and disarray of the fringe pits, this species is evidently assignable to *Cryptolithoides*. The presence of four to five concentric rows of pits anterior to the glabella combined with the reticulate ornamentation on the cheeks of most specimens separate this species from *C. fittsi*.

Two cranidia from USGS colln. D1880 CO (for example, pl. 5, fig. 14) show four to five concentric rows of pits anterior to the glabella and obviously belong to this species. They display eye ridges at about the midlength of the glabella and small eye lobes set close to the axial furrow. Small lenticular alae also extend along the side of the glabella anteriorly from the occipital furrow to the eye ridge.

Family RAPHIOPHORIDAE Angelin, 1854
Genus LONCHODOMAS Angelin, 1854

Lonchodomas sp.
Plate 6, figures 1–3

Cranidium from USGS colln. D1913 CO somewhat similar to that of *L. halli* (Billings) from eastern North America (see Shaw, 1968, p. 36–37, pl. 5, figs. 17–19, 23, 24, 31) in having a short (sag.) glabella tapering abruptly into anterior spine, maximum glabella width at three-fifths sagittal length. Anterior part of fixed cheek a flat, shelflike border.

Figured specimens.—USNM 169636, 169637.

Occurrence.—USGS collns. D1913 CO and D249a CO, Copenhagen Formation, member C.

Discussion.—The anterior part of the fixed cheek is like that of *L. halli* and *L. normalis* (Billings). (See Whittington, 1965, pl. 10, fig. 14.) The glabellar width to length ratio, however, appears to fall between the ratios in these two species. *L. retrolatus* Ross, 1967, from the Eureka Quartzite at the Nevada Test Site, differs from the above species in its exceptionally short (sag.), broad glabella.

The specimen from collection D249a (pl. 6, figs. 1, 2) is essentially similar to the one from D1913 CO except that it has an exceptionally thick (dorsoventral) anterior spine. Until additional specimens can be found with this thick spine, this feature cannot be utilized as a specific characteristic.

Genus AMPYXINA Ulrich, 1922

Ampyxina salmoni Churkin
Plate 6, figures 4–10

Ampyxina salmoni Churkin, 1963, Jour. Paleontology, v. 37, no. 2, p. 424–425, pl. 51, figs. 1–10.

Figured specimens.—USNM 169638; 169639a, b. AMNH 29116, 29117, 29120, 29121.

Occurrence.—Caesar Canyon Limestone, USGS collns. D1914 CO and D1916 CO, loc. GK. Previously described from Saturday Mountain Formation of Idaho (Churkin, 1963).

Discussion.—Two excellent complete specimens from the Caesar Canyon Limestone at locality GK ("Gatecliff") show the five segments typical of the genus. The free cheeks curve posteriorly to parallel the axis and project posterior to the rest of the exoskeleton. Churkin envisaged straight (trans.) or anteriorly recurved pygidial pleural ribs as distinctive for this species. This characteristic appears quite variable so that at least one specimen (pl. 6, fig. 6) closely resembles *A. powelli* (Raymond) from the Edinburg Formation of Virginia. Other described species of *Ampyxina* (Whittington, 1959) differ in having a stronger posterior curve to the pleural pygidial furrows and a longer (sag.) and narrower (trans.) glabella and (or) an anterior glabellar spine.

Genus RAYMONDELLA Reed, 1935

Raymondella nevadensis n. sp.
Plate 6, figures 11–13, 15, 17

Only cranidia and pygidia are known. Cranidial outline rounded triangular; length (sag.) one-half maximum transverse width at posterior border. Glabella ovoid in dorsal view, width (trans.) to length (sag.) ratio seven-ninths; maximum width (trans.) of glabella two-thirds sagittal distance anterior to occipital furrow; low, rounded keel developed on sagittal line of glabella. Small anterior spine on small specimen, none on large. At its posterior end, each side of glabella sharply indented anterior to occipital furrow; alae low and inconspicuous, paralleling divergent posterolateral sides of glabella for about one-third glabellar length (sag.). Fixed cheeks almost diamond shaped, rising steeply from axial and border furrows. Posterior cranidial border relatively long (exsag.) for the genus, length (exsag.) about one-sixth width (trans.). Occipital ring shorter (sag.) than border, not well shown on available material. Fixed cheeks bear raised line ornament typical of the genus.

Pygidium transversely semielliptical in dorsal view, length (sag.) 0.23–0.3 width (max., trans. at anterior end). Width of axis (trans. ant.) about 0.2 total pygidial width; tapering posteriorly to rim of pleural field; five axial rings; distal ends of rings with slight posterior curve. Three straight pleural furrows cross flat pleural field diagonally to rim. Pygidial border distal to rim forms nearly vertical face. No ornament visible on available pygidial material.

Holotype.—USNM 169640.

Paratypes.—USNM 169641a, b; 169642a, b.

Occurrence.—Caesar Canyon Limestone, USGS colln. D1914 CO. Copenhagen Formation, USGS colln. D1880 CO.

Discussion.—*R. elegans* (Cooper, 1953) previously was the only well-known North American representative of this genus. The present species is differentiated on the basis of total lack of an anterior glabellar spine in large specimens and the presence of at least four axial rings (rather than three) in the pygidium. As most of the Nevada specimens available are somewhat larger than those figured by Whittington (1959) and Cooper (1953), and their specimens show a gradual reduction in the anterior glabellar spine with increasing size, additional Nevada material conceivably might show the two species to be synonymous.

Raymondella Reed was based on *R. maconachiei* from the Balclatchie beds, Girvan District, Scotland. This genus, like *Toernquistia,* may indicate a link with southwest Scotland as well as with the Appalachians.

Family CHEIRURIDAE Salter, 1864
Genus CERAURINELLA Cooper, 1953

Ceraurinella sp.
Plate 6, figure 14

This description is based on a single cranidium. Cranidial length (sag.) equal to width (trans.) along a line across glabellar lobe 1*p*. Posterior end of glabella occupies 0.34 total cranidial width. Glabellar outline expands anteriorly; maximum width (trans.), anterior to furrow 3*p*, 1.18 times width across lobes 1*p*. Glabella furrows 1*p*, 2*p*, and 3*p* evenly spaced and of equal width (trans.), furrow 3*p* at about 0.6 total glabellar length. Lobe 1*p* set off from remainder of glabella by slightly indented longitudinal furrow. Fixed cheek evenly convex; eye lobe opposite furrow 2*p*; distance from outer edge of palpebral lobe to axial furrow equal to 0.5 glabellar width (trans.) at this point.

Posterior border furrow and occipital furrow well incised. Surface of cranidium uniformly covered with fine tubercles.

Figured specimen.—USNM 169643.

Occurrence.—Copenhagen Formation, USGS colln. D1880 CO.

Discussion.—The left genal angle of this small specimen cannot be further prepared without destroying one of the paratypes of *Anataphrus martinensis.* A genal spine seems to be present, but its size and shape cannot be determined.

Genus CERAURUS Green, 1832

Ceraurus? sp.
Plate 6, figure 18

Only a badly preserved internal mold of a cranidium is the basis for this description. Frontal lobe of glabella incomplete; therefore glabellar proportions cannot be determined. Lateral glabellar lobes of equal length (exsag.) and width (trans.). Lobe 1*p* virtually isolated by furrow 1*p* curving backward to occipital furrow. Fixed cheeks poorly preserved. Position of right palpebral lobe indicated by furrow to be opposite glabellar lobe 2*p*. Occipital and posterior border furrows well incised. Surface of glabella covered with coarse tubercles.

Figured specimen.—USNM 169645.

Occurrence.—USGS colln. D1860 CO, Copenhagen Formation, Hot Creek Canyon.

Discussion.—This specimen is so poorly preserved that it cannot be identified with certainty as to genus. Coarse pustules on the glabella seem to favor *Ceraurus,* but position and shape of the eye in the opinion of Ross suggest that this specimen may be a cybelid.

Cheirurinid genus, indeterminate

Plate 6, figure 16

A large fragment of the cranidium of a cheirurid trilobite shows part of the glabella, a small part of a fixed cheek, and the palpebral lobe. It is illustrated here as a matter of record.

Figured specimen.—USNM 169644.

Occurrence.—USGS colln. D1876 CO, Copenhagen Formation, member C.

Discussion.—Shaw comments that this specimen is most like *Hapsiceraurus* Whittington but differs from previously described species in the extreme anterolateral location of the eye lobe and peculiar arcuate tubercle arrangement on the anterior part of the glabella. The glabellar and free cheek ornament closely resembles that of *Paraceraurus ruedemanni* (Raymond). (See Shaw, 1968, pl. 16, figs. 1, 2, 5–8.)

Genus SPHAEROCORYPHE Angelin, 1854

Sphaerocoryphe sp.

Plate 7, figures 1, 2

A specimen, an anterior cranidial bulb, in spite being only a fragment, appears assignable to *Sphaerocoryphe*. Characteristic features are the roundness in dorsal and lateral views, the character of the pustulose ornament, and the presence of part of the smooth, shallow axial furrow along the left side of the bulb. It is illustrated as a matter of record.

Figured specimen.—USNM 169647.

Occurrence.—USGS colln. D1874 CO, Copenhagen Formation.

Discussion.—Ross (1967, p. D23) has recorded pygidia from the Antelope Valley Limestone near Pyramid Peak, Calif., which may belong to this genus. *Sphaerocoryphe* has a long stratigraphic range (Middle and Upper Ordovician) and is known from much of northern Europe and North America.

Family ENCRINURIDAE Angelin, 1854

Genus CYBELOIDES Slocum, 1913

Cybeloides Slocum. Shaw, 1968, New York State Mus. and Sci. Serv. Mem. 17, p. 66.

Cybeloides sp.

Plate 6, figure 19

Figured specimen.—USNM 169646.

Occurrence.—USGS colln. D1874 CO, Copenhagen Formation, member C.

Discussion.—This immature specimen is similar to pygidia described by Shaw (1968, p. 68, pl. 9, figs. 12, 17, 19, 20; pl. 10, fig. 7) and Cooper (1953, p. 31–32, pl. 13, figs. 6, 8, 11, 20). The major difference lies in the posteriorly poorly defined pleural ribs and a large post-axial field occupied by shallow pits. *C. prima* (Raymond) shows these same characteristics to a lesser degree. *C. virginiensis* Cooper displays a very small, unpitted post-axial area.

The genus has a wide stratigraphic and geographic range, being known from the Middle and Upper Ordovician of North America and Europe.

Family CALYMENIDAE Burmeister, 1843

Calymenid genus, indeterminate

Plate 7, figures 3–8

Figured specimens.—AMNH 29122–29125, USNM 169648, 169660.

Occurrence.—Caesar Canyon Limestone, USGS colln. D1914 CO and loc. GK. Saturday Mountain Formation, Bayhorse district, Idaho, USGS colln. D1916 CO.

Discussion.—The Caesar Canyon Limestone has yielded five specimens originally identified by Churkin (1963) as *Flexicalymene* sp. Generic identification of calymenids rests largely on details of the cephalon which are not available on this material. In addition, the very different characteristics of the anterior border and the glabellar outline in the two cranidia suggest that the cranidia have been badly deformed. The pygidia are relatively well preserved and differ from those of most other calymenids in having a length (sag.) to width (trans., anterior end) ratio of one-half. Six axial rings and five posteriorly curving pleural ribs set off by deep pleural furrows are visible; faint interpleural furrows are visible distally on ribs. These are the first described calymenids from upper Middle Ordovician formations of central Nevada.

A pygidium from the Saturday Mountain Formation of Idaho (USGS colln. D1916 CO) is somewhat more convex than any of the Caesar Canyon specimens and has a more robust axis.

Dr. W. T. Dean (oral commun., Aug. 8, 1970) has suggested that the cranidium illustrated in figure 6 of plate 7 might be assigned to *Platycoryphe*. Although this possibility warrants consideration, we lack enough well-preserved specimens to confirm it.

Family PTERYGOMETOPIDAE Reed, 1905

Genus CALYPTAULAX G. A. Cooper, 1930

Calyptaulax Cooper, 1930, Am. Jour. Sci., ser. 5, v. 20, p. 386–388.

Calliops Delo, 1935, Jour. Paleontology, v. 9, no. 5, p. 417–418.

Calyptaulax Cooper. Whittington, 1965, Harvard Univ. Mus. Comp. Zoology Bull., v. 132, no. 4, p. 430–431.

Calyptaulax Cooper. Shaw, 1968, New York State Mus. and Sci. Service Mem. 17, p. 83–84.

Calyptaulax cf. C. callirachis (B. N. Cooper)
Plate 7, figures 9–15

Cranidial length (sag.) to width (trans.) ratio 0.66. Anterior end of glabella and glabellar furrows damaged and largely obscured. Glabellar lobe 1*p* very small, completely detached from glabella; furrows and lobes 2*p* and 3*p* difficult to make out, furrow 3*p* seems to start opposite anterior end of palpebral lobe. Palpebral lobe length (exsag.) 0.66 cranidial length (sag.); palpebral rim wide (trans.), semicircular in outline; posterior end opposite occipital ring. Occipital ring length (sag.) 0.45 width (trans.), ring outline subtrapezoidal in dorsal view. Visual surface of eye curved, height in lateral view about half total cranidial height; facets arranged in vertical rows, as typical for the genus, about 125 facets present in each eye. Lateral and posterior cranidial borders wide; genal angle pointed, but seemingly not bearing a spine.

Pygidial outline subtriangular; length (sag.) 0.66 width (max. trans.) at anterior end; axis width (trans.) about 0.25 total pygidial width at anterior end, axis tapering gradually posteriorly, ending at 0.75 pygidial length (sag.); about eight axial rings present, articulating half-ring prominent and about same shape as axial rings. Axis semicircular in cross section, standing above pleural field; pleural field inflated, crossed by approximately seven pleural furrows. Interpleural furrows present on distal half of pleural field. Cranidial and pygidial surfaces pustulose.

Figured specimens.—USNM 169649a–c; 169650a, b.

Occurrence.—Copenhagen Formation, locs. MR and SR; USGS collns. D286 CO and D1880 CO.

Discussion.—These specimens appear distinct in having very long (exsag.) palpebral lobes and eye lobes. They most closely resemble *C. callirachis* (Cooper, 1953, pl. 18, figs. 1–4, 8) in glabellar, cranidial, and pygidial outline. They appear to differ from *C. cornwalli* Ross (1967a, p. 29, pl. 8, figs. 28–33) in possessing a relatively longer glabella.

C. callirachis is known from the Edinburg and Athens Formations of the Appalachians (Cooper, 1953, p. 39) and thus is probably about the same age as most of the Nevada material.

Family LICHIDAE Hawle and Corda, 1847
Genus AMPHILICHAS Raymond, 1905

Amphilichas aff. A. minganensis (Billings)
Plate 7, figures 16–20, 23

Figured specimens.—USNM 169651a, b; 169652.

Occurrence.—Copenhagen Formation, USGS collns. D1874 CO, D249a CO.

Discussion.—This species is very similar to *A. minganensis* (Billings) (Shaw, 1968, p. 89–94, pl. 3, figs. 2–25; pl. 4, fig. 1). The major difference between the two species is the narrower (trans.) median lobe in the Nevada species; however, variation in *A. minganensis* as shown by a cranidium with narrow median lobe (Shaw, 1968, pl. 3, fig. 9) may include the Nevada form. The Nevada cranidium closely resembles that of *A. dalecarlicus* Angelin (Warburg, 1925, pl. 7, fig. 24).

The hypostome has a markedly indented posterior border, the border itself bearing widely spaced terrace lines subparallel to the margin. The median body bears tubercles, with no trace of the prominent pits shown in one small specimen of *A. minganensis* (Shaw, 1968, pl. 3, fig. 8); the Nevada hypostome is very similar to a larger specimen illustrated by Shaw (1968, pl. 3, fig. 12).

The pygidium shows the proximal part of the right pleural field only and evidently belongs to the same genus, with no pleural furrow present on the third pleural lobe. In the absence of well-preserved pygidia and a graded size series of cranidia, no specific assignment of these specimens can be made.

Family ODONTOPLEURIDAE Burmeister, 1843
Genus MIRASPIS R. and E. Richter, 1917

Miraspis sp.
Plate 7, figures 21, 22

Primaspis sp. (part), Churkin, 1963, Jour. Paleontology, v. 37, no. 2, pl. 51, fig. 13 only.

Cranidial width (trans.) to length (sag.) ratio four-thirds, width (trans.) of median lobe 0.25 total cranidial width. Length of glabellar lobe 1*p* nearly half total cranidial length, lobe 2*p* 0.5 length of lobe 1*p* and same width. Lobes 1*p* and 2*p* separated by diagonal furrow. Lobe 3*p* very small, nearly circular in outline, and set off from median and other glabellar lobes by deep furrows. Occipital ring longest sagittally, possessing median tubercle and two posteriorly directed spines. Spine length nearly equal to cranidial length. Anterior and lateral cranidial structures not preserved.

Figured specimens.—USNM 169653a, b.

Occurrence.—Upper part Caesar Canyon Limestone at Caesar Canyon, USGS colln. D1915 CO.

Discussion.—Only two cranidia of this species were found. They and the one specimen illustrated by Churkin (1963, pl. 51, fig. 13) are the only specimens of *Miraspis* known from either the Nevada or the Idaho locality.

Except for the well-developed occipital spines, these specimens closely resemble those assigned to *Primaspis* elsewhere in this paper. Judged from recent descriptions by Whittington and Bohlin (1958) and Bruton (1965, 1966), the occipital spines of

Miraspis are the only cranidial features distinctive from *Primaspis*.

Genus PRIMASPIS R. and E. Richter, 1917

Primaspis churkini n. sp.

Plate 8, figures 1–10

Primaspis sp. Churkin, 1963, Jour. Paleontology, v. 37, no. 2, p. 425–426, pl. 51, figs. 11, 12, 14.

In his description of *Primaspis* sp., Churkin (1963, p. 425, pl. 51, fig. 13) included a cranidium with paired spines on the occipital ring; we have reassigned this specimen to *Miraspis* sp. Therefore, except for the reference to "a pair of small spines" on the occipital ring, Churkin's (1963, p. 425–426) description is used for this new species with the following emendation: Anterior part of glabella merges with anterior cephalic border; border furrow seemingly absent in front of glabella. Small median tubercle on occipital ring. On pygidium as many as six pairs of secondary spines present outside long primary pair.

Holotype.—USNM 169654.

Paratypes.—USNM 169655a–e, 169656; AMNH 29126–29128.

Occurrence.—Saturday Mountain Formation, Idaho, USGS colln. D1916 CO. Caesar Canyon Limestone, Nevada, loc. GK and USGS colln. D1914 CO.

Discussion.—Churkin's (1963, p. 425–426) description was based on specimens from the Saturday Mountain Formation. Ten cranidia and two pygidia are topotypic paratypes in USGS colln. D1916 CO. Two pygidia and a single free cheek from the Caesar Canyon Limestone at locality GK ("Gatecliff") comprise the material mentioned by Churkin (1963, p. 426).

This species most closely resembles *P. harnagensis* (Bancroft) (Dean, 1960–63) but carries one to two additional marginal spines anterior to the primary pygidial spine. The species discussed by Whittington (1956) and Bruton (1965, 1966) differ either in having more secondary spines posterior to the primary pygidial spine or in having one of the secondary spines partially fused with the primary spine.

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[Italic page numbers indicate major references]

PLATES 1–8

[Contact photographs of the plates in this report are available, at cost, from the U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225]

PLATE 1

FIGURE 1. *Triarthrus* sp. (p. 14)

USGS colln. D1914 CO. Cranidium; dorsal view. Stereophotograph; × 6. USNM 169601.

2. *Carrickia*? sp. (p. 14)

USGS colln. D1860 CO. Cranidium; dorsal view, left fixigene and glabella. Stereophotograph; × 5. USNM 169602.

3–7. *Hypodicranotus* n. sp. (p. 15)

All figures are stereophotographs.

3. Pygidium; dorsal view. × 10. USGS colln. D1873 CO. USNM 169603a.
4, 6. Cephalon; left lateral and dorsal views. × 2. USGS colln. D1873 CO. USNM 169603b.
5. Free cheek; dorsal view. × 4. Loc. SR(—30) (30 ft below USGS colln. D1880 CO). USNM 169604.
7. Hypostome, incomplete; ventral view. × 5. USGS colln. D1874 CO. USNM 169605.

8–15. *Robergia major* Raymond. (p. 16)

Figures 9–15 photographed by F. C. Shaw.

8. Pygidium; dorsal view. Stereophotograph; × 5. USGS colln. D1914 CO. USNM 169606.
9. Pygidium; dorsal view. × 3. Loc. GK. AMNH 29106.
10. Cranidium; dorsal view. × 3. Loc. GK. AMNH 29107.
11. Pygidium; interior of mold of dorsal surface. × 3. Loc. GK. AMNH 29108.
12. Pygidium; dorsal view. × 3. Loc. GK. AMNH 29109.
13. Pygidium; interior of mold of dorsal surface. × 3. Loc. GK. AMNH 29110.
14. Cranidium, partial; interior of mold of dorsal surface. × 3. Loc. GK. AMNH 29111.
15. Cranidium; dorsal view. × 3. Loc. GK. AMNH 29112.

16–21. *Robergia deckeri* B. N. Cooper. (p. 16)

All figures are stereophotographs.

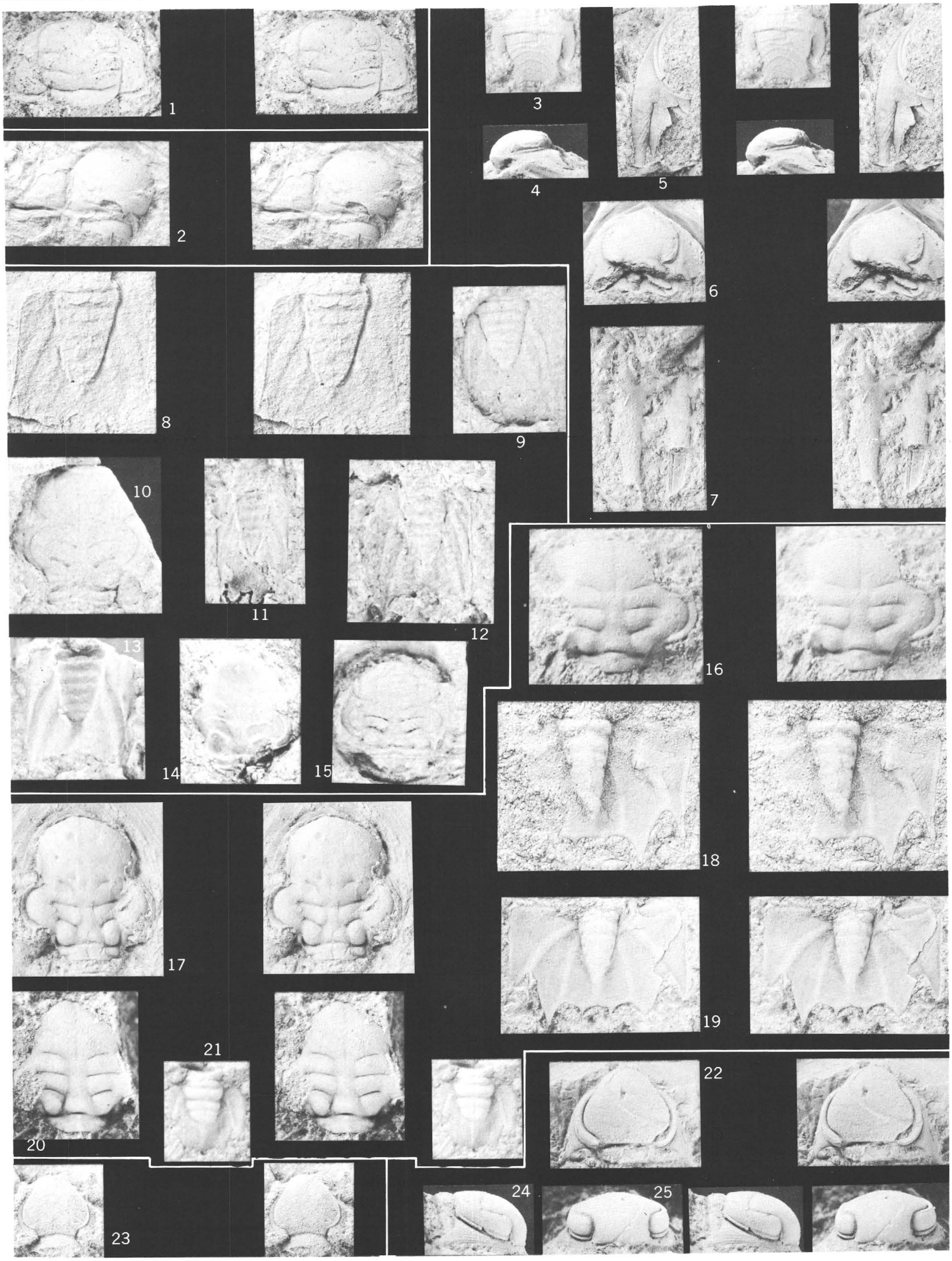
16. Cranidium, partial; dorsal view. × 10. USGS colln. D1880 CO. USNM 169607a.
17. Cranidium; dorsal view. × 3. Loc. CC (Same as USGS colln. D1915 CO.) USNM 169608a.
18. Pygidium, damaged; dorsal view. × 6. Loc. CC (essentially same as USGS colln. D1915 CO). USNM 169608b.
19. Pygidium; dorsal view. × 6. Loc. CC (essentially same as USGS colln. D1915 CO). Note doublure and its markings on right side. USNM 169608c.
20. Cranidium, partial; dorsal view. × 7. USGS colln. D1880 CO. Note crease in front of glabella resembling that of *R. yukonensis* Lenz and Churkin. USNM 169607b.
21. Pygidium, juvenile; dorsal view. × 10. USGS colln. D1880 CO. This pygidium strongly resembles that of *Onychopyge sculptura* Robison and Pantoja-Alor (1968, pl. 100, figs. 4, 5). USNM 169607c.

23. *Remopleurides* sp. 1 (p. 17)

Cranidium; dorsal view. Stereophotograph; × 3. Float, with USGS colln. D1880 CO. USNM 169609.

22, 24, 25. *Remopleurides* sp. 2. (p. 17)

Cephalon; dorsal, lateral, and anterior views. Stereophotographs; × 4. USGS colln. D1860 CO. USNM 169610.



TRIARTHRUS, *CARRICKIA*?, *HYPODICRANOTUS*, *ROBERGIA*, AND *REMOPLEURIDES*

PLATE 2

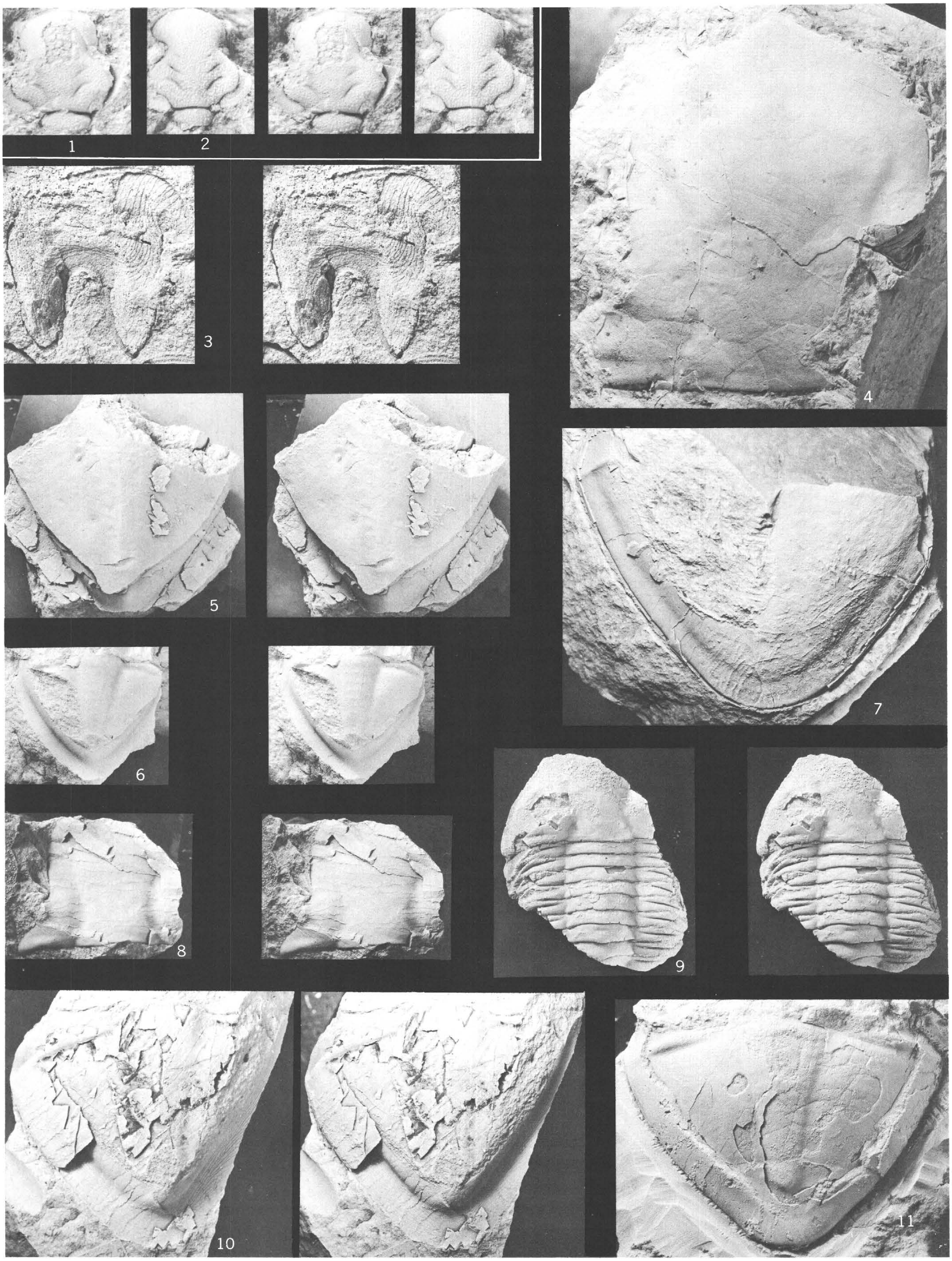
[All figures are stereophotographs except figures 4, 7, 11]

FIGURES 1, 2. *Robergiella* sp. (p. 17)

1. Cranidium; dorsal view. × 6. Loc. CC (essentially same as USGS colln. D1915 CO). USNM 169611.
2. Cranidium; dorsal view. × 7. USGS colln. D1880 CO. USNM 169612.

3–11. *Isotelus copenhagenensis*, n. sp. (p. 18)

3. Hypostome, paratype; mold of ventral surface. × 3. USGS colln. D1914 CO. USNM 169613.
4. Cranidium, holotype; dorsal view. × 1. USGS colln. D1878 CO. USNM 169614.
5. Pygidium, paratype; dorsal view. × 1. USGS colln. D286 CO. USNM 169615a.
6. Pygidium, paratype; dorsal view. × 1. USGS colln. D1905 CO. USNM 169616a.
7. Pygidium, paratype, largest specimen obtained; dorsal view. × 1. USGS colln. D1874 CO. USNM 169617.
8. Cranidium, paratype; dorsal view. × 1. USGS colln. D1872 CO. USNM 169618a.
9. Partial cephalon and thorax; dorsal view. × 1. USGS colln. D249c CO. USNM 169619.
10. Pygidium; dorsal view. × 1. USGS colln. D1872 CO. USNM 169618b.
11. Pygidium; dorsal view. × 1. USGS colln. D1905 CO. USNM 169616b.



ROBERGIELLA AND *ISOTELUS*

PLATE 3

[All figures stereophotographs except figure 15]

FIGURES 1–3. *Isotelus copenhagenensis* n. sp. (p. 18)

1. Cranidium, paratype; dorsal view of a latex cast. × 1. USGS colln. D286 CO. USNM 169615b.
2. Free cheek, paratype; lateral view, showing height of eye. × 1. USGS colln. D1905 CO. USNM 169616c.
3. Hypostome, paratype; ventral view. × 2. USGS colln. D1905 CO. USNM 169616d.

4–16. *Anataphrus martinensis* n. sp. (p. 20)

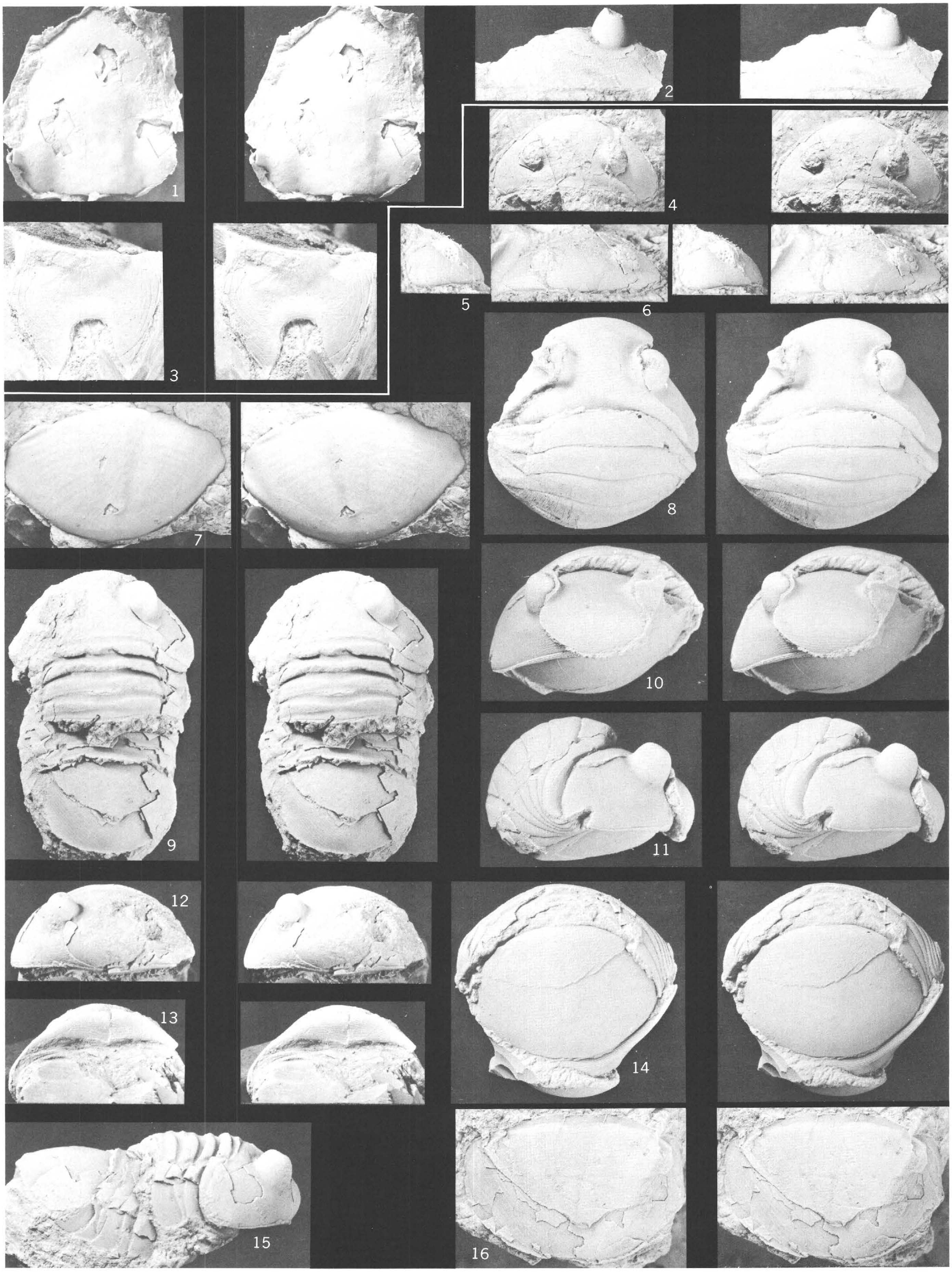
4–6. Cephalon, paratype; dorsal, anterior, and lateral views. × 2. USGS colln. D1912 CO. USNM 169621.

7. Pygidium, paratype; dorsal view. × 1. USGS colln. D1880 CO. USNM 169622.

8, 10, 11, 14. Holotype, enrolled individual, anteriorly deformed; dorsal, anterior, lateral, and posterior views. × 2. USGS colln. D1872 CO. USNM 169623.

9, 12, 13, 15. Paratype, nearly complete individual; dorsal, anterior, ventral, and lateral views. × 2. Figure 13 shows median suture cutting doublure. Loc. MR-U. USNM 169624a.

16. Pygidium, paratype; dorsal view showing doublure beneath decorticated portion of carapace. × 2. Loc. MR-U. USNM 169624b.



ISOTELUS AND *ANATAPHRUS*

PLATE 4

[All figures are stereophotographs except figures 3, 6, 8, 9, 11]

FIGURE 1. *Nileus*? sp. (p. 21)

Cranidium; dorsal view. × 3. Loc. SR-L (100 ft below USGS colln. D1880 CO). USNM 169625.

2, 3. Illaenid sp. 1 (p. 21)

Cranidium; dorso-lateral view and dorsal view. × 1. Loc. MR-U. USNM 169626.

4, 5. Illaenid sp. 2 (p. 21)

Cranidium; anterior and dorsal views. × 4. Loc. MR-U. USNM 169627.

6–9. *Toernquistia*? *idahoensis* Churkin (p. 22)

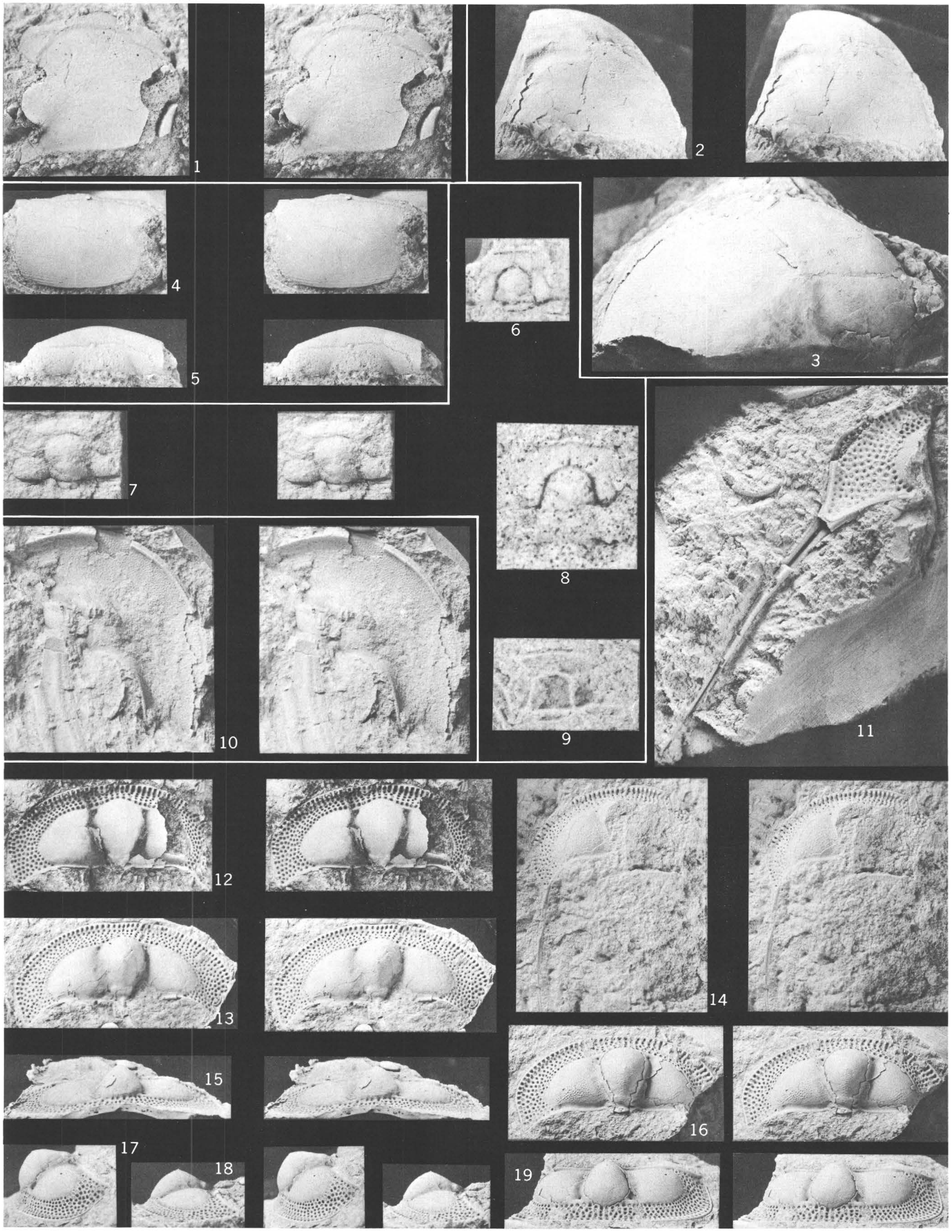
6. Cranidium; dorsal view. × 6. Loc. GK. AMNH 29113.
7. Cranidium; dorsal view. × 5. USGS colln. D1914 CO. USNM 169628.
8. Cranidium, partially obliterated; dorsal view. × 6. Loc. GK. AMNH 29114.
9. Cranidium, interior of mold; ventral view. × 6. Loc. GK. AMNH 29115.

10. Harpid genus, indeterminate (p. 22)

Latex cast. Partly preserved cephalon, lacking glabella; dorsal view. × 2. USGS colln. D249a CO. USNM 169629.

11–19. *Cryptolithoides reticulatus* n. sp. (p. 24)

11. Part of left side of cephalon, paratype; dorsal view showing long genal spine. × 3. USGS colln. D1880 CO. USNM 169631a.
12. Cephalon, paratype; dorsal view. × 2. USGS colln. D1880 CO. USNM 169631b.
13, 15, 18. Cephalon, paratype; dorsal, anterior, and lateral views. × 2. USGS colln. D1880 CO. USNM 169631c.
14. Partial cephalon, paratype; dorsal view showing length of genal spine. × 3. USGS colln. D1880 CO. USNM 169631d.
16, 17, 19. Holotype, cephalon; dorsal view showing reticulation on cheek lobes. × 2. USGS colln. D1880 CO. USNM 169630.



NILEUS?, ILLAENID *TOERNQUISTIA*?, HARPID, AND *CRYPTOLITHOIDES*

PLATE 5

[All figures are stereophotographs]

FIGURES 1–17, 19. *Cryptolithoides reticulatus* n. sp. (p. 24)

[All specimens are paratypes]

1. Pygidium; dorsal view. × 3. USGS colln. D1880 CO. USNM 169631e.
2. Pygidium; dorsal view. × 3. USGS colln. D1880 CO. USNM 169631f.
3. Cephalon, partial; dorsal view showing genal spine. × 3. USGS colln. D1880 CO. USNM 169631g.
4. Cranidium; dorsal view showing reticulate surface of cheek lobes and base of occipital spine. × 3. USGS colln. D1880 CO. USNM 169631h.

5, 6, 10. Cranidium; dorsal, anterior, and lateral views. × 2. USGS colln. D1880 CO. USNM 169631i.

7, 8, 12. Cranidium, immature; dorsal, anterior, and lateral views. × 5. USGS colln. D1880 CO. USNM 169631j.

9, 13. Cranidium; lateral and dorsal views, latex cast. × 2. USGS colln. D1880 CO. USNM 169631k.

11, 14. Cranidium, immature; lateral and dorsal views. × 7. USGS colln. D1880 CO. USNM 169631l.

15. Pygidium; dorsal view. × 3. Loc. CC (essentially same as USGS colln. D1915 CO). USNM 169632a.

16. Nearly complete carapace; dorsal view, latex cast. × 2. USGS colln. D1914 CO. USNM 169633.

17. Cranidium, immature; dorsal view showing eyes and eye ridges. × 10. USGS colln. D1880 CO. USNM 169631m.

19. Cephalic fringe; ventral view showing girder. × 2. Loc. CC (essentially same as USGS colln. D1915 CO). USNM 169632b.

18, 20, 21, 23. *Cryptolithoides fittsi* (p. 24)

18, 20, 21. Cranidium; anterior, lateral, and dorsal views. × 2. USGS colln. D1880 CO. USNM 169634.

23. Cranidium; dorsal view. × 2. Loc. CC (essentially same as USGS colln. D1915 CO). USNM 169635.

22. *Cryptolithoides* sp. (not described)

Cranidium; dorsal view, latex cast. × 3. Lower part of Viola Limestone, 3.5 miles north of Baum, Okla., on Okla. Highway 18. F. C. Shaw collection. USNM 169661.

CRYPTOLITHOIDES

PLATE 6

[All figures are stereophotographs except figures 5, 6, 9, 10]

FIGURES 1–3. *Lonchodomas* sp. (p. 25)

1, 2. Cranidium; dorsal and lateral views. × 2. USGS colln. D249a CO. USNM 169636.

3. Cranidium; interior of natural mold, with anterior spine partly preserved. × 3. USGS colln. D1913 CO. USNM 169637.

4–10. *Ampyxina salmoni* Churkin (p. 25)

4. Nearly complete specimen; dorsal view. × 3. USGS colln. D1914 CO. USNM 169638.
5. Cranidium; dorsal view. × 3. Loc. GK. AMNH 29116.
6. Nearly complete specimen; dorsal view. × 6. Loc. GK. AMNH 29117.
7. Cranidium, poorly preserved; dorsal view. × 3. USGS colln. D1916 CO. USNM 169639a.
8. Pygidium; dorsal view. × 5. USGS colln. D1916 CO. USNM 169639b.
9. Nearly complete specimen; dorsal view. × 6. Loc. GK. AMNH 29120.
10. Cephalon and partial thorax; dorsal view. × 3. Loc. GK. AMNH 29121.

11–13, 15, 17. *Raymondella nevadensis* n. sp. (p. 25)

11. Pygidium, paratype; dorsal view. × 10. USGS colln. D1914 CO. USNM 169641a.
12. Pygidium, paratype; dorsal view. × 10. USGS colln. D1880 CO. USNM 169642a.
13. Pygidium, paratype; dorsal view. × 10. USGS colln. D1914 CO. USNM 169641b.
15. Holotype, cranidium; dorsal view. × 7. USGS colln. D1914 CO. USNM 169640.
17. Cranidium, paratype; dorsal view. × 10. USGS colln. D1880 CO. USNM 169642b.

14. *Ceraurinella* sp. (p. 26)

Cranidium; dorsal view. × 4. USGS colln. D1880 CO. USNM 169643.

16. Cheirurinid genus, indeterminate (p. 27)

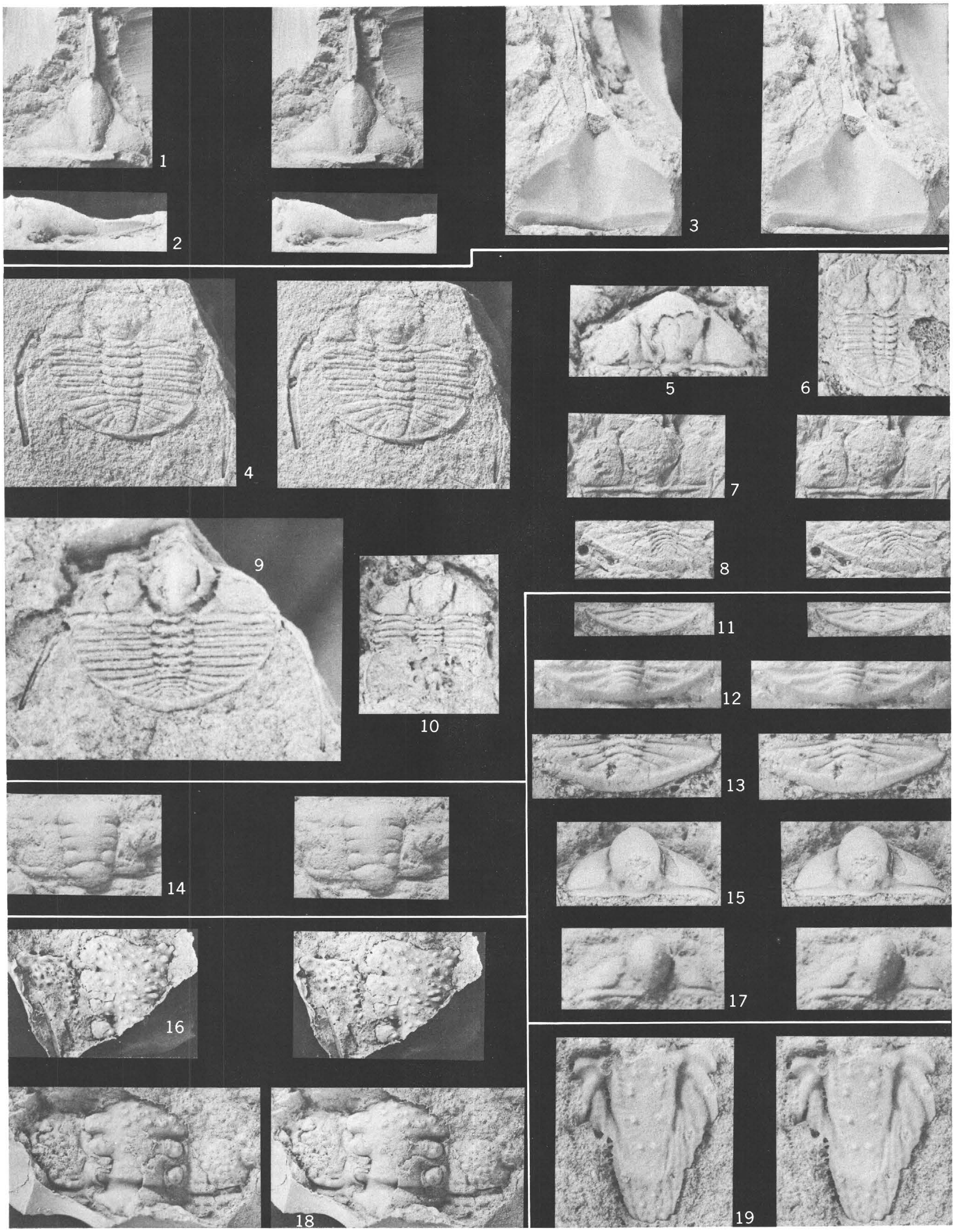
Cranidium, fragmentary; dorsal view, latex cast. × 1. USGS colln. D1876 CO. USNM 169644.

18. *Ceraurus*? sp. (p. 26)

Cranidium, fragmentary; dorsal view, latex cast. × 4. USGS colln. D1860 CO. USNM 169645.

19. *Cybeloides* sp. (p. 27)

Pygidium; dorsal view. × 10. USGS colln. D1874 CO. USNM 169646.



LONCHODOMAS, *AMPYXINA*, *RAYMONDELLA*, *CERAURINELLA*, CHEIRURINID, *CERAURUS*?, AND *CYBELOIDES*

PLATE 7

[All figures are stereophotographs except figures 3–7]

FIGURES 1, 2. *Sphaerocoryphe* sp. (p. 27)

Cranidial bulb; dorsal and left lateral views. × 7. USGS colln. D1874 CO. USNM 169647.

3–8. Calymenid genus, indeterminate (p. 27)

3. Pygidium; dorsal view, latex cast. × 3. Loc. GK. AMNH 29122.
4. Pygidium; dorsal view. × 3. USGS colln. D1914 CO. USNM 169660.
5. Pygidium, partial cast; dorsal view. × 3. Loc. GK. AMNH 29123.
6. Cranidium, partial; dorsal view. × 3. Loc. GK. AMNH 29124.
7. Cranidium; ventral view of mold. × 3. Loc. GK. AMNH 29125.
8. Pygidium; dorsal view. × 3. USGS colln. D1916 CO. USNM 169648.

9–15. *Calyptaulax* cf. *C. callirachis* (B. N. Cooper) (p. 28)

9. Cephalon, mostly decorticated; dorsal view. × 4. Loc. MR. USNM 169649a.

10, 14. Cephalon; dorsal and lateral views. × 3. Loc. MR. USNM 169649b.

11. Hypostome; ventral view. × 10. USGS colln. D1880 CO. USNM 169650a.

12, 13. Pygidium; dorsal and posterior views. × 3. Loc. MR. USNM 169649c.

15. Pygidium; dorsal view. × 3. Loc. SR (same as USGS colln. D1880 CO). USNM 169650b.

16–20, 23. *Amphilichas* aff. *A. minganensis* (Billings) (p. 28)

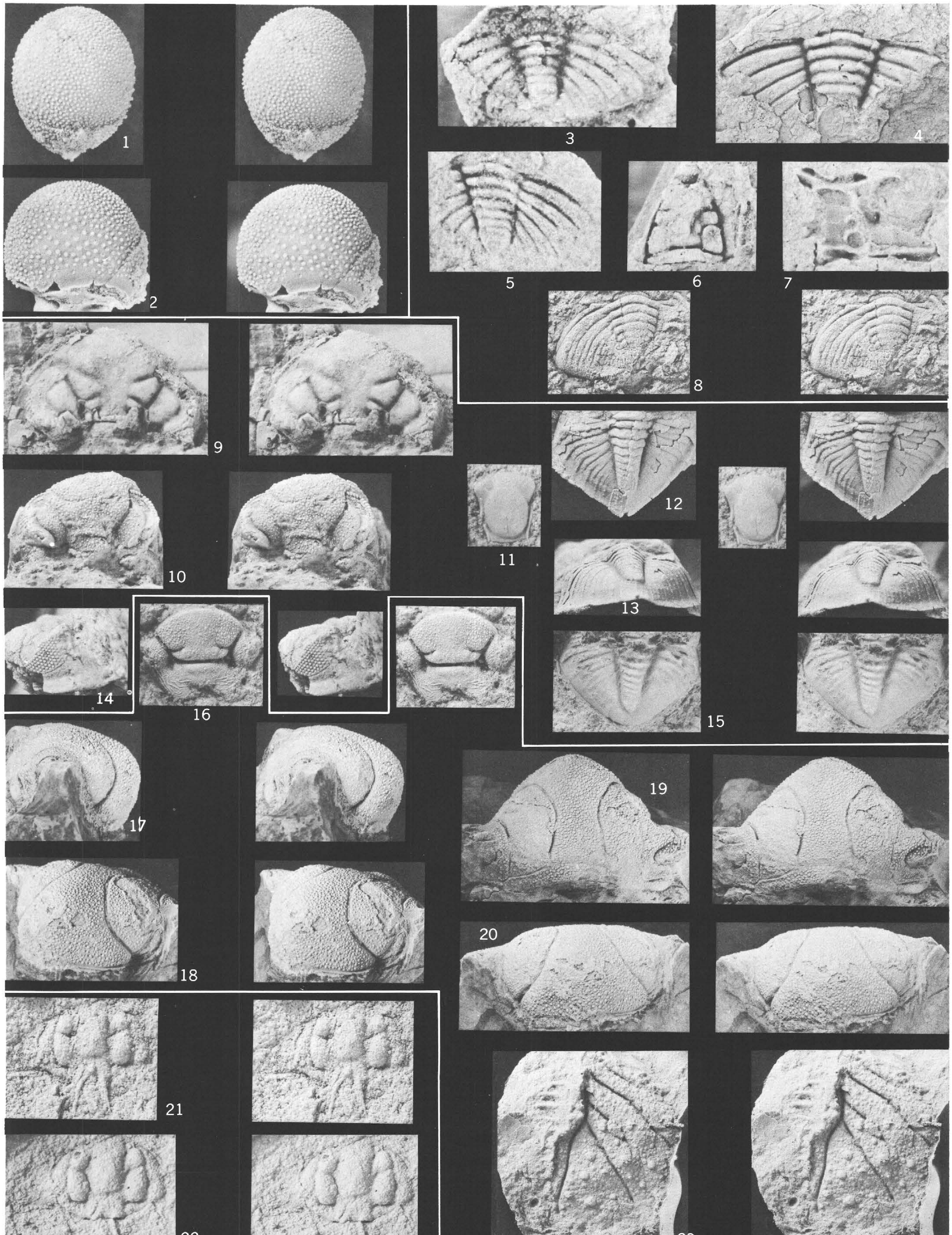
16. Hypostome; ventral view. × 3. USGS colln. D1874 CO. USNM 169651a.

17–20. Cranidium; lateral, anterolateral, dorsal, and anterior views. × 1. USGS colln. D1874 CO. USNM 169651b.

23. Pygidium, fragmentary; dorsal view, latex cast. × 3. USGS colln. D249a CO. USNM 169652.

21, 22. *Miraspis* sp. (p. 28)

21. Cranidium; dorsal view. × 5. USGS colln. D1915 CO. USNM 169653a.
22. Cranidium; dorsal view. × 5. USGS colln. D1915 CO. USNM 169653b.



SPHAEROCORYPHE, CALYMENID, *CALYPTAULAX*, *AMPHILICHAS*, AND *MIRASPIS*

PLATE 8

[All figures are stereophotographs except figures 2, 4, 5]

FIGURES 1–10. *Primaspis churkini* n. sp. (p. 29)

1. Cranidium, holotype; dorsal view, latex cast. × 5. USGS colln. D1916 CO. USNM 169654.
2. Pygidium, paratype, mold of posterior spines; dorsal view. × 6. Loc. GK. AMNH 29126.
3. Pygidium, paratype, latex mold; dorsal view. × 5. USGS colln. D1916 CO. USNM 169655a.
4. Free cheek, natural mold; dorsal view. × 6. Loc. GK. AMNH 29127.
5. Pygidium; dorsal view. × 6. Loc. GK. AMNH 29128.
6. Pygidium; dorsal view. × 5. USGS colln. D1916 CO. USNM 169655b.
7. Cranidium; dorsal view. × 5. USGS colln. D1916 CO. USNM 169655c.
8. Cranidium; dorsal view. × 3. USGS colln. D1916 CO. USNM 169655d.
9. Cranidium; dorsal view. × 5. USGS colln. D1916 CO. USNM 169655e.
10. Hypostome; ventral view. × 4. USGS colln. D1914 CO. USNM 169656.

11–16, 18. *Thaleops* sp. (not described)

USGS colln. D2215 CO, Copenhagen Formation, member B of Merriam, east side of Martin Ridge, Horse Heaven Mountain quadrangle, Nevada.

11, 14, 15, 18. Cranidium; lateral, dorsal, anterior, and posterodorsal views. × 1. USNM 169657a.

12, 13, 16. Cranidium, immature; dorsal, anterior, lateral views. × 2. Note pitted surface. USNM 169657b.

17, 19, 20. *Encrinuroides* sp. (not described)

USGS colln. D2216 CO, Copenhagen Formation, member C of Merriam, east side of Martin Ridge, Horse Heaven Mountain quadrangle, Nevada.

Cranidium; lateral, dorsal, and anterior views. × 3. USNM 169658.

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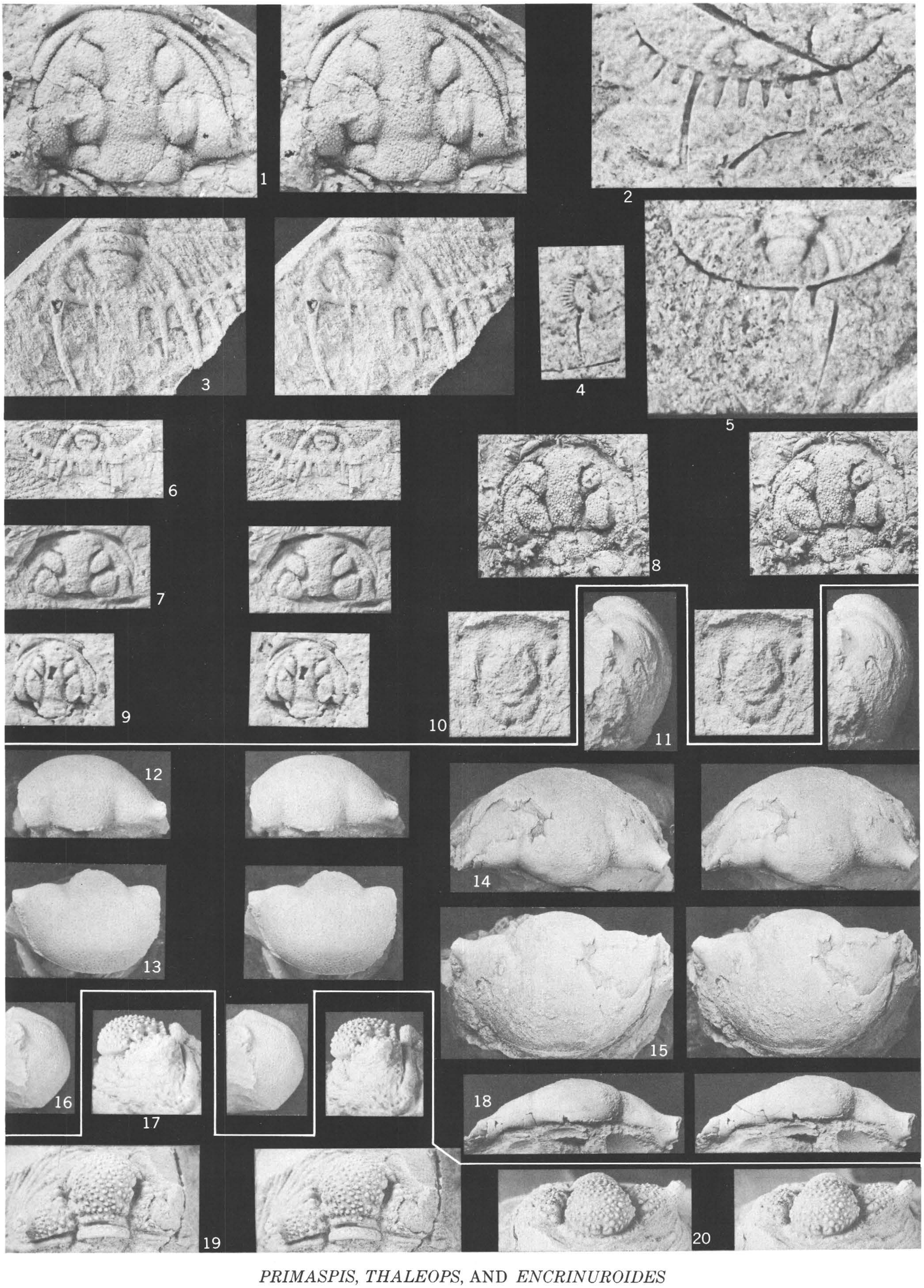

PRIMASPIS, THALEOPS, AND *ENCRINUROIDES*