CAMBRIAN STRATIGRAPHY AND PALEONTOLOGY NEAR CABORCA, NORTHWESTERN SONORA, MEXICO

(With 31 Plates)

BY
G. ARTHUR COOPER
A. R. V. ARELLANO
J. HARLAN JOHNSON
VLADIMIR J. OKULITCH
ALEXANDER STOYANOW
CHRISTINA LOCHMAN

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 6, 1952
CAMBRIAN STRATIGRAPHY AND PALEONTOLOGY NEAR CABORCA, NORTHWESTERN SONORA, MEXICO

(WITH 31 PLATES)

BY

G. ARTHUR COOPER
A. R. V. ARELLANO
J. HARLAN JOHNSON
VLADIMIR J. OKULITCH
ALEXANDER STOYANOW
CHRISTINA LOCHMAN

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 6, 1952
The Lord Baltimore Press
BALTIMORE, MD., U. S. A.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction and Stratigraphy, by G. Arthur Cooper and A. R. V.</td>
<td>1</td>
</tr>
<tr>
<td>Arellano</td>
<td>2</td>
</tr>
<tr>
<td>Localities</td>
<td>2</td>
</tr>
<tr>
<td>Proveedora Hills (locality 801)</td>
<td>9</td>
</tr>
<tr>
<td>Cañedo Hill (locality 812)</td>
<td>10</td>
</tr>
<tr>
<td>Prieto Hill (locality 809)</td>
<td>12</td>
</tr>
<tr>
<td>Difuntos Hills (locality 802)</td>
<td>13</td>
</tr>
<tr>
<td>Buelna Hills (locality 807)</td>
<td>13</td>
</tr>
<tr>
<td>Lista Blanca (locality 811)</td>
<td>14</td>
</tr>
<tr>
<td>Arrojos Hills (locality 800)</td>
<td>14</td>
</tr>
<tr>
<td>Additional localities of Cambrian rocks</td>
<td>15</td>
</tr>
<tr>
<td>Summary of Cambrian stratigraphy and correlation between localities</td>
<td>16</td>
</tr>
<tr>
<td>Localities and faunal lists</td>
<td>18</td>
</tr>
<tr>
<td>Girvanella, by J. Harlan Johnson</td>
<td>24</td>
</tr>
<tr>
<td>Systematic description</td>
<td>25</td>
</tr>
<tr>
<td>References</td>
<td>25</td>
</tr>
<tr>
<td>Pleopongeia, by Vladimir J. Okulitch</td>
<td>27</td>
</tr>
<tr>
<td>List of species</td>
<td>27</td>
</tr>
<tr>
<td>Systematic description</td>
<td>28</td>
</tr>
<tr>
<td>References</td>
<td>34</td>
</tr>
<tr>
<td>Brachiopoda, by G. Arthur Cooper</td>
<td>36</td>
</tr>
<tr>
<td>Introduction</td>
<td>36</td>
</tr>
<tr>
<td>Description</td>
<td>37</td>
</tr>
<tr>
<td>References</td>
<td>48</td>
</tr>
<tr>
<td>The Original Collection of Cambrian Trilobites from Sonora, by</td>
<td>49</td>
</tr>
<tr>
<td>Alexander Stojanow</td>
<td>49</td>
</tr>
<tr>
<td>Introduction</td>
<td>50</td>
</tr>
<tr>
<td>Description</td>
<td>59</td>
</tr>
<tr>
<td>References</td>
<td>59</td>
</tr>
<tr>
<td>Trilobites, by Christina Lochman</td>
<td>60</td>
</tr>
<tr>
<td>Introduction</td>
<td>60</td>
</tr>
<tr>
<td>Structure</td>
<td>62</td>
</tr>
<tr>
<td>Ecology</td>
<td>65</td>
</tr>
<tr>
<td>Collection and preparation of Cambrian fossils.</td>
<td>66</td>
</tr>
<tr>
<td>Identification of trilobites</td>
<td>70</td>
</tr>
<tr>
<td>Discussion of the faunas</td>
<td>70</td>
</tr>
<tr>
<td>Lower Cambrian faunas</td>
<td>70</td>
</tr>
<tr>
<td>Composition</td>
<td>70</td>
</tr>
<tr>
<td>Correlation</td>
<td>71</td>
</tr>
<tr>
<td>Middle Cambrian faunas</td>
<td>73</td>
</tr>
<tr>
<td>Faunal zones</td>
<td>73</td>
</tr>
<tr>
<td>Composition</td>
<td>76</td>
</tr>
<tr>
<td>Correlation</td>
<td>78</td>
</tr>
</tbody>
</table>
Systematic descriptions ........................................ 81
Lower Cambrian faunas ......................................... 81
Middle Cambrian faunas ......................................... 109
References ........................................................... 159
Explanation of Plates ............................................ 163
Index ................................................................. 181
ILLUSTRATIONS

PLATES

(All plates following page 180.)

2. Aerial view of the Proveedora Hills.
3. Difuntos Hills, north end of the Arrojos Hills, and pleosponge reef.
4. Puerto Blanco formation, Prieto Hill; Cañedo Hill; Buelna and Cerro Prieto formations, Proveedora Hills.
5. Lista Blanca; West Buelna Hill; Girtvamella on slope of Prieto Hill.
7. Ethmophyllum cooperi Okulitch, new species, E. americanum Okulitch, new species, and Ajacicyathus nevadensis (Okulitch).
8. Syringacnema species and Ethmophyllum whitneyi Meek.
10. Archaeocyathus yavorskii (Vologdin).
12. Acrothele concava Cooper, new species, Dictyonina species, Pegmatreta rara Cooper, new species, and Obolella mexicana Cooper, new species.
13. Micrometra species, Lingulella proveedorensis Cooper, new species, Pegmatreta arellanai Cooper, new species, Wimanella species, Diraphora arrojosensis Cooper, new species, and Nisusia species.
17. Salterella mexicana Lochman, new species, and Salterella, species undetermined.
18. Wanneria mexicana prima Lochman, new species and new variety, Olenellus (Fremontia) fremonti Walcott, and O. (Olenellus) truemani Walcott.

**FIGURES**

1. Map showing location of Cambrian sections by locality numbers............. 3
2. Topographic map showing the Proveedora Hills and collecting localities ........................................... following page 4
3. Topographic map of the Arrojos Hills showing collecting localities following page 4
4. Cross section of the Proveedora Hills showing formations and stratigraphic position of collections ........................................ 5
5. Columnar sections showing sequence in the Proveedora Hills and comparing Arrojos formation of the Arrojos Hills with same formation in the Proveedora Hills........................................ 6
6. Columnar sections of the Proveedora Hills and Arrojos Hills compared. 8
7. Columnar sections of Prieto Hill and the Buelna Hills compared........ 11
8. Diagram showing nomenclature of parts of a trilobite.......................... 62
9. Cambrian trilobite appendage......................................................... 64

**CHARTS**

1. Correlation of Mexican Cambrian formations........................................ 79
2. Known stratigraphic range of Mexican Middle Cambrian trilobite genera ......................................................... 80
INTRODUCTION AND STRATIGRAPHY

By G. ARTHUR COOPER

United States National Museum, Washington, D. C.

AND

A. R. V. ARELLANO

Instituto Geológico de México, México, D. F.

(PATES I-5)

Prior to 1941 Cambrian rocks were unknown in Mexico. But in that year Isauro G. Gómez L. and L. Torres, while making investigations for Petróleos Mexicanos, discovered trilobites in the Arrojos Hills 12 miles west-southwest of Caborca. The Mexican geologists sent their specimens to Dr. Alexander Stoyanow, University of Arizona, who identified them as Middle Cambrian trilobites. The published report of this discovery stimulated interest in México and in the Smithsonian Institution, long a leader in Cambrian stratigraphy and paleontology. The Smithsonian Institution therefore sent G. A. Cooper, representing its staff, and Ing. Alberto Arellano, representing the Instituto Geológico de México, to Caborca, Sonora, to investigate the reported Cambrian and other Paleozoic deposits. Happily, these geologists easily located the trilobite beds in the Arrojos Hills, but in addition they found several other areas exposing Cambrian rocks, especially one long and unbroken sequence 6 miles west of Caborca. Here Lower Cambrian rocks, as well as the previously reported Middle Cambrian, are well exposed. Several weeks in 1943 and 1944 were devoted to investigations of these rocks and making collections of fossils.

The collection of fossils obtained from the vicinity of Caborca is a very fine one and consists of numerous kinds of animals. In the interest of accuracy and to lend utmost authority to this report on the Mexican Cambrian it seemed best to invite specialists to describe the
various groups. Accordingly, Dr. J. Harlan Johnson, Colorado School of Mines, Golden, Colo., was invited to describe the peculiar algae known as *Girvanella*; Dr. Vladimir J. Okulitch, authority on the Pleospongia, contributed the chapter on these interesting and bizarre animals; G. A. Cooper, who has long been interested in the Brachiopoda, prepared the discussion of this group; Dr. Alexander Stoyanov, University of Arizona, who was the first to announce the discovery of Cambrian in this portion of Mexico, consented to describe the specimens that were first found; and Dr. Christina Lochman described the trilobites, which form the largest part of the fauna. She also described some of the peculiar and problematical forms which lend so much fascination to the Cambrian.

Seven areas containing Cambrian rocks were located in the vicinity of Caborca: (1) Cañedo Hill, on the east side of Caborca and on the south bank of the Magdalena River; (2) Prieto Hill, a small hill about 1½ miles southwest of the village; (3) Difuntos Hills, a group of small hills about 14 miles northwest of Caborca; (4) Buelna Hills, two small hills just south of the railroad about 9 miles northwest of Caborca; (5) Lista Blanca, 5-6 miles west-southwest of Caborca; (6) Arrojos Hills, about 12 miles west-southwest of Caborca; and (7) Proveedora Hills, on the north side of Puerto Blanco, 6-7 miles west of Caborca. Inasmuch as the Proveedora Hills include an unbroken section about 1 mile long, it seems best to describe it first and thus establish the units into which the Mexican Cambrian is divided. After the description of this section the sequences at other localities will be explained.

**LOCALITIES**

Proveedora Hills (Cerros de la Proveedora) (Locality 801)

The Cerros de la Proveedora are a roughly longitudinally oval group of hills trending northward and located about 6 miles west of Caborca on the north side of the road through the gap known as Puerto Blanco (text figs. 1, 2, 5). The main mass of the hills consists of two elongated ridges separated by a deep valley interrupted in its middle by a low saddle. These hills lie on the north side of a large granitic mass which has metamorphosed their southern edge and, in one place at least, intruded the Cambrian beds. The southern end of the hills is broken into several knobs of various sizes, mostly composed of white marble, clearly an alteration product of contact metamorphism.

The Proveedora Hills are composed wholly of Cambrian sediments but neither the stratigraphic top nor bottom of the sequence is known.
Fig. 1.—Map of region about Caborca showing location of Cambrian collecting localities. 800, North end Arrojos Hills; 801, Proveedora Hills; 802, Difuntos Hills; 807, Buelna Hills; 809, Prieto Hill; 811, Lista Blanca; 812, Cañedo Hill.
The lowest sediments appear in the small knob on the west end of the
hills. The strike of the sediments is a few degrees west of north
(N. 7° W.) and the dip is quite variable, but all the angles measured
are steep, generally greater than 60°. The dip in the west ridge and
the hills to the west is generally to the east. Dips on the west side of
the saddle between the two main ridges are to the west, but on the opposite
side of the saddle they are to the east. Strong lithological differences
in parts of the hills permit division into six formations, in ascending
order: Puerto Blanco, Proveedora, Buelna, Cerro Prieto, Arrojos,
and Tren formations (text figs. 4, 5). The fossil content of the first
three indicates a Lower Cambrian age. The Cerro Prieto formation
has not been dated, but the Arrojos and Tren formations belong in
the Middle Cambrian.

**Puerto Blanco formation.**—This formation occupies the low ridge
and knob at the west end of the hills. No basal contact is known at
this place and none was seen elsewhere; consequently, the full thick-
ness of the Puerto Blanco formation cannot be stated. The base of
the section consists of about 120 feet of greenish slaty rock followed
by 20 feet of limestone with a foot of sandstone at the base. In these
beds *Hyolithes, Olenellus,* and *Lingulella* were found. Reddish shale
and calcareous sandstone are followed by platy limestone containing
fragmentary olenellid trilobites. The formation is terminated by
quartzites, slates, and marble. The formation is 961 feet thick. The
type section is the west end of the Proveedora Hills.

The Puerto Blanco formation contains many fossils of a few
kinds, but the rock is usually too indurated to allow the specimens to be
broken out. Nevertheless, by searching for pieces softened by weather-
ing, or ones leached of lime, excellent specimens may be obtained.
The most significant fossils taken are the brachiopod *Obolella* and
olenellid trilobites. The brachiopod is characteristic of the earliest
zone of Cambrian life.

**Proveedora formation.**—This formation consists of 732 feet of
thick, white indurated quartzite and dark-gray slaty shale or greenish
slaty shale. The quartzite often forms low ridges. Fossils are rare in
the formation, but unidentifiable linguloid brachiopods and olenellid
fragments appear on some of the weathered surfaces. The type section
is in the Proveedora Hills.

**Buelna formation.**—This formation is composed chiefly of lime-
stone. Approximately the lower half is separated from the upper half
by a prominent ledge about 23 feet thick. The lower half is composed
of thin-bedded bluish-gray limestone. The upper half consists of
platy brownish limestone, *Girvanella* beds, thin-bedded gray limestone,
Fig. 2.—Map of Proveedora Hills showing formational boundaries and collecting localities 801-b, c, h-k, ka, l-o, q, x, y. EPB = Puerto Blanco; CP = Proveedora; EB = Buela; ECP = Cerro Prieto; EA = Arrojos; ET = Tren. Surveyed and drawn by Ing. A. R. V. Arellano.
Fig. 2.—Map of Proveedora Hills showing formational boundaries and collecting localities 8at-h, c, h-k, ka, l-o, q, x, y.
CPB = Puerto Blanco; CP = Proveedora; CB = Duetna; GCP = Cerro Prieto; GA = Arrojos; GT = Tren. Surveyed and
drawn by Ing. A. R. V. Arellano.
Fig. 4.—Profile across Proveedora Hills showing location of formations and collecting localities.
oolitic limestone, and brecciated limestone followed by platy limestone. Thin layers made up of the crowded shells of the peculiar cephalopod *Salterella* appear in the lower part of the section. In this part, too, olenellid trilobites are frequent. In the upper part of the section several characteristic trilobites, *Onchocephalus*, *Antagmus*, and *Bonnia* were collected. The first two define the zone that bears their names and that has a wide distribution in the United States. The Buelna formation measures 331 to 398 feet.

The presence of olenellid trilobites dates this formation as part of the Lower Cambrian sequence, but *Onchocephalus* and *Antagmus* prove the formation to be near the top of the Lower Cambrian.

*Cerro Prieto formation.*—This formation is characterized by its massive and resistant character. It forms the high ridge on the west side of the valley dividing the two main ridges of the Proveedora Hills. This limestone is dark gray to black in color and is without bedding. It often contains wavy banding, possibly produced by flowage. Irregular white calcite veins are another distinctive feature. It also contains some light-colored marble where it occurs near intrusions. The most distinctive character of all, however, is the abundance of dark spherical objects often with indistinct concentric layering. These suggest the probable alga *Girvanella* and occur in countless numbers. This formation is 329 feet thick.

Fossils other than the *Girvanella* mentioned above were not seen in this formation, although a diligent search was made for them. It is thus impossible to date this limestone. It overlies *Olenellus*-bearing Buelna limestone and underlies the Arrojos formation, which contains many Middle Cambrian fossils. Although no diagnostic fossil was found, the formation is here placed arbitrarily in the Lower Cambrian. The type section is in Prieto Hill about 1 ½ miles southwest of Caborca (locality 809).

*Arrojos formation.*—This formation is characterized by the thin-bedded nature of most of its different sediments. It makes a zone of weakness between the two main ridges of the Proveedora Hills. The lowermost 300 feet consists of thin platy limestone, sandy and limy shale, and shale. Fossils are not common, but a few were found in the thin limestones. This sequence is succeeded by 43 feet of olive-gray, smooth-weathering limestone having a blue to blue-gray color on fractured surface. Some of the layers weather to a bright orange-yellow or a light-brown color, making conspicuous patches or bands. The next 138 feet are composed mostly of shale and thin-bedded limestone. The upper 40 feet of this division is in red sandy shale, under-
lain by a conspicuous yellow band. Under this sequence is mostly thin-bedded limestone.

Following the preceding 40 feet is a ledge about 18 feet thick which makes an excellent datum. It forms a high wall on the west side of the saddle between the two hills (pl. 1, fig. 2; text fig. 4).

![Diagram showing stratigraphic sections of Proveedora and Arrojos Hills](image)

Fig. 6.—Columnar sections of Proveedora Hills (A) and Arrojos Hills (B) showing formations. Differences in thickness between the sections are clearly shown.

The succeeding division, 159 feet thick, abounds in fossils characteristic of the Middle Cambrian. In contact with the thick ledge is a cobbly, yellow-weathering limestone containing *Ptarmigania*. Above this, slightly higher in the section, are thin platy limestones containing *Albertella, Mexicaspis* and *Mexicella*, and *Glossopleura*.

The next succeeding 249 feet are composed of thin-bedded limestone
with some heavier-bedded layers. Many of the layers abound in *Girvanella* of various sizes. Near the top of this division *Kootenia* is common in a limestone that weathers bright orange yellow. The top of the section consists of 105 feet of dark shale containing some limestone layers. This shale is mostly covered by talus from the overlying Tren formation.

The Arrojos formation totals about 1,018 feet in thickness. It contains several zones of characteristic Middle Cambrian fossils, consequently no difficulty was experienced in dating this formation, but its correlation with other sections near Caborca is difficult. Although the fossils in the lower part are regarded as of Middle Cambrian age, it must be reported that *Salterella*, normally a Lower Cambrian fossil, was found on the west slope of the valley between the two main ridges. This specimen was not found in place, but it could not have been derived from any other part of the hills by natural means. This can be determined to anyone's satisfaction by examining the panorama of the Proveedora Hills (text fig. 4). It will be noted that the Cerro Prieto formation forms the crest of the highest ridge and effectively separates the *Salterella*-bearing Buelna formation from the Arrojos formation. Consequently, the *Salterella* must have been derived from the lower Arrojos limestone. The type section of the formation is at the north end of the Arrojos Hills, 12 miles west-southwest of Caborca.

*Tren formation.*—Overlying the thin-bedded and often shaly Arrojos formation occur 1,608 feet of dark dolomite, which forms the easternmost and highest ridge of the Proveedora Hills. This is named Tren formation from a similar mass in the Arrojos Hills. The formation is composed almost wholly of dark dolomite with some dark limestone beds and occasional layers of metamorphosed dolomite in the form of finely granular marble. No fossils were found in the section. The type of dolomite is not the kind to produce any fossils. In the Arrojos Hills this formation yielded three trilobite specimens which enabled it to be dated as Middle Cambrian in age. The type section of the formation is in the high hill on the east side of the north end of the Arrojos Hills. In the Proveedora Hills, as in the Arrojos Hills, this formation forms the top of the sequence, but the stratigraphic top of the Tren formation is unknown.

**Cañedo Hill (Cerro de Cañedo) (Locality 812)**

This is a small hill located on the south side of the Magdalena River on the east side of Caborca. The hill forms a monocline with steep dip (30° to 50°) to the south and lies at the north end of a long
chain of igneous hills. It thus has essentially the same relation to an igneous body as the Proveedora Hills, but in the case of the Cañedo Hill the metamorphism has greatly affected the entire mass. The shales, limestones, and sandstones are strongly metamorphosed but not enough to destroy completely the evidences of sedimentation and occasional fossils. Near the top of the hill Salterella was found, thus well establishing the age of the hill as Lower Cambrian.

On the north side of the road to Pitiquito, which goes east through the pass between Cañedo Hill and the igneous mass to the south, limestone and shale were examined which are lithologically similar to the Cambrian on the west side of the Proveedora Hills. Some of the limestone shows faint shadows of Girvanella although the rock is completely altered. In a thin marbleized limestone trilobite fragments and Obolella were identified. The latter dates the sequence as Lower Cambrian and correlates it with the lowest part of the Puerto Blanco formation of the Proveedora Hills.

Prieto Hill (Cerro Prieto) (Locality 809)

Prieto Hill, or Cerro Prieto, is a small, low, rounded eminence located about 1½ miles southwest of Caborca (text fig. 7, A). On the north side of the hill lies a small knob composed of quartzite which forms the lowest of the exposed sequence. The quartzite is 145 feet thick, hard, sugary, vitreous, heavy-bedded, often showing the bedding as black lines or bands. The dip is to the southwest and varies from 11° to 18°. No fossils were seen in it.

The north front of Prieto Hill consists of a steep slope surmounted by a scarp face of massive limestone. The lower part of the slope is made up of thin to moderately heavy-bedded limestone, generally gray to blue-gray in color. In yellowish shale at the base of the hill thin limestones are crowded with Salterella. Higher in the section much of the rock is covered, but the slope is strewn with cobbles abounding in fossils. About 60 feet below the bold cliff, limestone in place yielded numerous trilobites.

The fossils taken from this sequence include Onchocephalus and olenellid trilobites. These clearly indicate correlation with the Buelna formation of the Proveedora section. The formation measures 275 feet thick.

An interesting feature of these limestones is the lime sand in parts of the section. The rock grains strongly resemble oolites, but when the individual spheres are broken they do not show the characteristic concentric layers of oolites. The structure revealed is that of crystalline
calcite. The spheres are evidently grains of clear calcite rounded by wave or current action, forming a calcite "sand."

The main cliff forming the scarp of the hill and the long dip slope to the south are composed of dark-gray to black massive limestone. The upper surface near the brow of the hill shows numerous large

Girvanella on the weathered surfaces. These bodies are of two kinds: one is black and shows crude concentric structure; the other is light gray. This limestone is thus the Cerro Prieto formation, the same massive rock that lies between the Buelna and Arrojos formations in the Proveedora Hills. The capping ledge of Prieto Hill is the locality from which this formation is named. Here it is 267 feet thick. No trace of the Arrojos formation was seen at this place.
DIFUNTOS HILLS (CERROS DE LOS DIFUNTOS) (LOCALITY 802)

This is a small group of hills about 14 miles northwest of Caborca. The easternmost hill consists of thin-bedded yellow to pinkish limestone with some massive reezy lenses containing small Girvanella, particularly at the south end of the hill. Fossils are rare and include pleosponges and olenellid trilobites. These were found loose, but no question as to their place of origin can be raised. The olenellids date the formation as Buelna formation. The occurrence of pleosponges indicates reezy limestone as a facies of this formation. The Buelna formation is overlain by the Cerro Prieto formation.

On the northeast side of the largest hill, thin-bedded fossiliferous limestones occur in the lower part. Thirty to thirty-five feet vertically above the valley floor Albertella and Mexicella are abundant in brownish platy limestone. One hundred and ten feet above the plain Glossopleura is abundant. At the top of the thin-bedded limestone an 18-inch layer of reddish oolitic limestone contains abundant Pachyaspis. These beds are correlated with those in the saddle between the two ridges of the Proveedora Hills (localities 807a-L). The main mass of the western Difuntos Hills is made up of the Tren dolomite formation.

BUELNA HILLS (CERROS DE BUENEA) (LOCALITY 807)

These are two small hills located just south of the railroad about 9 miles northwest of Caborca (text fig. 7, B). The larger hill is here called West Buelna; the smaller is the East Buelna. In the West Buelna an excellent section of the Proveedora quartzite formation appears in the lower part of the section, estimated at 300 feet in thickness. It is here notable for the occurrence low in the section of extensive layers containing vertical tubes of Scolithus (see pl. 11). Blocks nearly 2 feet thick marked by the carbon-filled tubes occur in profusion.

The Proveedora quartzite is overlain by the Buelna formation, about 280 feet of thin-bedded limestone. Just above the quartzite, olenellid trilobites and Salterella are abundant in dark-gray limestone. Above this occur massive light-gray limestones with much calcite veining. This is followed by yellowish limestone with Salterella, Onchocephalus, and Paedeumias. Girvanella is abundant in many parts of the sequence. This is the type section of the Buelna formation.

The top of the section is composed of massive dark-gray limestone containing many small calcite veins. This is the Cerro Prieto formation. The Buelna Hills thus duplicate the sequence seen in Prieto Hill southwest of Caborca (text fig. 7).
Lista Blanca (Locality 811)

Lista Blanca consists of a series of small elongate hills on the south side of the Magdalena River about 5 to 6 miles west-southwest of Caborca and occurs at the north end of a chain of igneous rocks extending for some distance to the south. Actually it occupies a position between two igneous masses; the one on the north is the igneous block on the south side of the Proveedora Hills. Lista Blanca therefore appears to be a block caught in igneous masses on the north and south. Its situation is similar to that of the Proveedora Hills but, as it occupies a position between the two igneous blocks, it is considerably more metamorphosed than the rocks of the Proveedora Hills. For this reason fossils are extremely difficult to find and are poor when found. Nevertheless, the evidence accumulated makes it clear that the rocks of Lista Blanca belong to the Middle Cambrian.

Lithologically the rock of Lista Blanca is a metamorphosed dolomite, some of which is altered to white marble. The latter is especially prominent at the east end of the hills. In a bed of shale about 20 feet thick three specimens definitely recognizable as trilobites were found. These are of Middle Cambrian types, although their precise identification is not possible. Lithologically the Lista Blanca sequence strongly suggests the Tren formation of the Proveedora Hills.

Arrojos Hills (Cerros de los Arrojos) (Locality 800)

The Arrojos Hills are located on the south side of the Magdalena River about 12 miles west-southwest of Caborca. Like the Proveedora Hills and Lista Blanca these hills lie at the north end of a long igneous chain and were affected by the baking action of the intrusion. The northernmost of the Arrojos Hills are not greatly metamorphosed, but when they are followed to the south along the strike of the Cerro Prieto formation, which forms a prominent part of them, the black limestone alters to white marble and the quartzites are baked and considerably altered.

The longest and best section is at the north end of the hills. The lowest beds exposed are in the highest hills. On the west side of this hill a short section of the Proveedora quartzite is followed by the Buelna formation with trilobites and Salterella. The Cerro Prieto formation is prominent and forms the main bulk of the westernmost chain of hills. As elsewhere, it is dark gray to black with calcite veins and black Girvanella. Traced to the south along the hills the Cerro Prieto formation becomes more and more altered as one approaches the igneous body south of the Cambrian hills. On the north side of the
pass between the Cerro Prieto and the igneous body the limestone is altered to marble. On the south side of the pass, baked Proveedora quartzite overlies the igneous rock. Even at the north end of the hills some flow structure is visible. The thickness of the Cerro Prieto formation as measured was about 300 feet.

The Arrojos formation is well exhibited at this place. It is the type section of the formation selected by Dr. Alexander Stoyanow, who named it. It was measured as 620 feet thick, but the accuracy of the figure may well be questioned.

The dip to the east in the lower part of the section is about 20°, but it varies up to 50°. Furthermore, a small fault on the northwest side of the hills makes it impossible to measure the sequence in a continuous section. The lowest beds are greenish, fine-grained slaty shales with thin limestone lenses containing numerous trilobites and brachiopods. Then follows platy limestone, a little red shale, and a fine-grained limestone with conchoidal fracture that weathers orange-yellow. These beds are followed by shales, salmon-weathering limestone and more greenish micaceous slaty shale containing thin limestone layers. The shales often weather red. This shale sequence contains the lowest zone of Glossopleura-Sonoraspis. The shale sequence is capped by a thick bed of banded limestone that forms a ridge of dark-gray to black massive limestone along the brow of the hill. The top beds are oolitic.

The heavy ledge of limestone is succeeded by thin-bedded dark shale containing lenses of limestone. At the base the lenses abound in fossils, particularly the brachiopod Diraphora, the sponge Chancelloria, and the trilobite Kootenia. The dark shales are succeeded by a long sequence of thin-bedded dark-gray limestone containing the trilobite Mexicaspis at the top.

The Mexicaspis beds are followed by another band of slaty shale containing the second Glossopleura-Sonoraspis zone. The shale is dark, splintery, and grades into limestone along its strike. Banded limestone, thin-bedded, oolitic, and with abundance of Girvanella, follows the second Glossopleura-Sonoraspis zone.

The longest sequence of shale, green to black, crumbly and fossiliferous, succeeds the Girvanella beds. This shale contains a variety of trilobites but none of them are very well preserved. Of considerable interest at this level is the occurrence of the trilobite Zacanthoides.

The Arrojos sequence at this place is capped by a band of cobbly yellow-weathering limestone abounding in Acrothele, a typical Middle Cambrian brachiopod. The cobbly beds make a striking contrast to the overlying Tren formation.
The Tren formation is a complicated sequence of limestones and dolomites, some of the beds in places altered to marble. The thickness of the Tren formation as measured was 1,744 feet. As would be expected in a dolomite sequence, especially a considerably altered one, fossils are absent or exceedingly rare. Nevertheless, in the gray granular limestone at the base of the section fossils are fairly common. These are mostly brachiopods, particularly the small conical Pegmatreta.

In spite of its unfavorable lithology, a mottled limestone 1,320 feet above the base produced three poorly preserved trilobite heads. Although these cannot be identified more closely than their genus, they show beyond question that the entire sequence of the Tren formation is of Middle Cambrian age.

ADDITIONAL LOCALITIES OF CAMBRIAN ROCKS

In addition to the localities listed above, a few small isolated hills show parts of the sequence not represented in the sections described or parts not easily located or identified with any portion of the measured sections. These are located west and northwest of the west end of the Proveedora Hills.

Locality 801q.—This may be reached by traveling 0.7 mile (3,468 feet) N. 23° W. of the Proveedora Hills. Here is a small knob of limestone having the strike N. 18° W. and dip 17° to 20° to the southwest. The lowest bed consists of 15 feet of heavy-bedded gray limestone. This is followed by a 10-foot covered interval. The next bed is gray massive limestone showing little bedding. Then follows 5 feet of limestone in beds 6 to 8 inches in thickness containing oolites and fossils: Hyolithes and Salterella. This is followed by thin-bedded sandy limestone, some of it pink in color. On this layer occur two reef masses of pink limestone having thin, wavy bedding and containing pleosponges. These masses are about 20 feet thick. Overlying them is massive gray limestone with numerous calcite veins.

Locality 801x.—About 0.6 mile (3,225 feet) N. 60° W. from the knob just described is situated another small hill composed of massive hard limestone much fractured and with the seams filled by calcite. No fossils were seen in this knob, but its situation in relation to the previous one and those described below suggests that it, too, belongs to the Lower Cambrian.

Locality 801y.—North of this knob occurs another pleosponge reef having a diameter of about 75 feet. The beds dip 36° to the southwest. This reef lies about 0.8 mile N. 48° W. of the first reef (801q).
Locality 807j.—About 0.7 mile (3,750 feet) N. 55° W. of the hill of massive fractured limestone (3,750 yards N. 48° W. of the west end of the Proveedora Hills) occurs a small hill structurally a syncline of sandstone. The lowest bed consists of about 11 feet of massive dark quartzite. This is followed by 11 feet of calcareous dark-brown sandstone. On top of this bed 5 feet of fossiliferous quartzite was measured containing chiefly olenellid trilobite debris. The section is capped by massive quartzite, about 18 feet thick with fossils at the base. This sequence suggests relationship to the Proveedora quartzite, but it is not now possible to be certain of such an assignment.

Locality 8012.—Another hill lies to the southwest of the quartzite hill. This is located S. 75° W. about 4,438 feet. It is a long, low hill composed of limestone beds striking N. 22° W. and dipping 25° to the northeast. About 160 feet of thin-bedded alternating dark and gray limestone is exposed. This is much brecciated at the south end of the exposure. On the north it is bordered by basaltic rock, and a low hill of the same-appearing material lies to the south. The limestone suggests the Tren formation, but no further proof or evidence is available than appearance.

SUMMARY OF CAMBRIAN STRATIGRAPHY AND CORRELATION BETWEEN LOCALITIES

With present knowledge it is easier to understand the correlation between localities of the Lower Cambrian in the Caborca region than with the overlying beds (text fig. 5). The Puerto Blanco formation is known only at the west end of the Proveedora Hills and in the highly altered mass at Cañedo Hill. At the former place, however, a complete section is not present because the base has not been found. No Cambrian beds were seen in contact with any of the Pre-Cambrian rocks on the east side of Caborca or in the vicinity of Pitiquito where pre-Cambrian beds are well displayed. It is not known, moreover, to what part of the section the pleosponge reefs west of the Proveedora Hills are to be assigned. They are definitely Lower Cambrian, but may lie under the Puerto Blanco sequence.

The overlying Proveedora formation occurs in several sections: Prieto Hill, Buelna Hills, Proveedora Hills, sparingly at Arrojos Hills. The quartzite hill west of the Proveedora Hills probably belongs to the Proveedora quartzite, but this is not a certainty.

The Buelna formation is well exposed in several hills, and little difficulty attends its recognition. Excellent exposures occur in Prieto Hill, the Proveedora and Buelna Hills. A less extensive exposure is known in the Arrojos Hills. In the Difuntos Hills this formation
contains pleosponges. This is the only locality at which these fossils were found in a sequence.

The Cerro Prieto formation has the same distribution as the Buelna formation, but its exposures are very extensive in the Proveedora and Arrojos Hills. The occurrence at Prieto Hill is of considerable interest because of the fine development of *Girvanella* on the surface. This hill was previously identified as of Pennsylvanian age and a Caborca series (Gamusa) of beds was established to accommodate these supposed Upper Paleozoic rocks. It is quite probable that the large *Girvanella* of the Cerro Prieto formation were mistaken for Pennsylvanian *Chaetetes* on which the dating was based. The abundance of algae in the Cerro Prieto formation leads to the belief that it may represent a great Cambrian algal reef.

The Arrojos formation is known from two very fine, thick sequences and a shorter section (text fig. 3). Although the bulk of the fossils described in this report came from the Arrojos formation in the Arrojos Hills and Proveedora Hills, the sequences are not well enough known to establish a satisfactory correlation. This is not true of the Arrojos formation exposed in the Difuntos Hills. This short section belongs to the *Mexicella-Mexicaspis-Albertella* zone. This is the same horizon as that located on the east side of the saddle in the Proveedora Hills (locality 801ka-L).

One zone of the Arrojos section seems to correlate with one in the Proveedora sequence. This is the *Kootenia* zone which in both sections contains similar fossils although the lithologies are not alike. Correlation of these two zones, however, does not lead to any other agreement between the two sections. In the Proveedora sequence *Mexicella* occurs under the *Kootenia* zone, whereas in the Arrojos section *Mexicella* is present above *Kootenia*. No structural complications were detected while making the Arrojos section, although they may have escaped notice. It is possible that a considerable facies difference occurs between the two sections.

That a facies difference exists between the two sections is suggested by a comparison of the lithologies. In the Proveedora sequence limestone predominates except in the upper 105 feet from which few fossils were taken because of heavy cover. In the Arrojos section, on the other hand, several important shale beds appear and in each of these fossils characteristic of shales were seen. This is especially true of *Glossopleura-Sonoraspis* which occurs in several parts of the section. *Kootenia* has a long range in the Middle Cambrian outside of Mexico and it is therefore possible that the two Mexican occurrences of this trilobite cannot be correlated. The problem cannot be settled
in this discussion and must await solution in further collecting and reference to other sections.

The Tren formation is known in the Difuntos, Arrojos, and Proveedora Hills. In each place it is chiefly a dolomite which yields few fossils or none at all.

LOCALITIES AND FAUNAL LISTS

Locality 800. North end of the Arrojos Hills, 12 miles west-southwest of Caborca, Sonora.

800a. Arrojos formation, basal shale, on east side of northwesternmost small hill.

*Micromitra* species.
*Pegmatreta rara* Cooper.
*Acrothele* species.
*Dictyonina* species.
*Arellanella caborcana* Lochman.
*A. sonora* Lochman.
*Kistocare tontocensis* (Resser).
*Chancelloria eros* Walcott.
*Hyolithes sonora*, Lochman.

800b. Arrojos formation, first *Glossopleura-Sonoraspis* bed, under heavy ledge of limestone, west face of largest hill.

*Arellanella aff. A. sonora* Lochman.
*Glossopleura-Sonoraspis* species.

800c and c'. Arrojos formation, *Caborcella* bed, base of dark shale about 260 feet above base of section, northwest side of largest hill.

*Diraphora arrojosensis* Cooper.
*Athabaskia bela* (Walcott).
*Caborcella arrojosensis* Lochman.
*Kistocare corbini* Lochman.
*Alokistocarella mexicana* Lochman.
*Kootenia exilaxata* Deiss.
*Hyolithes sonora* Lochman.
*Chancelloria eros* Walcott.
*Helcionella* species undetermined.

800d. Arrojos formation, *Mexicaspis* bed, about 312 feet above base of section, northwest side of largest hill.

*Mexicella mexicana* Lochman.
*Mexicaspis stenopyge* Lochman.
*Problematicum III*

800e. Arrojos formation, upper *Glossopleura-Sonoraspis* bed, northwest side of largest hill.

*Glossopleura-Sonoraspis* species.
*Inglefieldia imperfecta* Lochman.

800e'. Arrojos formation, 15-20 feet below top of uppermost shales with *Zacanthoides*, saddle at north end of largest hill just west of
northernmost knob, just northwest of elbow of canyon in largest hill.

_Glossopleura-Sonoraspis_ species.

_Zacanthoides aff. Z. holopygus_ Resser.

_Inglefieldia imperfecta_ Lochman.

80f. Arrojos formation, _Acrothele_ beds, uppermost 8 feet of yellowweathering cobbly beds at top of Arrojos formation. Saddle on west-side knob at north end of largest hill.

_Dictyonina minutipuncta_ Cooper.

_Acrothele concava_ Cooper.

_Glossopleura-Sonoraspis_ species.

_Inglefieldia imperfecta_ Lochman.

80g. Tren formation, basal limy beds, saddle on southwest-end knob at north end of largest hill

_Dictyonina_ species.

_Acrothele_ species.

_Pegmatreta arellanoi_ Cooper

_Athabaskia minor_ Resser.

_cf. Inglefieldia imperfecta_ Lochman.

80h. Tren dolomite, 1,320 feet above the base, near the top of the northeast-southwest ridge on south side of largest hill.

_Parachlamia_ species undetermined.

Genus and species undetermined 3.

Locality 801. Proveedora Hills on north side of Puerto Blanco, 6-7 miles west of Caborca.

80ib. Puerto Blanco formation, _Obolella_ beds, west end, Proveedora Hills.

_Obolella mexicana_ Cooper.

_Lingulella proveedorensis_ Cooper.

_Olenellus_ species undetermined.

_Salterella_ species.

_Hyolithes aff. H. princeps_ Billings.

_Problematica_ I, II.

80ic. Puerto Blanco formation, 590 feet above base of section, west side, Proveedora Hills.

_Wanneria mexicana prima_ Lochman.

_Zacanthoides aff. Z. holopygus_ Resser.

80id. Proveedora formation.

_Linguella_ species.

_Olenellid trilobite fragments.

80ie. Buelna formation, near center, Proveedora Hills.

_Salterella mexicana_ Lochman.

_Pacidennias puertoblancoensis_ Lochman.

80if. Buelna formation, west central part, Proveedora Hills.

_Paterina_ species.

_Pacidennias puertoblancoensis_ Lochman.

_Onchocephalus buelnensis_ Lochman.

_O. mexicanus_ Lochman.

80ig. Cerro Prieto limestone.

_Girvanella?_ species.
80ih. Base of Arrojos formation, center of the Proveedora Hills.
   *Nisusia* species.
   *Strotocephalus arrojosensis* Lochman.
   *Kochaspis?* species undetermined.
   *Hyolithes* species.
   Genus and species undetermined 2.

80ii. Arrojos formation, 100 feet above base, center, Proveedora Hills.
   *Albertella proveedora* Lochman.
   *Proveedoria starquista* Lochman.
   *Kochaspis?* species undetermined.

80ij. Arrojos formation, cobbly beds with *Ptarmigania*, just above
   ledge on west side of saddle.
   *Ptarmigania bispinosa* Lochman.
   *Mexicella mexicana* Lochman.

80ik. Arrojos formation, *Albertella* beds about 625 feet above base,
   saddle between ridges.
   *Mexicella mexicana* Lochman.
   *Albertella proveedora* Lochman.
   *Kochaspis cooperi* Lochman.

80ika. Arrojos formation, 178 feet above 18-foot-high ledge, 20 feet
   below *Mexicaspis* bed, saddle.
   *Mexicella mexicana* Lochman.
   *Mexicaspis stenopyge* Lochman.

80IL. Arrojos formation, *Mexicaspis* bed, 198 feet above high ledge
   in saddle, 736 feet above base of formation.
   *Wimanella* species.
   *Mexicella mexicana* Lochman.
   *Mexicaspis stenopyge* Lochman.
   *Hyolithes sonora* Lochman.

80im. Arrojos formation, 50 feet above *Mexicaspis* bed, east side
   saddle.
   *Glossopleura leona* Lochman.
   *Pachyaspis isabella* Lochman.
   *Girvanella* cf. *G. sinensis* Yabe.

80im'. Arrojos formation, shaly beds with *Glossopleura* between 801m
   and 80im.
   *Glossopleura* species.

80in. Arrojos formation, *Kootenia* beds, top of hard ledge on east
   slope above saddle.
   *Diraphora arrojosensis* Cooper.
   *Pachyaspis isabella* Lochman.
   *Ahabaskia bela* (Walcott).
   *Alokistocare modestum* Lochman.
   *Alokistocarella mexicana* Lochman.
   *Kistocare corbini* Lochman.
   *Kootenia exilaxata* Deiss.
   *Hyolithes sonora* Lochman.
   *Chancelloria eros* Walcott.
   *Glossopleura leona* Lochman.
   *Zacanthoides aff. Z. holopygus* Resser.
801-o. Arroyos formation, shaly beds between Kootenia beds and Tren dolomite.

*Diraphora arrojosensis* Cooper.
*Alokistocare althea* Walcott.
*Hyolithes sonora* Lochman.


*Albertella proveedora* Lochman.

801q. Lower Cambrian, small hill 0.7 mile N. 23° W. of west end of the Proveedora Hills.

*Ajacicyathus rimouski* Okulitch.
*Syringocnema?* species.
*Ethmophyllum americanum* Okulitch.
*E. whitneyi* Meek.

801q'. Lower Cambrian, just under pleopponge reef.

*Hyolithes aff. H. princeps* Billings.

801t. Buelna formation.

*Salterella mexicana* Lochman.

801y. Lower Cambrian, pleopпонgian reef 0.8 mile N. 48° W. of 801q, west of Cabo Cora, Sonora.

*Archaeocyathus yavorskii* (Vologdin).
*Ajacicyathus nevadensis* (Okulitch).
*Ethmophyllum cooperi* Okulitch.

Locality 802. Difuntos Hills, 14 miles northwest of Caborca, Sonora.

802a. Arroyos formation, 30–35 feet above the valley floor, near the base of the western hill at its northern end.

*Mexicella mexicana* Lochman.
*Mexicaspis difuntosensis* Lochman.
*Pachyaspis* species undetermined.

802b. Arroyos formation, about 110 feet above the valley floor, north end of west hill.

*Mexicella mexicana* Lochman.
*Mexicaspis difuntosensis* Lochman.
*Glossopleura leona* Lochman.
*Kochaspis aff. K. celer* (Walcott).

802c. Arroyos formation, top 10 to 20 feet, north end west hill.

*Pachyaspis deborra* Lochman.
*Glossopleura leona* Lochman.

802d. Upper part of Buelna formation, east hill.

*Coscinocyathus* species.
*Protopharetra* species.
*Cambrocyathus cf. C. occidentalis* Okulitch.

Locality 807. Buelna Hills, 9 miles northwest of Caborca, Sonora.

807a. Lower Cambrian, Proveedora quartzite, west hill.

*Scolithus* species.

807b. Lower Cambrian, Buelna formation, *Olenellus* zone, west hill.

*Olenellus (Olenellus) truncmani* Walcott.
*Wanneria walcottana buelnensis* Lochman.
*Paedeumias puertoblancoensis* Lochman.
Hyolithes whitei Resser.
Salterella mexicana Lochman.
Orthotheca buelna Lochman.

*Paterina* species.
*Olenellus (Olenellus) truemanii* Walcott.
*Paedeumias puertoblancoensis* Lochman.
*Wanneria* species.
*Onchocephalus buelnaensis* Lochman.
*O. mexicanus* Lochman.
*Salterella mexicana* Lochman.

807d. Buelna formation, *Olenellus* zone, east hill.
*Olenellus truemanii* Walcott.
*Salterella mexicana* Lochman.

807e. Buelna formation, *Olenellus* zone, east hill.
*Girvanella mexicana* Johnson.
*Olenellus (Olenellus) truemanii* Walcott.
*Paedeumias puertoblancoensis* Lochman.
*Wanneria* species.
*Salterella* species.

807f. Buelna formation, upper *Salterella* bed, west hill.
*Salterella mexicana* Lochman.

807g. Buelna formation, upper *Salterella* bed, east hill.
*Salterella mexicana* Lochman.

807i. Buelna formation, upper *Salterella* bed, west hill.
*Salterella mexicana* Lochman.

807j. Lower Cambrian, Proveedora formation, quartzite hill 3,750 yards N. 48° W. of west tip of the Proveedora Hills, west of Caborca, Sonora.
*Wanneria?* species undetermined.

Locality 809. Prieto Hill, 1½ miles southwest of Caborca, Sonora.

*Olenellus (Fremontia) fremonti* Walcott.
*Paedeumias puertoblancoensis* Lochman.
*Onchocephalus buelnaensis* Lochman.
*O. mexicanus* Lochman.
*Antagmus solitarius* Lochman.
*A. buttsi* (Resser).
*Sombrerella mexicana* Lochman.
*Bonnia sonora* Lochman.
Genus and species undetermined 1.
*Salterella mexicana* Lochman.
*S. cf. S. pulchella* Billings.
*Hyolithes whitei* Resser.
*Scenella cf. S. reticulata* Billings.

809b. Buelna limestone, *Antagmus-Onchocephalus* zone, beds in place 60 feet below the Cerro Prieto limestone.
*Olenellus* species.
*Onchocephalus mexicanus* Lochman.
Hyolithes species.

Salterella mexicana Lochman.

809c. Cerro Prieto formation, upper surface on top of hill.

Girvanella species.

809d. Buelna limestone, Salterella bed at base of Cerro Prieto.

Salterella mexicana Lochman.

Locality 811. Lista Blanca, 6-7 miles southwest of Caborca, south side of Magdalena River, Sonora.

811a. Middle Cambrian, slaty beds at west end.

Unidentifiable trilobites.


812a. Near top of hill.

Salterella species undetermined.

812b. Lower Cambrian, Puerto Blanco formation (Obolella beds), north side of road in pass between Cañedo sediments and igneous rocks.

Obolella mexicana Cooper.

Trilobite fragments.
GIRVANELLA
By J. HARLAN JOHNSON
Colorado School of Mines
Golden, Colo.

(Plate 6)

Girvanella are lime-secreting algae. They form small nodular calcareous masses composed of numerous tiny entwined tubes. They occur in great numbers in the Cambrian rocks of many parts of the world, having been reported from China (Blackwelder, 1907), Manchuria (Yabe, 1912; Yabe and Ozaki, 1930), Australia (Howchin, 1918; Mawson and Madigan, 1930), Canada (Lewis, 1942), France (Mercier, 1934), and many localities in the United States. The United States Geological Survey, in resurveying the Eureka District, Nevada, found Girvanella in abundance. Hazzard and Crickmay (1933) mention their occurrence in the eastern Mohave Desert of California and give a good illustration of the rock but do not describe the species. In 1937 Hazzard mentioned their wide distribution in Nevada, Arizona, and California and suggested a comparison with the "Girvanella" described by Yabe from Manchuria.

SYSTEMATIC DESCRIPTION

Following the system proposed by Pia (1927 and 1937), the fossils may be classified as follows:

Class: Chlorophyta (possibly Cyanophyta).
Family: Porostromata.
Subfamily: Agathidia.
Genus: Girvanella Nicholson and Etheridge, 1880.

GIRVANELLA MEXICANA Johnson, new species

Plate 6, figures 3-5

Description.—Fossils consist of spherical to elliptical pellets measuring 0.5 to 0.9 cm. in diameter, or 0.6 to 1.0 cm. long and 0.3 to 0.5 cm. high, composed of tubular filaments. Tubes have a surprisingly constant diameter of 0.02 to 0.028 mm., with well-defined, rather thick walls (0.002 to 0.0028 mm. thick). The filaments form a feltlike mat. They are not so strongly twisted as in many species of Girvanella, as

1 See references at end of paper, p. 25.
sections show a considerable length of tube. They occasionally branch.

Remarks.—This species has larger tubes and thicker tube walls than any Girvanella previously described from the Cambrian. The nearest species is Girvanella problematica f. moniliformis Hoeg from the Ordovician. However, G. mexicana differs in a larger average size tube diameter, thicker walls, and less frequent branching.

Holotype.—U.S.N.M. No. 115658a.

Formation and locality.—Buelna limestone (lower), 807e.

GIRVANELLA cf. SINENSIS Yabe

Plate 6, figures 1, 2


Description.—Fossils consist of elongated, flattened elliptical pellets 1.6 to 2.2 cm. long (average about 1.8 cm.) and 0.6 to 0.9 cm. wide (average 0.7 cm.), usually oriented with long axis nearly parallel to the bedding of the rock. They are composed of small tubelike filaments having a diameter of 0.009 to 0.012 mm., with thin walls (0.0009 to 0.0015 mm. thick). Tubes are highly twisted and entwined. They show branching rarely.

Remarks.—It is customary to separate the species of Girvanella on the basis of diameter of tube and thickness of the walls. In appearance and tube diameter this species closely resembles Girvanella sinensis. Unfortunately, Yabe did not give the wall thickness. The pellets of the Mexican material are larger than those described from China. However, the author does not consider this to be a very diagnostic feature as pellets of a species frequently show a wide range in size, even in a single hand specimen, and the Mexican specimens show considerable variation. The species is considered to be close to, if not identical with, Yabe’s species.

Holotype.—U.S.N.M. No. 115659.

Formation and locality.—Arrojos formation, 801m.

REFERENCES

Blackwelder, E.

Hazzard, J. C.

Hazzard, J. C., and Crickmay, C. H.
Howchin, W.
1918. The geology of South Australia, Adelaide, S. Australia.

Kobayashi, T.

Lewis, H. P.

Mawson, D. , and Madigan, C. T.

Mercier, J.

Pla, J.

Yabe, H.

Yabe, H., and Ozaki, K.
PLEOSPONGIA

By VLADIMIR J. OKULITCH

University of British Columbia
Vancouver, Canada

(Plates 7-10)

Most of the specimens described herein come from a low hill, a pleospongian reef, 0.7 mile N. 23° W. of the west end of the Proveedora Hills (locality 801q). A few specimens were collected in another pleospongian reef (locality 801y) 0.8 miles N. 48° W. of the preceding locality. A few specimens were taken from the small eastern hill of the Difuntos Hills. The latter specimens are the only ones collected in a sequence. The two reefs west of the west end of the Proveedora Hills may belong anywhere in the Lower Cambrian section. No hint as to their true position was found in fossils associated with the reefs.

These specimens are of more than average interest because they come from a hitherto unrecorded locality and extend the geographic range of the pleosponges. The nearest localities previously described are in the Waucoba Springs-Silver Peak region of California and Nevada. The collection adds several new forms to the list of North American species and indicates a strong similarity to the California and Nevada fauna. In both localities Ethmophyllum whitneyi is the most common species. All the genera listed belong to the subclass Archaeocyatha of the class Pleospongia.

LIST OF SPECIES

Ajacicyathus nevadensis (Okulitch).
A. rimouski (Okulitch).
Ethmophyllum whitneyi Meek.
E. coaperi, new species.
E. americanum, new species.
Coscinocyathus species.
Archaeocyathus yavorskii (Vologdin).
Protopharetra species.
Cambrocyathus cf. occidentalis Okulitch.
Syringocnema? species.
SYSTEMATIC DESCRIPTION
Class PLEOSPONGIA
Subclass ARCHAEOCYATHA
Order AJACICYATHINA
Family AJACICYATHIDAE

AJACICYATHUS NEVADENSIS (Okulitch)

Plate 7, figures 5, 6; plate 9, figure 4


Ajacicyathus nevadensis Okulitch, Geol. Soc. Amer. Spec. Pap. No. 48, p. 55, fig. 18a, b, pl. 1, figs. 1, 2, 4, 1943.

A small ajacicyathid usually not exceeding a few millimeters in diameter. Most typical representative of Ajacicyathidae in North America. Represented in the collection by three specimens. Characterized by elongated, tubular cups, with simple parietes with few pores. Both inner and outer walls simple, perforated by numerous small pores.

Hypotype.—U.S.N.M. No. 111815.
Formation and locality.—Lower Cambrian, at Silver Peak, Nev., pleospongian reef, 801y.

AJACICYATHUS RIMOUSKI Okulitch

Plate 9, figure 5


Very small acutely conical cups. Closely related to Ajacicyathus nevadensis, from which it differs in parietal coefficient and shape of cup. Represented by one specimen. Poor preservation makes the inner wall appear thickened.

Hypotype.—U.S.N.M. No. 111823.
Formation and locality.—Lower Cambrian, Bic Harbour, Quebec, 801q.

Family ETHMOPHYLLIDAE

ETHMOPHYLLUM WHITNEYI Meek

Plate 8, figures 3-5


This common species is represented in the collection by 11 specimens. The chief characteristic of the species is its inner wall, which consists of an area of vesicular tissue, one or two rows deep.

The inner wall of E. whitneyi is less regular than the wall in E. cooperi, new species, which has a very distinct double row of vesicles. The skeletal elements are thin, enclosing large and irregular empty spaces which are in communication with each other. Very few of the vesicles appear completely enclosed. This observation is at variance with illustrations published by Walcott. The vesicles open into the central cavity. In many cases the inner wall is poorly preserved and the identification has to be based on crenulated inner ends of the parietes and the general appearance of the cup.

_Hypotypes._—U.S.N.M. Nos. 111818a-c.

_Formation and locality._—Lower Cambrian, Silver Peak district, Nev., 801q.

**ETHMOPHYLLUM COOPERI** Okulitch, new species

Plate 7, figures 1, 2; plate 9, figure 4

The new species is represented in the collection by two specimens, exposed in transverse sections. One is fully developed, the other is young. The species is found in association with Ethmophyllum whitneyi and Ajacicyathus nevadensis. The new species has a remarkably regular structure of its inner wall which immediately and unmistakably separates it from all other species of Ethmophyllum.

_General shape._—Unknown, since the specimen is imbedded in a solid fragment of limestone and it seemed unwise to try to clean it out because of the danger of losing it. Total probable diameter 8 mm.

_Outer wall._—Not preserved in the adult specimen; thick and simple in the young, with small pores.

_Intervallum._—The intervallum, counting the vesicular zone, is 3 mm. wide and contains 26 parietes of the Ethmophyllum type, with few or no pores. The parietal coefficient is therefore 3.25. The intervallum coefficient is 3 mm.: 2 mm. or 1.5.

.Inner wall._—Complex, of Ethmophyllum type. The width of the vesicular zone varies from 1 mm. to 1.5 mm. It consists of two to three rows of very regular, almost completely enclosed vesicles, made of rather thick skeletal elements. Their position suggests that they were in the nature of vertical tubular to prismatic canals only slightly inclined to the axis of the central cavity. Because of this inclination the
canals open into the central cavity. They are also in communication with each other and the zone of regular parietes by means of smaller openings, and in places directly open into the interparietal space.

The central cavity is devoid of any skeletal tissue.

*Neptonic stage.*—The second specimen is at the 6-paries stage and has a diameter of about 1 mm. The outer and inner walls, as well as the parietes are very thick. The inner wall shows the early development of the vertical canals as minute circular tubes extending vertically down the wall. If it were not for this feature the specimen could be taken for a young ajacicyathid. It is therefore to be assumed that the spitz is of ajacicyathid type.

The species differs from other Ethmophyllidae in the regularity of the vesicular zone of its inner wall, the completely enclosed, tubular, or canal-like vesicles two or three rows deep, and the parietal and intervallum coefficients.

*Types.*—Holotype, U.S.N.M. No. 111814; paratype, U.S.N.M. No. 111814a.

*Formation and locality.*—Lower Cambrian, pleospongian reef, 801 y.

**ETHMOPHYLLUM AMERICANUM** Okulitch, new species

Plate 7, figures 3, 4

This species is represented in the collection by four specimens. It can be best recognized from a transverse polished or thin section. It has a surprisingly strong resemblance to the Siberian genus *Clathrocyathus*, but conventional outer-wall pores rather than the slitlike ones of *Clathrocyathus* place it with *Ethmophyllum*. It differs from all other American species of *Ethmophyllum* by its very narrow intervallum and large number of parietes.

*General shape.*—Long, tapering conical. Diameter of 9 to 10 mm. Width of intervallum is 1 mm. where diameter of central cavity is 7 mm., giving an intervallum coefficient of 1 mm. : 7 mm. or 0.142.

*Outer wall.*—Thin with numerous small pores arranged in quincunx, five to eight rows of pores per intersept. Pores in places appear clathriform where the wall has become thickened. Thickness of outer wall is 0.054 mm.

*Intervallum.*—Very narrow for the size of the cup, resembling the intervallum of *Clathrocyathus* or *Cambrocyathus profundus* in this respect. Intervallum coefficient varies from 0.142 to 0.162. The intervallum is crossed by numerous straight, radial parietes. The number of parietes is 4 per millimeter, or about 72 for the entire cup, resulting in a very constant parietal coefficient of 7.6. There are no visible pores in the parietes.
Inner wall.—Complex, of Ethmophyllum type. Consists mainly of a single row of elliptical vesicles or S-shaped imbricating skeletal elements with large openings directed obliquely into the intervallum area and the central cavity. Some of the free edges of the S-shaped elements project into the central cavity. The wall is 0.2 mm. thick.

Central cavity.—Large, with a diameter of 7 mm. Contains no other skeletal tissue except the projecting edges of the inner wall. Young stages unknown, but presumably with a spitz of ajacicyathid type. Possibly related to the Siberian genus Clathrocyathus, but more probably an Ethmophyllum.

Holotype.—U.S.N.M. No. 111816.

Formation and locality.—Lower Cambrian, 801q.

Family COSCINOCYATHIDAE

COSCINOCYATHUS species

Plate 9, figures 1A, 2

On the same piece of limestone with Cambrocyathus occidentalis is a naturally weathered longitudinal section of a Coscinocyathus. The preservation is poor and it is impossible to distinguish the details of intervallum structures. There appear, however, to be the usual arched porous tabulae inclined inward and downward. The inner wall appears to be simple, with a single row of pores per intersept. At the base is an indication of some vesicular tissue. This characteristic may possibly indicate that the specimen is a Metacoscinus or Archaeosycon and not a Coscinocyathus.

Holotype.—U.S.N.M. No. 111820.

Formation and locality.—Upper Buelna formation, 802d.

Order METACYATHINA

Family ARCHAEOCYATHIDAE

ARCHAEOCYATHUS YAVORSKII (Vologdin)

Plate 10

Spirocyathus yavorskii Vologdin, United Geol. Prosp. Surv., U.S.S.R., 1931, pp. 40, 110, pl. 3, figs. 9-11, pl. 10, fig. 10; idem, 1932, p. 23, pl. 3, figs. 1, 2, pl. 4, figs. 3-6, 8, text fig. 17.

The species is represented in the collection by one specimen. It is the first time that a definitely Siberian species of Archaeocyathus has been recognized in North America. It has to be admitted, however, that the highly irregular structure of the intervallum in the genus
Archaeocyathus makes it necessary to form an opinion on general resemblance; and since cases of convergence are known among Archaeocyatha the specimen may belong to a distinct species.

The nearest American form is Archaeocyathus atlanticus Billings from the Lower Cambrian of Labrador and Silver Peak region, Nevada. The main distinguishing features are the more open complex intervallum structure consisting of thin curved plates and a different intervallum coefficient from that of A. atlanticus.

Original description of Vologdin follows: "The most typical feature of this form is the most exceptional complexity of splitting of its septa. Transverse sections of the cup reveal complicated branching curved lines, from the feebly developed discontinuity of which we may judge on the faintly developed porosity of the septa."

New description:

General shape.—Unknown, but probably subcylindrical to turbinate. Total diameter of cup about 20 mm.

Outer wall.—Somewhat indefinite because it is made of skeletal elements similar to those within the intervallum, in places continuous where the elements are fused together, in others open with projecting ends of taenia extending a short distance beyond the outer wall. Pore pattern probably irregular, the pores fairly large.

Intervallum.—Filled with taenia, continuous and discontinuous. In part taenia completely enclose the empty spaces, in part form a very loose meshwork of curved anastomosing bars and plates. The structure shows a tendency to become more regular toward the inner wall where radial pattern is more obvious and resembles parietes and synapticulae of the Cambrocyathidae. Pores pierce the taenia in many places and more regularly the parietes. Width of intervallum varies from 8 mm. to 10 mm. while the diameter of inner cavity varies between 6 mm. and 7.5 mm. giving an intervallum coefficient of 8 mm.: 6 mm. or 1.3. This is considerably different from the intervallum coefficient of A. atlanticus which is 0.9. It should be pointed out, however, that the intervallum coefficient is variable and not entirely dependable as a specific characteristic. The more constant parietal coefficient cannot be applied to Archaeocyathus as regular radical septa are practically lacking.

Inner wall.—Indistinct, made of much thinner elements than outer wall, pierced by numerous small pores.

Central cavity.—Narrow, probably tubular or turbinate, with no vesicular tissue in the upper portion. Condition of lower portion and spitz unknown.
Hypotype.—U.S.N.M. No. 111824.
Formation and locality.—Lower Cambrian pleospongian reef, S01y.

PROTOPHARETRA species

Plate 9, figure 1B

On the same piece of limestone with Coscinocyathus species described above are several poorly preserved fragments of Protopharetta. Genus Protopharetta is characterized by an intervallum filled with irregular tissue and a narrow central cavity. These requirements are fulfilled by the specimens. It is likely that the specimens are conspecific with Protopharetta raymondi Okulitch, but poor preservation prevents a definite identification.

Formation and locality.—Upper Buelna formation, 802d.

Family CAMBROCYATHIDAE

CAMBROCYATHUS cf. C. OCCIDENTALIS Okulitch, 1943

Plate 9, figure 3

This species is represented by one partly crushed specimen. However, the simple walls, numerous porous parietes with dissepiments, and the very wide intervallum cause it to be identified tentatively as Cambrocyathus occidentalis. The species is fairly common in the Lower Cambrian of Silver Peak, Nevada. It is distinguished from the other species of Cambrocyathus by having a very wide intervallum with very numerous parietes and synapticulae.

Hypotype.—U.S.N.M. No. 111821.
Formation and locality.—Upper Buelna formation, 802d.

Order SYRINGOCNEMINA

Family SYRINGOCNEMIDAE

SYRINGOCNEMA? species

Plate 8, figures 1, 2; plate 9, figures 6, 7

Three specimens in the collection, evidently belonging to the same species, could not be definitely identified. The mode of preservation is mostly responsible. The specimens, as seen on the weathered surface of the limestone, appeared in oblique longitudinal section. Attempts to polish them gave very little additional information, and the granular nature of limestone in another case prevented the making of a thin section. The organism consists of two walls. The inner and
outer walls are apparently connected by tubes or canals of very thin curved plates. The canals are irregular in cross section, but tend to be hexagonal and are directed outward and downward.

The inner and outer walls are actually made of the ends of these transverse radial tubes and appear as a slender meshwork, each loop of which represents the opening of a tube. The width of the intervallum is small; in the widest part of the specimen not exceeding one-fourth of the diameter of the central cavity. The general shape is tapering tubular, with a diameter of some 6 mm. for a length of 40 mm. Transverse sections were unobtainable, but consideration of the structure suggests that a transverse thin section would resemble that of an *Ethmophyllum* with a very narrow intervallum, and somewhat vesicular inner wall.

A search through the literature indicates that no comparable pleo-sponge was previously collected in North America. The nearest in general appearance and structure would be the Australian genus *Syringocnema* originally described by Taylor (1910) and later amended by Bedford (1936). However, our specimens seem to be distinct from the *Syringocnema favus* Taylor. A more definite description will have to wait until better material is found.

**Figured specimens.**—U.S.N.M. Nos. 111817a, b.

**Formation and locality.**—Lower Cambrian, 801q.

**REFERENCES**

BEDFORD, R., and BEDFORD, W. R.

MEEK, F. B.

OKULITCH, V. J.

RAYMOND, P. E.

TAYLOR, T.
Vologdin, A. G.


Walcott, C. D.

BRACHIOPODA

By G. ARTHUR COOPER

United States National Museum
Washington, D. C.

(Plates 11-13)

INTRODUCTION

Brachiopods can be easily recognized by their bilateral symmetry. The animals possess two shells, which are unequal in size when viewed from the side. When seen from the front, with the beaks vertical, one half of the shell is the mirror image of the other half. The shells were attached to the sea bottom or hard objects by a peduncle protruded from an opening in or under the beak of the larger valve. The brachiopods may be divided into two major groups by the nature of their shell. One group is characterized by a horny shell and the valves of this group are held together only by muscles. The other group has calcareous shells and the valves are fastened together by teeth and sockets. In the Cambrian both of these groups occur but the former is more abundant than the latter. Furthermore, the articulated brachiopods of the Cambrian are quite simple types.

Brachiopods are not usually common in Cambrian rocks anywhere, but when found many individuals of the same species may occur together. Seldom is a variety of genera and species found in the same layer. In the Cambrian near Caborca brachiopods are common at the base of the Puerto Blanco formation and there give their name to the lower faunal zone (Obolella beds). They are fairly common in parts of the Arrojos formation but in other beds they are generally rare animals.

It is seldom that the articulated brachiopods are found in good preservation or that their shells are recovered with both inner and outer surfaces revealed. The locality in the Arrojos formation (locality 800c) that yielded Diraphora arrojosensis is unusual in this respect.

Usually the brachiopods having a horny shell are difficult to obtain in a condition suitable for careful study unless treated chemically. These shells, which are insoluble in acetic acid, may be freed from limestone by dissolving the matrix away. The shells remain in exquisite perfection but they are often so delicate and fragile that they are handled or photographed only with the greatest difficulty. The Sonora
Cambrian contains a number of localities that produce excellent material for etching. The base of the Arrojos formation in the Arrojos Hills (locality 800a) yields Pegmatreta in abundance and Acrotheca and Dictyonina uncommonly. The base of the Tren limestone (locality 800q) in the Arrojos hills is another excellent locality for this type of material.

DESCRIPTION

Genus LINGULELLA Salter, 1866

Linguloidal, rounded or longitudinally oval in outline, biconvex in profile; surface marked by concentric lines and undulations of growth; pedicle valve with bluntly pointed beak and long pedicle groove; brachial valve with rounded beak and thickened posterior inner margin.

LINGULELLA PROVEEDORENSIS Cooper, new species

Plate 13B, figures 4-6

Shell small for the genus, elongate with the length equal to about 1 1/2 times the width; ornamented by fine concentric growth lines and concentric undulations.

Pedicle valve with acutely pointed beak forming an angle of 77°; lateral margins gently convex but with the anterior margin narrowly convex. Widest at about the middle. Lateral profile evenly and very gently convex with the maximum curvature at about the middle. Anterior profile broadly and gently convex, but more so than the lateral profile. Umbonal region narrowly swollen and with steep umbonal slopes. Narrow umbonal swelling continued anteriorly as a low fold but with anteriorly diminishing slopes to about the middle where a fairly even convexity is maintained to the anterior margin. Anterior and anterolateral slopes, convex, long, and fairly steep.

Brachial valve unevenly convex in lateral profile and with the maximum convexity in the posterior third; anterior profile somewhat narrowly convex, with a well-rounded crest and short, steep lateral slopes. Lateral margins broadly rounded and bending somewhat abruptly into the posterolateral margins to give definite shoulders and a subpentagonal form. Apical angle 115°. Anterior margin narrowly rounded. Umbonal region broadly swollen, the swelling gradually merging into the more gentle convexity of the anterior half. Postero-lateral slopes short and steep, becoming progressively less steep anteriorly where the lateral slopes are moderately steep. Anterior slope nearly flat, long and gentle.

Interior.—Details difficult to ascertain and none obtained from the
pedicle valve. Brachial interior with thick low ridge extending from near the beak to about the middle.

**MEASUREMENTS IN MM.**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Greatest width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holotype, pedicle valve</td>
<td>6.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Paratype, brachial valve, U.S.N.M. No. 116040a</td>
<td>6.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Paratype, brachial valve, U.S.N.M. No. 116039b</td>
<td>5.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Paratype, brachial valve, U.S.N.M. No. 116039d</td>
<td>5.2</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**Types.**—Holotype, U.S.N.M. No. 116039a; figured paratypes, U.S.N.M. Nos. 116039b, 116040c; unfigured paratypes, U.S.N.M. Nos. 116040a, b, 116039b-d.

**Formation and locality.**—Puerto Blanco formation (*Lingulella* bed) west end, Proveedora Hills, 801b.

**Discussion.**—Few species of *Lingulella* are known from the Lower Cambrian. This one is similar to *L. granvillensis* Walcott in size and proportions, but has a somewhat more attenuated pedicle valve and a brachial valve with broader shoulders. Furthermore, the interiors of the two species do not agree because the broad and pronounced ridges of the Mexican species are not present in the New York and Vermont specimens.

**Genus PATERINA** Beecher, 1891

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

**PATERINA species**

Plate 11B, figures 7, 8

Shell small for the genus, conical in profile and subcircular in outline; sides and anterior margin rounded; surface marked by strong regular concentric lines.

Pedicle valve forming a misshapen cone; lateral profile moderately convex with the maximum convexity at about the middle; anterior profile strongly convex; median region swollen; umbo and beak prominent. Brachial valve moderately convex in both profiles; median region swollen with moderately long and moderately steep lateral slopes.
Pedicle valve length 1.7 mm., width 1.9 mm., brachial valve length 1.5 mm., width 2.0 mm.

_Figured specimens._—U.S.N.M. Nos. 116050a, b.

_Formation and locality._—Buelna formation, 807c.

_Discussion._—These small specimens seem to be young. The pedicle valve is strongly convex, more so than any known species, but it is fruitless to compare them to adult specimens.

**Genus MICROMITRA Meek, 1873**

Outline, profile, and homoeodeltidium like that of _Paterina_, but surface marked by irregular elevated radial lines crossing the concentric ones.

**MICROMITRA species**

Plate 13 A, figures 1-3

Transversely but broadly elliptical in outline, sides rounded; anterior margin broadly rounded; surface marked by fine, even, elevated concentric lines and irregular radial wrinkles, about five wrinkles to a millimeter at the front margin.

Pedicle valve subconical in outline; gently convex in lateral profile but with the maximum curvature at the umbo; anterior profile strongly convex; beak forming highest part of cone, narrowly rounded and protruding slightly; umbal and median region full; sides narrowly rounded and steep.

Brachial valve with less-elevated beak than pedicle valve; lateral profile moderately convex; anterior profile strongly convex but less so than the pedicle valve; umbal region slightly inflated; median region full; umbal slopes short but gently concave.

**MEASUREMENTS IN MM.**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedicle valve</td>
<td>2.9</td>
<td>3.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Brachial valve</td>
<td>3.2</td>
<td>4.6</td>
<td>0.9</td>
</tr>
</tbody>
</table>

_Specimens._—Figured specimens, U.S.N.M. Nos. 116046a-c; unfigured specimen, U.S.N.M. No. 116046d.

_Formation and locality._—Base of Arrojos formation, 800a.

_Discussion._—The specimens of this species are too fragmentary to warrant a specific name. Nevertheless they cannot be identified with any described species.
Genus DICTYONINA Cooper, 1942

Like Paterina and Micromitra in outline, profile, and homoeodeltidium but external ornamentation consisting of oblique raised lines which produce quincuncially arranged minute pits.

DICTYONINA MINUTIPUNCTA Cooper, new species

Plate II A, figures 1-6

Shell large for the genus, transversely elliptical in outline; biconvex in profile; lateral and anterior margins rounded; surface marked by concentric growth undulations and fine lines of growth, radial wrinkles irregularly arranged and possibly produced by flowage within the limestone and small closely crowded transversely elliptical pits.

Pedicle valve gently convex in lateral profile with the greatest convexity located in the posterior half and anterior half flattened; anterior profile narrowly convex in the median region but sloping fairly steeply on the sides; umbonal region narrowly swollen and prominent, the swelling extending somewhat anterior to the middle where it merges into the flattening anterior portion; umbonal slopes steep and concave; homoeodeltidium short and very thick, forming a callosity at the beak. Apical angle about $125^\circ$-$140^\circ$.

Brachial valve gently convex in lateral profile and broadly convex in anterior profile; beak small, marginal.

**MEASUREMENTS IN MM.**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holotype, pedicle valve</td>
<td>10.4+</td>
<td>11.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Paratype, brachial valve, U.S.N.M. No. 116045b</td>
<td>9.5</td>
<td>10.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Types.**—Holotype, U.S.N.M. No. 116045a; figured paratypes, U.S.N.M. Nos. 116045b-d; unfigured paratypes, U.S.N.M. Nos. 116045e-h.

**Formation and locality.**—Uppermost Arrojos formation (Acrothele bed), 800f.

**Discussion.**—This species is characterized by its erect pedicle beak, small homoeodeltidium, fairly large size, and the fine, densely pitted surface. It is suggestive of D. burgessensis (Resser) but is more finely ornamented. This feature separates the species from other members of this genus except D. nyssa (Walcott), which is a finely ornamented species, but it occurs in a soft shale and the specimens available are too badly crushed to show its true shape.
A second species of Dicthyonina is much smaller than the preceding and with considerably different external form. Indications point to the umbo of the pedicle valve as not being so narrowly convex and prominent as in D. minutipuncta; the ornamentation is somewhat stronger than that of the preceding. Its combination of characters is not like those of any known species but the specimens are too poor for description.

_Figured specimens._—U.S.N.M. Nos. 116044a, d, e.

_Formation and locality._—Tren formation (basal 12 feet of limestone), 800g.

**Genus OBOLELLA Billings, 1861**

Valves subcircular to longitudinally oval in outline, subequally convex in profile; surface marked by concentric lines and undulations of growth, and, when well preserved, by radiating costellae. Pedicle valve with a minute foramen located slightly anterior to the beak.

**OBOLELLA MEXICANA** Cooper, new species

_Plate 12 D, figures 20-31_

Shell small for the genus, subcircular to oval in outline, biconvex, the brachial valve having the greater convexity; surface marked by concentric lines of growth.

Pedicle valve with lateral and anterior margins strongly rounded; posterior produced into an acutely pointed beak. Lateral profile gently convex, with the greatest convexity in the posterior half; anterior half somewhat flattened. Anterior profile broadly and gently convex. Beak long and sharply pointed, very slightly incurved. Pseudointerarea broad. Umbonal cavities moderately deep; opening of pedicle tube on interior large, located just anterior to the umbonal cavities. Muscular and pallial markings not discernible.

Brachial valve nearly circular in outline; fairly evenly and moderately convex in lateral profile; broadly and gently convex in anterior profile. Median sulcus shallow, narrow, extending from the umbo to the anterior margin. Umbonal region moderately swollen. Brachial interior with well-defined posterolateral ridges and a low median elevation, but other details of the musculature and pallial markings not defined.
MEASUREMENTS IN MM.

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holotype</td>
<td>9.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Paratype, U.S.N.M. No. 116056a</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Paratype, U.S.N.M. No. 116051c</td>
<td>6.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Paratype, U.S.N.M. No. 116051d</td>
<td>5.0</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Types.—Holotype, U.S.N.M. No. 116056b; figured paratypes, U.S.N.M. Nos. 116056a, c, 116041a, c, d, f, 116051c, e, f; unfigured paratypes, U.S.N.M. Nos. 116041b, e, 116051a, b, d.

Formation and locality.—Puerto Blanco formation, 8101b, 812b.

Discussion.—This is a small species characterized by its nearly circular form and the low convexity of both valves. In these respects it differs from *O. chromatica* Billings which is a strongly convex species. *Obolella crassa* (Hall) is a much larger species and has a different outline and more convex valves. *Obolella atlantica* Walcott is close but is generally larger and the valves somewhat more convex.

It is interesting to note that this genus commonly is found in crystalline limestone. The Mexican specimens occur in a pinkish crystalline matrix which is highly siliceous. When weathered the *Obolella* shells appear as imprints in a punky brown residue. When fresh the shells have a dull brownish color. *Obolella chromatica*, *atlantica*, and *crassa* occur in crystalline limestone. The former two are in matrix very much like that of the Mexican specimens, a pinkish limestone with pearly luster. A few specimens of *O. mexicana* were taken from white marble.

Genus PEGMATRETA Bell, 1941

Shells minute; pedicle valve a misshapen cone with short posterior pseudointerarea and minute foramen. Pedicle interior with large boss just anterior to foramen and two strong divergent pallial trunks. Brachial valve circular in outline, more or less strongly convex; brachial interior without propareas and with a long, more or less elevated median septum.

PEGMATRETA RARA Cooper, new species

Plate 12 C, figures 10-19

Shell small, forming a low, circular cone in outline; surface marked by fine, elevated concentric lines. Foramen minute.

Pedicle valve gently convex in lateral profile with the deepest part in the umbonal region; anterior slope long and gently convex, steepening somewhat near the front margin; lateral profile somewhat narrowly
convex and with long, steep, flat sides, posterior slope short and
steep; interior with a small, short pedicle callosity, vascula media
widely divergent. Pseudointerarea narrow; intertrough shallow,
narrow.

Brachial valve fairly evenly and strongly convex in lateral profile,
the greatest depth at about the middle; umbo curved in lateral profile;
anterior profile broadly convex with a flattened median area, but short,
moderately steep sides. Beak small, marginal; umbo inconspicuous;
median region swollen and with fairly steep slopes to the margins;
sulcus inconspicuous, narrow, extending from the umbo to the front
margin. Interior with a long but low median ridge; triangular pit
small, deep. Propareas wide but short.

**MEASUREMENTS IN MM.**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holotype</td>
<td>2.2</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Paratype, pedicle valve, U.S.N.M. No. 116059a</td>
<td>2.4</td>
<td>2.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Paratype, brachial valve, U.S.N.M. No. 116059b</td>
<td>2.3</td>
<td>3.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Types.**—Holotype, U.S.N.M. No. 116057d; figured paratypes,
U.S.N.M. Nos. 116057a-c, 116059a, b, d, f, g; unfigured paratypes,
U.S.N.M. Nos. 116059c, e.

**Formation and locality.**—Base of Arrojos formation, Sooa.

**Discussion.**—This species differs from *P. arellanoi* in its much
rounder outline, longer pseudointerarea, less convex profile, more
greatly developed subapical callosity in the pedicle valve, and a less
elevated median septum in the brachial valve.

**PEGMATRETA ARELLANOI** Cooper, new species

Plate 13 C, figures 7-12

Shell minute, forming a depressed cone, elongate oval in outline;
sides gently rounded; anterior margin narrowly rounded; surface
marked by fine concentric lines of growth.

Pedicle valve a depressed cone with a short and steep posterior slope
but long and gently convex anterior slope; greatest convexity located
at about the middle; inside the pedicle valve the prefemoral swelling
is short, narrow, prominent.

Brachial valve almost circular in outline, fairly strongly convex
in lateral profile and about equally convex in anterior profile; interior
with a median septum extending from the posterior margin nearly to
the anterior margin; septum separating two large muscle scars at the
posterior end.
MEASUREMENTS IN MM.

<table>
<thead>
<tr>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>1.8</td>
<td>1.8</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Types.—Holotype, U.S.N.M. No. 116058f; figured paratypes, U.S.N.M. Nos. 116058a, c, e, h; unfigured paratypes, U.S.N.M. Nos. 116058b, d, g.

Formation and locality.—Tren formation (basal 12 feet), 800g.

Discussion.—This species is characterized by its short pseudointerarea, strongly oblique conical form and strong biconvexity. It differs from P. rotunda Bell in its apsacine and shorter pseudointerarea, longitudinally oval outline and strongly convex brachial valve. Pegmatreta perplexa Bell is also a transversely elliptical form and therefore differs markedly from P. arellanoi.

Genus ACROTHELE Linnarsson, 1876

Valves unequal in depth, circular in outline; pedicle valve an irregular cone with a small round foramen on the posterior slope; interior with two widely divergent pallial trunks. Brachial valve gently convex in lateral and anterior profiles. Surface marked by concentric lines and a dense mat of minute pustules.

ACROTHELE CONCAVA Cooper, new species

Plate 12 A, figures 1-6

Shell of about usual size for the genus, subcircular to transversely elliptical in outline; all margins strongly rounded. Surface marked by strong, somewhat wavy concentric undulations. Obscure radial markings occur on the median portions of each valve and extend from the beak to the anterior margins.

Pedicle valve conical, with the apex of the cone located about one-fifth the length from the posterior margin. In lateral profile the anterior slope long and moderately concave; posterior slope flat to gently convex. Lateral slopes steeper than anterior slope and moderately concave. Foramen small, longitudinally and narrowly elliptical, located very slightly posterior to the apex. Pseudointerarea moderately broad, nearly flat but with a faintly impressed median groove extending posteriorly from the foramen to the posterior margin.

Brachial valve very gently convex in lateral and interior profiles; umbonal and posterior regions forming a broad and moderately deeply depressed basin. Anterior and lateral areas gently convex. Beak
slightly anterior to the posterior margin and formed of two shiny points with a short, shallow depression extending a short distance anterior to them.

**Measurements in MM.**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holotype</td>
<td>8.5</td>
<td>9.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Paratype, pedicle valve, U.S.N.M. No. 116035c</td>
<td>4.4</td>
<td>5.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Paratype, brachial valve, U.S.N.M. No. 116035a</td>
<td>8.2</td>
<td>9.3</td>
<td>?</td>
</tr>
</tbody>
</table>

*Types.*—Holotype, U.S.N.M. No. 116035d; figured paratypes, U.S.N.M. Nos. 116035a, c; unfigured paratypes, U.S.N.M. Nos. 116035b, e, f.

*Formation and locality.*—Uppermost Arrojos formation, 8oof.

*Discussion.*—This species is most strongly suggestive of *A. colleni* Walcott in its strongly concave brachial umbo and strongly pyramidal pedicle valve. It differs from the Montana species, however, in having the umbonal concavity covering a somewhat larger area of the posterior and in having a greater convexity of the median area. The pseudointerarea of the pedicle valve of the Mexican species is broader than that of *A. colleni*, the apex of the latter is narrower than that of *A. concava*. The anterior slope is more concave in the Montana species than that of *A. concava*.

Inasmuch as the preservation of the two species is quite different, some of the variations between them may be accounted for by the fact that *Acrothela colleni* occurs in a soft shale and some of the specimens are crushed. *Acrothela concava* occurs in a limestone which shows some signs of flowage. It is therefore difficult to determine the true characters with precision. It seems best to establish the Mexican form as a new species because of the definiteness of its characters, while at the same time admitting the close resemblance.

**Genus NISUSIA Walcott, 1905**

Valves unusual in depth, the pedicle valve hemiconical, the brachial valve gently convex in lateral profile; surface multicoastellate. Delthyrium covered by a convex pseudodeltidium; pedicle apex perforated by a large round foramen; interior with incipient dental plates. Brachial valve sulcate and with primitive brachiophores.

**NISUSIA** species

Plate 13 F, figures 26, 27

Shell of about the usual size for the genus; wider than long, with the hinge equal to, or slightly less than, the width at the middle; car-
dinal extremities acute or nearly rectangular, depending on age. Anterior commissure rectimarginate. Lateral margins gently convex; anterior emarginate because both valves are sulcate. Ornamentation difficult to ascertain in exfoliated specimens, but seems to consist of distant and somewhat irregularly arranged costellae.

Pedicle valve hemiconical in lateral profile but broadly and gently convex in anterior profile and with the median region indented by the sulcus. Umbonal region somewhat elongated and moderately convex, terminating in a narrow beak truncated at its apex by a round foramen. Sulcus originating near beak and extending to anterior margin, shallow and narrow. Flanks bounding sulcus moderately swollen and elevated above sulcus. Slopes to cardinal extremities long and moderately steep. Interarea moderately long, steeply apsacline; pseudodeltidium short, strongly arched.

Brachial valve gently convex in lateral profile; moderately convex and medianly depressed in anterior profile. Umbonal region moderately swollen and protruded posterior to the posterior margin. Sulcus originating on umbo, narrow and shallow and extending to the anterior margin. Flanks somewhat narrowly swollen with steep slopes to the lateral margins and cardinal extremities.

Interior details of both valves obscure.

**Measurements.**—Not one of the specimens available for study is sufficiently complete to take measurements, but the species must have been a fairly large one having a length of at least 12.5 mm. and a width of about 17 mm.

**Figured specimens.**—U.S.N.M. Nos. 116037b, c.

**Formation and locality.**—Basal Arrojos formation, 801h.

**Discussion.**—Inasmuch as all the specimens are shorn of their shells and only impressions of the interior are preserved, it is impossible to make detailed comparisons with other better-preserved species. It is evident that the Mexican shells represent a large form perhaps suggestive of *N. deissi* Bell or *N. montanensis* Bell.

**Genus WIMANELLA** Walcott, 1908

Thin-shelled; subquadrate to subsemicircular; hinge-line straight; biconvex, the pedicle valve having the greater depth; delthyrium open; surface covered by fine concentric lines of growth; pedicle interior with large diductor muscle scars tapering anteriorly, separated dorsally by a low ridge which forks anteriorly about the adductor impression; vascula media prominent. Brachiophores short; billingsellid median ridge low; no cardinal process.
WIMANELLA species
Plate 13 D, figures 13, 14

Small for the genus, subrectangular in outline; wider than long, with the hinge forming the widest part. Sides sloping gently toward the middle; anterior margin broadly rounded. Lateral profile moderately convex; anterior profile fairly strongly convex; surface marked by concentric lines of growth.

Measurements.—Length of figured specimen U.S.N.M. No. 116054, 7.9 mm.; midwidth, 8.7 mm.; hinge width, 9.0 mm.

Figured specimens.—U.S.N.M. Nos. 116054, 116055a.

Formation and locality.—Middle Arrojos formation, 801L.

Discussion.—This species is not quite like any other described, but, because it is known from three specimens only, and all of them are small, one cannot be certain that he is dealing with an adult. Consequently, the species is not named. Most of the known species of Wimanella are much larger than this one and generally have a more quadrate outline. This is true of Wimanella rossensis Resser which is only a moderate-sized shell. The Manchurian species W. takayamai Resser and Endo is comparable in size, but it is much more convex and more transverse.

Genus DIRAPHORA Bell, 1941

Like Wimanella in outline and profiles and with open delthyrium and notothyrium, but surface marked by radial costellae.

DIRAPHORA ARROJOSENSIS Cooper, new species
Plate 13 E, figures 15-25

Shell of about medium size for the genus; subrectangular in outline and slightly wider than long; hinge usually narrower than the greatest shell-width, which is near the middle; cardinal extremities usually obtuse; young specimens with hinge slightly wider than shell at middle and with acutely angular cardinal extremities; lateral margins usually gently convex, but nearly straight or slightly concave if cardinal extremities are acute; anterior margin broadly rounded. Anterior commissure sulcate in young but becoming rectimarginate in mature specimens. Ornamentation consisting of narrowly rounded costellae separated by interspaces equal in size to, or narrower than, the costellae. In a specimen 6 mm. long, 4 or 5 costellae occur in a space of 1 mm. at the front margin.

Pedicle valve strongly convex in lateral profile with the greatest convexity in the posterior half; anterior profile narrowly convex with
steeply sloping sides. Umbo narrowly convex; beak narrow and strongly incurved. Narrowed umbo continued anterior to about the middle as a low fold, but anterior to the middle the convexity gradually decreases to the front margin. Posterolateral slopes steep and gently concave in profile. Anterolateral and anterior slopes moderately convex. Interior moderately long, strongly curved and generally apsacline.

Brachial valve gently to moderately convex in lateral profile in adults but nearly flat in the young; anterior profile nearly flat to broadly and gently convex. Umbonal region sulcate; sulcus well defined, originating in a pit at the umbo, moderately deep in the posterior third to half, but becoming shallow or barely perceptible in the anterior portions. Flanks gently convex; cardinal extremities depressed toward the pedicle valve.

Pedicle interior without dental places; delthyrial cavity moderately deep; adductor track moderately wide; diductor tracks narrow, continuous with the pallial trunks which are not widely separated. Brachial valve with incipient cardinal process, short, stout brachiophores and strongly impressed adductor scars.

**Measurements in mm.**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Hinge width</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedicle valve, U.S.N.M. No. 116042a</td>
<td>7.6</td>
<td>9.2</td>
<td>8.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Pedicle valve, U.S.N.M. No. 116042b</td>
<td>9.6</td>
<td>10.0</td>
<td>9.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Paratypes, brachial valve, U.S.N.M. No. 116042c</td>
<td>7.0</td>
<td>8.5</td>
<td>8.2</td>
<td>?</td>
</tr>
<tr>
<td>Brachial valve, U.S.N.M. No. 116042d</td>
<td>8.6</td>
<td>9.9</td>
<td>7.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Types.**—Holotype, U.S.N.M. No. 116042h; figured paratypes, U.S.N.M. Nos. 116042c, e, g, i, j, 116048a-c; unfigured paratypes, U.S.N.M. Nos. 116042a, b, d, f.

**Formation and localities.**—Arrojos formation, 800c, 801n, 801-O.

**Discussion.**—This species is characterized by its small size, compact and thick shell, and the fairly uniform character of the costellae. It differs from *D. bellicostata* (Walcott) in its smaller size, more rounded form, and more finely costellate valves.

**References**

Bell, C. W.

Cooper, G. A.

Walcott, C. D.
THE ORIGINAL COLLECTION OF CAMBRIAN TRILOBITES FROM SONORA

By ALEXANDER STOYANOW

University of Arizona
Tucson, Ariz.

(Plate 14)

INTRODUCTION

Discovery of Cambrian faunas in Mexico in general, and in Sonora in particular, dates from the time (1941) when Isauro G. Gómez L. and L. Torres, two Mexican geologists then working in Sonora on behalf of Petróleos Mexicanos, brought to me for identification and stratigraphic interpretation the fossils collected in the Magdalena River Valley, northwestern Sonora. After identification of specimens it was agreed, upon the writer’s suggestion, that the name “Arrojos formation” should be applied to the strata characterized by the collected Middle Cambrian trilobites, whereas the underlying beds with algal structures, presumably of pre-Cambrian age, should be referred to as the Jojoba formation.

I was unable to find in the geological literature any previous indication of the presence of Cambrian fossils in Mexico. In either of the two best-known treatises dealing with the Paleozoic stratigraphy of that country—Schuchert’s “Historical Geology of the Antillean-Caribbean Region, or the Land Bordering the Gulf of Mexico and the Caribbean Sea” (1935) and R. E. King’s “Geological Reconnaissance in Northern Sierra Madre Occidental of Mexico” (1939)—and likewise in the publications listed as references in these works, there was no mention of the age of any strata as Cambrian based on paleontological evidence. Realizing that there might have been relevant indications in the undescribed material preserved in the United States National Museum and the United States Geological Survey, I interrogated Dr. C. E. Resser and Dr. J. Bridge on this matter, forwarding photographic pictures of the specimens examined. Both scientists answered in the negative. Dr. Bridge wrote (January 22, 1942):

I know of no Cambrian in Sonora, other than the problematical Cambrian just across the border near Bisbee. I think that this has been discussed by Taliaferro, but he had no fossils, and the correlation was purely on lithology and position.

Resser knows of none.
I have just called Philip King, whose brother has done a lot of work in Sonora, and I have also talked to Ralph Imlay, who has worked there himself, and neither of them knows of any, although they both admit that there is a possibility such as you suggest.

It would appear that you have something new, and I sincerely hope that you get a statement about it into print as soon as possible. I have always thought that the Cordilleran geosyncline must have opened to the southwest, but I never knew of any evidence for it. I am sure that Dr. Schuchert would be much interested in hearing about this.

The purpose of the present article is a description of the original collection of Gómez and Torres on which the presence of Cambrian strata in Mexico was established. To this is added a description of related specimens collected later under the direction of Dr. G. A. Cooper at the type locality and presumably from the same strata.

None of the photographic illustrations of the fossil specimens has been retouched. Many additional details may be seen with a magnifying glass.

DESCRIPTION
SONORASPIS Stoyanow, new genus

In my announcement on discovery of Cambrian trilobites in Mexico (Stoyanow, 1942, pp. 1263-1264), the specimens collected in the Arrojos Hills by Gómez and Torres were listed as Glossopleura, Anoria?, and Alokistocare. The incongruity of placing the related Sonora forms under the first two genera presented itself when it became apparent that, while the thorax of Poulsen’s and Walcott’s genera contained seven segments, the trilobites under description had eight thoracic segments. This characteristic had also been observed in the additional specimens sent to me later by Dr. Cooper. Further studies led to the conclusion that the two species described and illustrated in this paper under Sonoraspis, new genus, have mixed features that would make it difficult to place them either under Glossopleura or under Anoria.

My attention was further attracted by an interesting specimen from the Stephen formation, Mount Bosworth, B. C. (U.S.N.M. No. 62707), included by Walcott in his original description of Dolichometopus boccar (Walcott, 1916, p. 363, pl. 52, fig. 1e). Although, as stated in “Description of Plate 52,” this specimen contains “Pygidium and five thoracic segments flattened in shaly limestone,” it may be inferred from the illustration that it has six thoracic segments in the fragmented left side but eight segments in the complete right side. Another specimen, identified by Walcott as D. productus (Hall and Whitfield, in Walcott, 1916, pl. 53, fig. 2c), also may be interpreted
as having eight segments in the left side of the thorax. Resser, queried on this matter, replied (April 3, 1942):

Regarding the *Glossopleura boccar* to which you refer, 8 segments are visible in the picture and Walcott recorded 5. The specimen is not available for examination, but I would expect to find that the fault is in the drawing. Figure 1e is the holotype and you will observe that it has 7 segments. This species is rare and you will find closer affinities with those from the Grand Canyon where I am adding several new ones. All of your species that I have seen are new and should not be identified with any previously described.

It should be noted in this connection that Poulsen (1927, p. 268, footnote) established his genus *Glossopleura* on all syntypes of *Dolichometopus boccar* Walcott. As far as I am aware at present, Resser had never specified in published works his preference for this questionable specimen as the holotype of *Glossopleura boccar*, and in the critical analysis (Resser, 1935, pp. 29-34) of several species under *Glossopleura* he interpreted Walcott’s species as based on three syntypes: U.S.N.M. Nos. 62703, 62705, and 62707. Syntype No. 62703 (Walcott, 1916, pl. 52, fig. 1a) is better preserved than the rest. Although Resser stated that its cranidial features are imperfect, anterior part of the glabella damaged, and Walcott’s photograph foreshortened, he also added that the defective parts are essentially as in the second syntype, U.S.N.M. No. 62705 (Walcott, 1916, pl. 52, fig. 1c). As to the third syntype, U.S.N.M. No. 62707, it is probable that Resser had in view to separate it as the holotype, as per his letter above. However, his photograph of this specimen reproduced in Shimer and Shrock’s “Index Fossils of North America” (1944, pl. 258, fig. 10) is in no way an improvement over Walcott’s drawing; the critical right side of the thorax is blurred so that it is impossible to be sure about the number of segments. Independently of the number of thoracic segments, this type lacks the entire cephalon, and probably the anterior part of the thorax is seriously damaged.

The first critical comparison between *Anoria* and *Glossopleura* was made by Walcott (1916, p. 373) in his original description of *Dolichometopus tontoensis*:

The species differs from *D. productus* (pl. 53) in having a smaller palpebral lobe, a median spine on each thoracic segment and the ankylosed segments of the axial lobe of the pygidium, also in the enlargement of the fifth thoracic segment. This character is present in the 13 specimens preserving the thorax, and is not present in the 11 associated specimens of *D. productus* . . .

The combination of small eye lobe, median spine on thoracic segments and enlarged fifth thoracic segment, suggests a reversion to primitive characters in this species that might be recognized by a subgeneric name if further investigation justifies it.
Later, when genus *Anoria* was erected (Walcott, 1924, p. 54; 1925, p. 67), the nature and course of facial suture and the presence of tubercles on the anterior axial segments of the pygidium were included in the diagnosis.

Poulsen (1927, p. 268) specified the following principal characteristics as diagnostic of *Glossopleura*: 1, absence of tubercles on the axial segments of thorax and pygidium; 2, lack of macropleural development of the fifth thoracic segment; 3, long palpebral lobes.

**Diagnosis.**—The new genus *Sonoraspis* is established on two new species, *S. torresi* and *S. gomesi*, and is characterized by two features common to both species: the presence of eight segments in the thorax, unlike *Glossopleura* and *Anoria*, which have only seven thoracic segments, and by absence of macropleural development of the fifth thoracic segment, as in *Glossopleura*. The other principal characteristics are so arranged in these two species that it is impossible to place either of them under Walcott's and Poulsen's genera. So, for instance, in *S. torresi*, which lacks the axial tubercles of *Anoria*, the palpebral lobes are short, as in that genus. On the other hand, in *S. gomesi*, which has the axial tubercles, but only in the posterior segments of the thorax and none on the axis of the pygidium, the palpebral lobes are very long, as they are in *Glossopleura*. Other details are presented in the description of the species. If Walcott was right in his interpretation of *Anoria tontoensis* as a species showing a reversion to more primitive forms, the strata with *Sonoraspis* of northwestern Sonora may be stratigraphically older than the *Anoria-Glossopleura* zone of the Cambrian sequence in the Grand Canyon area of Arizona. Summarily, the diagnosis of *Sonoraspis* is as follows: In general appearance the dorsal shield is as in *Anoria* and *Glossopleura* but with eight thoracic segments. Macroleural development of the fifth thoracic segment is absent. Median tubercles may be present on the posterior segments of the thoracic axis. Pygidium with smooth or weakly segmented axis and without tubercles. Palpebral lobes may be short or long in different species.

It may be argued that the forms with tuberculate and smooth thoracic segments should not be placed in the same genus, as was the case with Resser's (1935, pp. 10-11) grouping together both kinds of species under *Anoria*. There are intermediate forms, "*Anoria*" baton and "*Anoria*" bessus (Walcott, 1916, pl. 51, figs. 2, 2a, and 3), which have a cephalon of *Anoria* but, as *Glossopleura*, want tubercles on the seven thoracic segments. It may also be noted that probably there are more than two species in the described assemblage. However, considering the very limited amount and nature of the material available,
I believe that a differentiation of the described eight-segmented forms further than on the basis of certain of their major characteristics, observable also in the seven-segmented Anoria and Glossopleura, respectively, would be unwarranted at this time.

Genotype.—Sonoraspis torresi Stoyanow, new species, is so designated as the first found.

SONORASPIS TORRESI Stoyanow, new species

Plate 14, figures 1-4

The Sonora specimens assigned to this species belong in two sets: (a) two forms represented by a rather large and relatively wide dorsal shield with a gradually tapering axis, as in figures 1 and 2 of plate 14, and (b) two smaller, narrower forms with a more rapidly tapering axis, as shown in figures 3 and 4 of the same plate.

The specimen of the set (a), illustrated in figure i of plate 14, is better preserved. Although the anterior of the cephalon is obliterated, the nature of the posterior parts of the glabella and fixed cheeks, and of the posterolateral limbs is clearly indicated on the cranidium. Of importance is the course of the facial suture as inferred from the outline of the fixed cheek. It is as in Anoria (compare A. baton, A. bessus, A. tontoensis, Walcott, 1916, pl. 51, figs. 2b, 3b; 1925, pl. 18, fig. 16), that is, the facial suture has a wide and shallow embayment in its posterior part and cuts the posterior border of the cephalon closer to the genal angles, which makes the extremities of the posterolateral limbs rather wide, and not as in Glossopleura (compare G. stephen-ensis, G. boccar, G. producta, Walcott, 1916, pl. 52, figs. 1, 1a, 1c; pl. 53, fig. 2) with the facial suture that forms nearly a right angle between the long palpebral lobes and very narrow, shorter, posterolateral limbs.

In all eight thoracic segments the pleural lobes carry oblique pleural furrows strongly impressed from the proximal upper margin to the pleural facet, and terminate in sharp, bent-backward, pleural spines.

Broad and rather short somewhat subtriangular pygidium has a wide and tapering axis composed of five segments and a terminal section which overlaps the marginal furrow on a broad and concave posterior border with an inflection impressed by the doublure posterior to the axis. With the exception of the axis, there is no evidence of distinct segmentation on the pygidium. This specimen is designated as holotype of the species.

The second specimen of the same set, figure 2 of plate 14, is less satisfactorily preserved, and no part of its cephalon is present. Nevertheless, the eight thoracic segments being clearly indicated and the
general resemblance to the specimen just described rather strong, it is considered as conspecific with the holotype. Pygidium is semioval, with a well-outlined pygidial platform on which only one anterior segment is feebly indicated. Eroded condition of the axis, the terminal part of which overlaps the platform, makes it impossible to infer whether it was segmented. Posterior border is strongly concave, with the impressed doublure visible (with a magnifying glass) in its right half.

The first specimen of the set (b) has the posterior part of the facial suture sufficiently preserved in the right side of the cephalon to see that it was as in Anoria, with a shorter palpebral lobe. None of the eight thoracic segments seems to have carried the tubercles, although of this there cannot be an absolute assurance because of eroded condition at the critical parts of the axis. In the suboval pygidium the axis is elevated, semicylindrical, and smooth. However, the anterior segment is feebly indicated on the pygidial platform. This specimen is illustrated in figure 3 of plate 14. Barring the difference is size, it appears to be supplementary to the preceding specimen.

The second specimen of the set (b) is remarkable for its narrow dorsal shield and the rapidly tapering axis. The two visible posterior thoracic segments are free from tubercles. Due to an occasional crack in the posterior right side of the thorax, the last segment appears as macroleural. This is an optical illusion. Actually the pleuron is outlined as its counterpart on the left side. The strongly semicircular pygidium is with a very narrow smooth axis and with an unsegmented pygidial platform. On the same slab, but above, is a cranidium with an Anoria-like facial suture and palpebral lobe. It is too large, however, to belong to the described specimen.

Types.—Holotype, U.S.N.M. No. 116348; paratypes, U.S.N.M. Nos. 116333, 116349-116350.

Formation and locality.—Arrojos formation, probably loc. 8ooe.

SONORASPIS GOMEZI Stoyanow, new species

Plate 14, figures 5, 6

The forms placed in this species have eight thoracic segments, as in S. torresi, but their facial sutures outline a long palpebral lobe, as in Glossopleura, and the posterior thoracic segments carry median tubercles, as in thoracic segments of Anoria, whereas the pygidial axis, unlike Anoria, not only is deprived of tubercles, but does not show any trace of segmentation. The difference from Anoria is enhanced also by the lack of macroleural development in the thorax.
The course of the facial suture is better indicated in the specimen illustrated in figure 6 of plate 14, the holotype. It is quite evident that in this species the two anterior segments of the thorax do not carry tubercles and that the tuberculation is restricted only to six posterior thoracic segments. It also seems that the pleural spines in the thorax are turned backward less abruptly than in S. torresi. The pygidial axis is rather narrow, pointed, and relatively long. Paratype, figure 5 of plate 14, has the pygidial platform better outlined and with anterior segments clearly indicated, whereas in the holotype it is smooth and barely marked off the posterior border.

**Types.—** Holotype, U.S.N.M. No. 116334; paratype, U.S.N.M. No. 116335.

**Formation and locality.—** Arrojos formation, probably loc. 800e.

**AMECEPHALUS? cf. A. PIOCHENSIS** (Walcott)

Plate 14, figures 7, 8

*Ameccephalus piochensis* (Walcott), Smithsonian Misc. Coll., vol. 75, No. 3, p. 66, pl. 15, fig. 9, only, 1925.

Described trilobite is represented by two incomplete conspecific specimens. In one of them (pl. 14, fig. 7) a diagonal break from upper right to lower left has cut off obliquely the anterior part of the dorsal shield leaving intact the entire right side of the thorax but reducing the axis to 14, and the left side of the thorax to 12, complete segments. In the other specimen (pl. 14, fig. 8) a similar break, but running from the left side to the right, removed the preglabellar area, upper right part of the glabella, the entire right side of the cephalon, and the genal spine of the left free cheek of which only a faint impression on the matrix of the slab is observable with a magnifying glass.

The following description is made from both specimens. Dorsal shield oval save for a gradual contraction in the posterior third. Cephalon semicircular, with a wide preglabellar area and a very narrow frontal border. Fixed and free cheeks subequal. Facial suture considerably eroded but fairly visible (with a lens) below and above a small, roundly outlined palpebral lobe. Glabella tapering and lacking both occipital and glabellar furrows, though narrow postrolateral furrows are strongly indicated on the fixed cheeks.

Thorax of 16 segments with dorsal furrows subparallel down to the sixth segment but converging posteriorly. Pleural furrows close to anterior pleural margin from one-third to one-half distance from the axis whence they cut diagonally and pass into the lower margin of
pleural spines. Pleural spines progressively turned backward, becoming vertical and adpressed in the posterior segments.

Pygidium small, broad, smooth, and trilobed, with the axial lobe somewhat short of the posterior margin.

I am strongly impressed by the similarity of these trilobites to one of the forms figured by Walcott (1925, pl. 15, fig. 9) in his illustration of *Amecephalus piochensis*. However, Resser, to whom I submitted photographic pictures of the Sonora specimens, including those herein described, briefly commented (letter of March 30, 1942): “Numbers 4 to 7 all represent one species of *Alokistocare*.” What he apparently had in view was his previous removal of *Amecephalus piochensis* (Walcott) to *Alokistocare*.

In his original description of *Ptychoaria piochensis*, Walcott (1886, p. 201, pl. 26, figs. 2, 2a-b; pl. 28, figs. 1, 1a-e) included nine specimens. Later (1924, p. 54) he restricted the genotype of *Am. piochensis* only to the syntypes illustrated in figure 2 of plate 26 and in figures 1 and 2 of plate 28 of the 1886 publication. In a subsequent paper (Walcott, 1925, p. 66), however, under *Am. piochensis* are listed figures 2, 2a, b of plate 26 and figures 1, 2-2e of plate 28, all of the original publication. As has been mentioned above, Resser (1935, pp. 7-8) placed *Am. piochensis* in *Alokistocare* Lorenz, restricting the species to Walcott’s specimens illustrated in figure 2b of plate 26 and in figures 1, 1a, b, e, of plate 28 of his 1886 description.

One of the principal characteristics of *Alokistocare subcoronatum* (Hall and Whitfield, 1877, p. 237, pl. 2, fig. 1; Walcott, 1916, pp. 182, 187), the genotype, is the presence of a preglabellar boss. Walcott (1925, p. 66) mentioned the tendency toward formation of a preglabellar boss in *Am. piochensis*, adding, however, that this is “a feature which seems to occur in a greater or less degree in nearly all trilobites with a wide frontal limb.” Resser’s comment on the relation between the two genera is as follows (1935, p. 8):

Closer examination shows conclusively that it [*Am. piochensis*] is congeneric with *A. subcoronatum* and must therefore be referred to it as the older genus. Because the specimens are considerably flattened, *A. piochensis* appears somewhat different from *A. subcoronatum*, but if several specimens are carefully examined and variations due to preservation noted, generic distinctions are wanting.

Resser also regarded the entire dorsal shields of *Am. piochensis* as tapering from the cephalon to the pygidium, and pointed out that because of a lesser number of thoracic segments this feature is less pronounced in Walcott’s genus. It should be noted, however, that 19 thoracic segments is the maxium indicated for both *Alokistocare* and
Amecephalus (Walcott, 1916, p. 183; 1925, p. 66), and if the axis and the entire thorax are examined separately, it is quite evident that in the latter genus only the axis tapers rapidly, whereas the entire shield contracts posteriorward gradually, which gives it a characteristically oval appearance, quite unlike the triangular posterior part in Alokistocare. This difference is well seen in such renowned species of Alokistocare as Al. althea Walcott (1916, pl. 25, fig. 4a; Resser, 1945, pl. 2, fig. 7) of which I have good topotypes, and in all illustrations of Am. piochensis in which the dorsal shield is preserved (Walcott, 1886, pl. 28, figs. 1a, 1b; 1924, pl. 9, fig. 1; 1925, pl. 15, fig. 9).

I should like also to point out the absence of occipital furrow in certain described specimens of Amecephalus piochensis (Walcott, 1886, pl. 28, fig. 1; 1924, pl. 9, fig. 1; 1925, pl. 15, figs. 8 and 9), a feature which, on the other hand, is invariably present in Alokistocare (Hall and Whitfield, 1877, pl. 2, fig. 1; Walcott, 1916, pl. 25, figs. 2-4a; Resser, 1945, pl. 22, fig. 7). Resser (1935, p. 8) mentions shallowness of the occipital furrow in his critical description of Am. piochensis. Two more characteristics of Amecephalus should be noted: the shovel-like head, which feature has been incorporated in the generic name, and the tendency of the posterior pleural spines to press against the sides of a small pygidium (Walcott, 1925, p. 66).

Walcott presented the following illustrations of Am. piochensis with the thorax and the pygidium preserved: two drawings, one in his paper of 1886 (pl. 28, figs. 1a and 1b. The specimens of plate 28 marked 1b and 1d have been placed by Resser under certain species of Alokistocare); one, a diagrammatic sketch, in the paper of 1924 (pl. 9, fig. 1); and one, and the only photographic picture with which I compare the described specimens from Sonora, in the paper of 1925 (pl. 15, fig. 9). The diagrammatic sketch, which is said to be of natural size (Walcott, 1924, p. 53), cannot be either the specimen of figure 1a, plate 28, 1886 (less tapering glabella and incomplete cranidium), or that of figure 9, plate 15, 1925 (no glabellar furrows). It may be an enlarged reproduction of a much smaller figure in figure 1b, plate 28, 1886, although there is a considerable variance in the course of facial suture.

There is an appreciable difference in the nature of the frontal border in Walcott’s types, from very narrow (1886, pl. 28, fig. 1b; 1925, pl. 15, fig. 9) through broad to very broad (1886, pl. 28, figs. 1, 1a; 1924, pl. 9, fig. 1; 1925, pl. 15, figs. 8 and 10). Originally Walcott (1886, p. 202) regarded the expansion of the frontal border as a result of individual growth, but later he (Walcott, 1925, pp. 66-67) reconsidered this change in favor of relative proportions in small and large
forms. There is also a mention of a narrow, seldom-preserved rim which limits the periphery of the border. According to Resser (1935, p. 8) the broad frontal border seen in many illustrations of *Am. piochensis* is the result of a pressed doublure.

Besides the general appearance and similarity in the parts of the dorsal shield, the following characteristics are common to *Amecephalus piochensis* (Walcott, 1925, pl. 15, fig. 9 only) and the described forms from Sonora: A very narrow frontal border; lack of glabellar furrows; lack of occipital furrow; to all appearances a similar course of the facial suture; backward orientation of relatively long pleural spines which become more pressed against the body of the dorsal shield in the last segments of the thorax. There may be a slight difference in the relative width of fixed and free cheeks, and the number of thoracic segments is appreciably less in the described trilobite, only 16 against 19. Although, as mentioned above, Resser held that the number of thoracic segments is less in the types of *Amecephalus* than in *Alokistocare*, I could not find a corroboration for this statement. The smallest number, as seen in one of Walcott’s illustrations (1924, pl. 9, fig. 1), is 18.

Since the Sonora specimens are few and incomplete, and because there may be more than one genus within Walcott’s *Amecephalus*, as already has been interpreted by Resser, I have placed the described forms in this genus provisionally, pending the discovery and study of better-preserved material.

*Hypotypes.*—U.S.N.M. Nos. 116337, 116351-116352.

*Formation and locality.*—Arrojos formation, probably loc. 800e.

**INCERTAE SEDIS**

Plate 14, figure 9

In Dr. Cooper’s collection there are two poorly preserved cranidia of which the better specimen is illustrated in figure 9 of plate 14.

Though the specimen is eroded and somewhat deformed, it appears that the glabella is truncated or broadly rounded in front, the occipital and posterolateral furrows are present and of narrow character, and the slightly elevated preglabellar area is strongly separated from a more elevated border by a relatively wide and deep frontal furrow. The second cranidium, not illustrated, supports these observations. It was suggested that such forms may be connected with *Inglefieldia* which was interpreted by Poulsen (1927, p. 261) as closely related to *Amecephalus*, but the nature of the occipital ring and the relation between the preglabellar area and the border seem to be sufficiently different.
No. 1 Original Collection of Trilobites—Stoyanow

Figured specimen.—U.S.N.M. No. 116337.
Formation and locality.—Arrojos formation, probably loc. 800e.

References

Hall, James, and Whitfield, R. P.

King, Robert E.

Poulsen, Chr.

Resser, C. E.

Schuchert, C.

Shimer, H. W., and Shrock, R. R.

Stoyanow, A.

Walcott, C. D.
TRILOBITES

By CHRISTINA LOCHMAN

Chicago, Ill.

(Plates 15-31)

INTRODUCTION

The first Cambrian fossils reported from this region (Stoyanow, 1924) were several trilobite specimens obtained from slates in the Arrojos formation. The many collections upon which the present report is based were made by Dr. G. A. Cooper and Ing. A. R. V. Arellano during the field seasons of 1943 and 1944. Some shale specimens were obtained, but the greater part of the material comes from limestone. These are much better preserved and more satisfactory for study than the shale material.

A more exact age determination can now be made for the several formations that have furnished adequate fossil collections, and correlations with known fossil assemblages in other parts of North America can be attempted. In the Puerto Blanco formation a zone of Obolella shells occurs near the base, and through the upper half occurs a series of beds characterized solely by genera of the Olenellidae. The overlying Proveedora quartzite has furnished a few fragments of Olenellidae. The succeeding Buelna limestone carries a third, very fossiliferous, trilobite bed. The latter appears unquestionably to represent the Antagmus-Onchocephalus zone (Lochman, 1947) at the top of the Lower Cambrian. The first-mentioned zone may be correlated with an Obolella zone reported from near the base of the Lower Cambrian sections in southeastern United States. The highest formation assigned to the Lower Cambrian in the Mexican section, the Cerro Prieto limestone, contains only Girvanella "reefs."

The overlying Arrojos formation carries several faunal zones, all of Middle Cambrian age. The lower beds contain a limited fauna apparently representative of the Albertella zone, and about 100 feet higher appears a very fossiliferous bed characterized by a fauna best correlated with the Glossopleura-Kootenia zone. The few species from the shales in the upper half of Arrojos appear to belong to this zone also. All the overlying Tren dolomite is very poorly fossiliferous. The few specimens obtained from beds near the top serve only to sug-
gest that the rest of the section is also in the Middle Cambrian, and
that no Upper Cambrian rocks occur in this region.

These Cambrian collections contain fossils representative of only
six groups of animals: Sponges, brachiopods, trilobites; Scenella, an
early gastropod; Salterella, a primitive cephalopod; and Hyolithes.
Of these only the trilobites, brachiopods, and Salterella are abundant.
Trilobite fossils dominate Cambrian faunas the world over. Several
factors are believed responsible for this fact. The trilobite, a primitive
member of the highest invertebrate phylum (Arthropoda), was one
of the few animals at this time that had a protective dorsal covering
impregnated with calcium carbonate and thus capable of preservation.
Moreover, these coverings were shed periodically as the animal grew,
thus making available for burial and preservation a large number of
mols. However, paleontologists have long suspected that a normal
fauna of the Cambrian sea contained not only the few types repre-
sented by the fossils, but also many soft-bodied animals possibly
belonging to all the other invertebrate phyla. Proof was finally ob-
tained in 1910 when Walcott discovered the famous fauna of the Mid-
dle Cambrian Burgess shale on Mount Stephen, British Columbia.
Here, owing to a combination of unusual physical conditions at the
time of deposition, an amazing number of soft-bodied Middle Cam-
brian marine animals had been preserved as flattened carbon films
on the shale. These fossils showed that several phyla of worms, the
sponges, sea-cucumbers, jellyfish, and many primitive Arthropoda,
as well as the brachiopods and trilobites, were alive and abundant in
the Cambrian seas.

Thus the Cambrian seaway of Sonora should be pictured as a warm,
sunlit, shallow sea teeming with an abundance of primitive soft-bodied
invertebrates as well as the shelled brachiopods and trilobites. In this
Cambrian fauna the trilobites were probably one of the commonest
and most successful groups, and certainly in their body structure were
one of the most advanced types living at that time.

This paper describes the fossils that have been obtained to date from
this early Cambrian seaway in northwestern Mexico. A fairly large
amount of material was collected, and the 32 genera and 45 species here
described furnish the first detailed information on the Cambrian of
this region. However, the first work in any area should be regarded as
a preliminary report. Many additional problems have been raised
during this study which are now awaiting solution. They should serve
as an incentive for more extensive and detailed work on the Cambrian
stratigraphy and paleontology of Mexico.
STRUCTURE

The Trilobitae are a now extinct class of animals that belong to the great invertebrate phylum Arthropoda. They fulfill the basic requirement of this phylum by possessing jointed legs, a fact fortunately revealed by some rare fossils on which these soft parts are preserved (Raymond, 1920; Störmer, 1939). These appendages consist of a variable number of paired legs and one pair of antennae, all on the ventral surface. The bodies of arthropods are composed of a series of articulating segments which tend to fuse together particularly in the head region. This feature is not unique to the Arthropoda, as it is found in other phyla as well, but in the Arthropoda this fusion has proceeded farther than in other groups.

Figure 8 is a diagram of the complete dorsal covering, or carapace of a trilobite—the part of the animal that was composed of a horny material impregnated with calcium carbonate, and thus capable of being preserved as a fossil. This carapace apparently duplicates faithfully the segmentation of the inner soft body. In the diagram (fig. 8) all the parts of the dorsal carapace are labeled with the terms that are used in this paper. These terms were recently suggested for standard use (Howell, Frederickson, et al., 1947), and the reader is referred
to that paper for a definition of each term and synonyms of terms. Three additional features of the carapace which lie on the ventral surface, the doublure, hypostoma, and metastoma, do not appear in the diagram, but they are defined in the above-mentioned paper.

The carapace on the dorsal surface reveals a striking threefold longitudinal division of the body into a central convex axis and two lateral lower pleural lobes. This division is believed responsible for the name of the class—Trilobitae, three-lobed. The carapace also shows a threefold transverse division produced by the fusion of a number of the anterior and posterior segments of the body. These divisions consist of a head portion called the cephalon, formed of six fused segments (Størmer, 1941) and carrying the important sense organs and the mouth; a middle portion called the thorax, formed of a variable number of freely articulating segments; and a hind portion called the pygidium, composed of a variable number of fused segments and carrying the anus. In the cephalon the axial portion, the glabella, covers the enlarged part of the intestine which serves as a stomach, and probably also the digestive glands around it. The arched construction of the cephalon indicates that there was an appreciable thickness to the cephalon in the fixed and free-cheek areas. Very probably the major nerve ganglia, blood vessels, and the reproductive organs were located within these portions of the cephalon, as is the case in the living Limulus. Such a concentration of body organs in the cephalic region is suggested by the adult structure in the trilobites and also by the embryonic development. In the thorax and pygidium the axis covers the long, segmented abdomen, which probably contained the intestine, a dorsal blood vessel, and a ventral nerve cord. The thin pleural lobes cover and protect the appendages which are attached to the ventral surface of the abdomen and project laterally on each side (fig. 8).

The ventral surface of the trilobite is rarely preserved, because, with the exception of the doublure, hypostoma, and metastoma, it is covered only by a thin, horny ventral membrane. A similar membrane also covers the appendages. The relatively short legs of the trilobite did not lift the animal far off the sea bottom but served only to push it along over the surface. Thus in normal position the ventral surface was naturally protected, and it mattered little that the group was not able to develop a hard ventral covering. But if the trilobite were rolled over by a strong wave or some larger animal, the ventral surface was exposed and the animal was defenseless. By the Middle Cambrian the trilobites had acquired the habit of rolling up into a tight ball when disturbed. The legs were tucked inside, the front of the
Cephalon met the back of the pygidium, the ends of the pleura interlocked along the sides, and the soft ventral surface was completely concealed. The value of this feature is revealed by the fact that all trilobites living after the Cambrian possessed the ability to enroll.

The structure of the trilobite appendage has always been of utmost importance to paleontologists because the classification of the modern Arthropoda is based upon the character of the legs. Through the years students have persistently worked at reconstructing and interpreting the rare finds of trilobite appendages. The reconstructions have differed and the classifications varied, some authors favoring crustacean, others arachnidan affinities. All students agree that the first pair of appendages are jointed antennae. These are followed by a long series of paired legs, the first four pairs on the cephalon being apparently exactly like those on the thorax and pygidium, except for somewhat smaller size. A row of strong bristles, the gnathobases, on the inner edge of the coxa is believed to have served to crush and tear the food and push it into the mouth. Figure 9 gives the latest reconstruction of the trilobite appendage (Størmer, 1939). The appendage consists of a walking leg (the telopodite) of a coxa and seven distal segments, and a proximal segment, the precoxa, which lies against the body. A dorsal branch (the pre-epipodite) originates on the precoxa, consists of a shaft bearing a fringe of flexible filaments, and apparently functions as a gill. There is no clear evidence of a swimming appendage. This reconstruction is considered by Størmer to indicate a close relationship between the Trilobitae and the class Arachnida. The primitive xiphosuran Limulus is generally believed to be the closest living relative of the trilobites.

![Diagram of trilobite appendage with labels]

**Fig. 9.**—Reconstruction of the trilobite appendage.
ECOLOGY

Trilobites are believed to have been important sea-bottom scavengers of the early Paleozoic. During the Cambrian the various genera fully occupied the benthos, crawling actively over the surface, hiding in crevices on reefs, lying partially buried in the bottom sediments, or burrowing slowly through soft mud and sand. The structure of certain later Paleozoic trilobites is interpreted as indicating a semiplanktonic type of life, but there is no evidence of such specializations in the Cambrian forms. I also seriously doubt whether any Cambrian trilobites were truly nektonic, as the structure of the appendages would have made them poor swimmers at best. Moreover, the increasingly strong tendency to enroll to protect the exposed ventral surface does not fit into the nektonic habitat. All living animals using enrollment are rather sluggish benthos.

The trilobite probably crawled forward over the surface bending from side to side in a more or less sinuous manner. This body motion, inherited from the pre-Cambrian wormlike ancestor, was most noticeable in the Olenellidae and other Lower and Middle Cambrian trilobites in which the thorax was composed of many articulating segments and the pygidium was small. It must have been gradually lost as a larger fused pygidium was developed and the muscles of the thorax were changed for enrollment.

With its antennae and its legs, the trilobite explored the sea floor for dead or dying organisms. When found, these fragments were moved toward the mouth either mechanically by the legs or by water currents. They were caught and held at the mouth by the hypostoma and metastoma while the gnathobases tore or crushed them into small enough particles to be swallowed. The primitive mouth parts sharply limited the trilobites' food supply to small, soft, and inactive animals. Although the majority of Cambrian animals were apparently without hard parts, the gnathobases were probably not capable of holding an actively struggling animal.

We may risk certain postulates concerning temperature, depth, and facies adaptations among the trilobites, although it will always be difficult to obtain any positive proof of these deductions. The largest number of trilobite genera and species always occurs in a limestone facies and in such faunal assemblages as to indicate that the majority of the trilobites, like the brachiopods, favored a clear, shallow, sunlit seaway where normal marine conditions permitted slow accumulation of limy oozes. However, many Cambrian genera and species are found in beds of all three types of facies. Some, such as the Middle
Cambrian Zacanthoides and Albertella, show, apparently, a decided preference for a shaly type of facies; while others, such as the Upper Cambrian Crepicephalus or Elvinia, occur in equal abundance in all facies. In this respect the Cambrian trilobites appear to be definitely more primitive and generalized than the later Paleozoic stocks. After the Cambrian a more and more rigid specialization to one particular habitat appears to have developed in most of the surviving genera.

Concerning depth ranges we can only indirectly conclude from the facies distributions that the Cambrian trilobites certainly occupied all depths in the neritic zone. It is possible that certain genera may have penetrated to greater depths.

The cosmopolitan distribution of many Cambrian genera suggests either a ready adaptation of the trilobites to a wide range of temperatures or else a uniformity of temperature over large areas in the Cambrian. Some conclusions can be drawn from analogies with modern faunal assemblages. A fauna such as that of the Glossopleura-Kootenia zone, in which a variety of genera and species is represented by a moderate number of individuals, may be regarded as indicative of warm waters. As the waters become progressively cooler, the variety in the fauna becomes less. In cool-temperate to cold waters the fauna is characterized by an excessive number of individuals of a few limited genera and species. The Upper Cambrian Aphelaspis fauna is considered an excellent example of such a trilobite assemblage in cold waters (Lochman and Duncan, 1944).

COLLECTION AND PREPARATION OF CAMBRIAN FOSSILS

Cambrian trilobites may be found in most types of sedimentary rocks, a fact that demands the use of different techniques of collecting and preparation to fit the different facies. The trilobites from the Sonora region occur in quartzites, shales, limestones, and dolomites.

Cambrian dolomites are notorious for their lack of fossils, and the Tren dolomite at the top of the section is no exception. The best chance of obtaining fossils in such a rock is to locate, if possible, small beds or patches of limestone within the dolomite. This limestone is more likely to be fossiliferous. In the dolomite, persistent and pains-taking breaking of pieces and examination of weathered surfaces may yield a fossil or two, but their discovery will be quite accidental. In the Tren dolomite only three trilobite cranidia were obtained through 1,300 feet of rock, and they were poorly preserved and distorted.

Shales yield attractive fossils, but their appearance is often deceptive. Fossils may be found on pieces exposed at the surface, but fresh
material is preferable for study. Therefore, the outcrop should be cleared to a depth of several feet until perfectly fresh shale is reached. Collecting consists simply of splitting apart the shales with a knife or hammer. Many of the Cambrian green and gray shales are soft and, in order to be transported satisfactorily, must immediately, upon collecting and while still moist, be wrapped tightly in tissue paper, and these small bundles placed in receptacles. Many of these shales crumble when left exposed. The complete trilobite carapace is most apt to be preserved in shale; hence the most interesting fossils to the lay eye are obtained from this facies. But a careful inspection of the specimen reveals that all too frequently it is nothing more than a flat mud mold of the original carapace which has been leached away. Distortion in shales is also quite common. In a few instances in fresh moist shales a thin calcite film retaining the original convexity of the carapace is present. This film is, however, so fragile that it is often broken and lost before the specimen can be wrapped. Although shale and slate specimens make striking and noticeable fossils (the first fossils discovered in this region came from slates), they are poor specimens for study as it is often impossible to determine them specifically or even generically with any degree of accuracy. The carapaces are often distorted or so flattened as to make accurate identification impossible.

A similar situation exists in the case of fossils in sandstone and quartzite. The fossils are generally fine- to medium-grained sand molds of disarticulated carapaces. The specimens do show some convexity, and distortion is relatively rare; but as most of them are internal molds of the carapace, it is hard to be sure of the true depth and width of the furrows and the actual amount of convexity as they would have occurred on the dorsal surface. Moreover, a clear-cut outline is often lacking as the edges blend into the sand grains of the matrix.

Fossils freshly broken from medium- or fine-grained limestone are by far the most valuable specimens for careful study and accurate identification. Such fossils are generally disarticulated parts of the carapace replaced by very fine-grained gray or brown calcite which has preserved accurately all details of the original surface and convexity. In the field each outcrop should be examined thoroughly both vertically and laterally by breaking apart the limestone blocks along planes parallel to the bedding. After a fossiliferous bed has been located in this manner, large pieces of the limestone can be collected to be broken and examined in detail in the laboratory.

However, not all fossils in limestone are good specimens. Many Cambrian sections of western North America contain thin-bedded
dense limestones with shaly partings. Weathering along the shale partings loosens the limestone slabs and etches out the fossils on the surface. The texture of the replacement calcite of the fossil and of the rock matrix is so nearly the same that the weathering affects both at about the same rate. By the time the slab has been loosened and the fossils exposed, the original surface and convexity of the fossil have been irreparably damaged. Cross sections reveal the slabs filled with additional specimens, but they cannot be broken from the matrix. This type of fossil is most disheartening. In the field the slabs are striking specimens usually carefully collected, but, because of the deep weathering, specific identification of the fossils is always uncertain and often impossible. The beds in the Puerto Blanco formation containing *Wanneria mexicana prima* illustrate this type of dense limestone and the preservation of the fossils in it. A considerable amount of material was brought from this horizon, but not a single freshly broken specimen could be obtained.

The cleaning and preparation in the laboratory of all types and sizes of fossils should be done under a low-power binocular (Greenough type) microscope. Small details of the texture both of the fossils and of the rock matrix must be seen and appreciated if the specimen is to be cleaned with maximum efficiency. Only a fine needle, pointed or beveled as desired, should be used for cleaning shale and sandstone specimens. The small pieces of shale or grains of sand should be individually lifted or flaked off until the fossil is completely uncovered.

The limestone specimens should receive the greatest emphasis in preparation as they furnish the maximum return for the effort made. The large blocks of limestone are broken into smaller pieces with a hammer or a wedge; the latter is preferred because the plane of breaking can be more carefully controlled. It is desirable to do most of the rock breaking, specimen examination and trimming in the laboratory because the fossils as they break out are more readily retrieved, and when large or choice specimens are broken through, the pieces can be immediately glued together. Nothing is so discouraging as to open a small field collection and find that several important pieces of a good specimen have been left on the outcrop.

The broken pieces of limestone are then examined under the microscope, and all small fossils or fossils partially covered by the matrix are indicated by a red line or circle. Each piece or specimen has an individual label noting locality, section, and horizon pasted or written on it in India ink at this time. Several short systems employing fractional or decimal numbers, or letters and numbers combined, can be used. Thus each specimen may then be handled separately without
danger of confusion. The matrix is now cleaned from the specimen with a small hand drill and a needle. The coarser drilling—working down the matrix around the specimen—is done with a 5-mm. wheel. Cleaning on the specimen should be done by working off the individual calcite crystals, always under the microscope. By the beginner only needles of varying sizes and edges should be used. With practice and experience the student can learn to flake off the calcite with a 1-mm. wheel in the hand drill, but as successful results depend entirely upon the amount of pressure applied and the feel of the break, it is not recommended for the beginner, since the drill can cut quickly into the specimen. For all finishing and detailed work, only a fine needle should be used. The preparator's finger, a piece of clay, or a coating of cellulose acetate can be used to protect already exposed parts. All broken pieces should be immediately glued in place. The author wishes to emphasize that under no circumstances should acid, no matter how weak, be used on the specimens during preparation. Any strength of acid will etch the surface and thus smooth and destroy the small details that should be observed. During cleaning the needle or drill may unavoidably slip and make a hole or scratch in the calcite of the specimen. The preparator should never try to do anything to remove this hole or scratch because such an attempt will result only in additional damage to the surrounding surface. Excess dust may be wiped off with a soft brush, but the original cleaned surface with scratches must be left untouched. It should be noted that when the specimen is whitened for study and photography, all ordinary scratches fade out and only the deepest holes and cuts are still visible. But they are preferable to the willful damaging of a good specimen by attempting to remove them.

In order to heighten detail in study or making photographs two whitening agents, ammonium chloride and magnesium oxide, may be used. These have different properties and must be handled differently for best results. For sturdy calcite specimens, magnesium oxide may be used. It gives a fine-grained, brilliant coating which does not react with the calcite and so may be left on the specimen for some time. However, it can only be removed thoroughly by vigorous brushing under water. Therefore, ammonium chloride must be used on all shale, sandstone, and delicate calcite specimens. This chemical reacts slowly with calcite and in time will damage the surface so that it should be removed from the specimen immediately after use. A gentle stream of water may be used for some, but for soft shale, friable sandstone, and delicate silicified specimens a drop or two of water or
simply blowing the coating off will suffice. On these more delicate specimens it is best to use whitening only at the time of photography.

IDENTIFICATION OF TRILOBITES

During preparation specimens which look alike may be sorted into separate groups, and the study and identification can start with making generic determinations for these groups. A closer analysis of the characteristics, aided by measurements, must now be made. Peculiarities of preservation and evidences of distortion must be noted. For the trilobites, the greater emphasis in classification is usually placed upon the cranidium. In most Lower Cambrian and many Middle Cambrian species this is the only part of the carapace available, and experience shows that the most diagnostic features of the carapace are often to be found in the cranidium.

A detailed search and careful study of the literature must be made. The student should work out a clear and accurate concept of each genus by an examination of the original description, the illustrations, and, if possible, the actual specimens of the genotype. It is often convenient to use a large card for each genus, on which is noted the original reference and the diagnostic generic characters of the genotype. Then as the literature is examined, all species referred to the genus, with their locality, stratigraphic horizon, and the original reference, may be listed on the card.

After the genus has been satisfactorily determined, the finer specific distinctions must be studied. A large suite of specimens of each species is definitely desirable. It permits a clearer and more accurate picture of the amount of individual variation within a species, and a better idea of the effects of preservation and distortion upon the carapace. It is urged that clear and definite distinctions between species be cited by each student. The laborious searching for some minute difference between two cranidia, or the off-hand erection of a new species because the material is from a new locality, add nothing to our knowledge of Cambrian paleontology or stratigraphy.

DISCUSSION OF THE FAUNAS
LOWER CAMBRIAN FAUNAS
COMPOSITION

Fossils of Lower Cambrian age have been obtained from the Puerto Blanco formation, Proveedora quartzite, and the Buelna limestone. Three stratigraphic horizons of fairly abundant fossils can be recognized. Near the base of the Puerto Blanco formation are beds con-
taining large numbers of *Obolella* shells and sporadic fragments of *Olenellus* cephal.a. Fragments of Olenellidae occur throughout the long series of alternating sandstones and limestones that comprise the Puerto Blanco, but identifiable specimens in abundance occur only in some of the upper limestone beds. These beds carry a new species and variety of *Wanneria* and weathered cephal.a possibly referrable to *Olenellus*. The Proveedora quartzite furnished a few fragmentary cephal.a of *Wanneria* or *Olenellus*, which are believed to belong to the same faunal assemblage as the Olenellidae of the underlying Puerto Blanco. The Buelna limestone carries another very fossiliferous horizon. It appears to represent a distinct and different faunal zone. This horizon has proved very useful in the field as a stratigraphic marker. The faunal assemblage is small in actual numbers of genera and species, but hundreds of cranidia of two species of *Onchocephalus* crowd the limestone beds. The Olenellidae are represented by the widespread western species *Olenellus truemani* Walcott and *Olenellus* (*Fremontia*) *fremonti* Walcott, a new variety of *Wanneria walcottana* (Wanner), and a new species of *Paedeunias*. Three small opisthoparian genera, *Bonnia*, *Antagmus*, and *Sombrerella*, also occur in this fauna.

Several reddish-yellow limestone beds at various levels throughout the Buelna limestone are crowded with the small shells of the primitive cephalopod, *Salterella*. Sporadic specimens of *Salterella* and of the presumed pteropod, *Hyolithes*, were obtained both from the Puerto Blanco and Buelna formations. From the uppermost Lower Cambrian formation, Cerro Prieto, only certain algal remains, tentatively referred to *Girvanella*, were obtained.

**Correlation**

Correlation of the Mexican faunas with those reported from other Lower Cambrian sections of North America may be attempted, but the conclusions must be regarded as tentative because of the present incomplete state of knowledge of this part of the Cambrian sequence. On the Cambrian correlation chart for North America (Howell et al., 1944) four faunal zones are listed. These are, in ascending order, *Obolella* zone, *Bonnia* zone, *Olenellus* zone, and *Syspacephalus* zone. The name of the last zone was changed (Lochman, 1947) to the *Antagmus-Onchocephalus* zone as it was subsequently found that these two genera, rather than *Syspacephalus*, are really the widespread and diagnostic forms of this assemblage. Chart 1 (this paper) gives the Lower Cambrian faunal zones now recognized by the author.
In the Mexican sections the lowest fossiliferous beds contain great numbers of *Obolella* shells. Similar concentrations of *Obolella* shells occur near the base of the Lower Cambrian in southeastern United States. This occurrence led to the tentative proposal of an *Obolella* zone, characterized by a great abundance of *Obolella* shells in association with sporadic specimens of the Olenellidae, usually *Olenellus*. The similarity in faunal composition and stratigraphic position at present suggests that this *Obolella* zone may well represent the same time unit wherever found in North America.

No indication of a *Bonnia* zone has yet been obtained either in the Mexican section or anywhere else in western North America. Its validity is still to be substantiated.

In all Lower Cambrian sections in both eastern and western North America a long series of beds occurs in which genera of the Olenellidae are the predominant and usually the sole members of the trilobite fauna. All these beds are at present lumped together and referred to the all-inclusive *Olenellus* zone. It should be understood, however, that the genus *Olenellus* is definitely not restricted to this zone in the Mexican sequence, nor probably in other Lower Cambrian sections as well. Possibly a more correct name would be the Olenellida zone, with the understanding that it referred to the time of faunal prominence of the group. The considerable stratigraphic thickness occupied by this zone, and the apparent appearance and dominance of different genera at various levels within it suggest that in the future more careful and detailed stratigraphic and faunal studies may affect a subdivision. It should be pointed out, however, that the four age divisions of the *Olenellus* fauna suggested by Walcott (1915) have yet to be substantiated in a complete Lower Cambrian section. There is no evidence of such a subdivision in the Mexican sections, especially that on the north side of Puerto Blanco, which appears to be an uninterupted section through the Lower Cambrian. Neither *Nevadina* nor *Elliptocephala* occurs, and species of *Olenellus*, *Wanneria*, and *Paedeumias* occur together in the same beds. Two fragmentary cephalas of *Olenellus* occur in the *Obolella* beds, and the genus is known to extend through 2,040-2,060 feet of the Lower Cambrian sequence from the base of Puerto Blanco formation to the top of the Buelna limestone. At present those beds above the *Obolella* zone in which only trilobite genera of the Olenellidae occur may be considered the time equivalent of the *Olenellus* zone.

The highest recognized faunal zone of the Lower Cambrian is characterized by the appearance and dominance of several generalized opistharian genera. In the Mexican sections *Olenellus*, *Paedeumias*,
and *Wanneria* are still present in moderate numbers. In other North American sections at this horizon sporadic specimens generally referred to *Olenellus* have usually been recorded. It is customary now to place the end of the Lower Cambrian at the time of the disappearance of the Olenellidae rather than of the rise of the Opisthoparia. The faunal assemblage of the *Antagus-Onchocephalus* zone is characteristic of this time of transition. The occurrence of the two diagnostic genera, *Antagus* and *Onchocephalus*, near the top of many Lower Cambrian sections in North America, suggests that the zone is widespread. At present, knowledge of the complete and characteristic faunal assemblage of this zone is lacking. The horizon of *Olenellus* and *Antagus* in the Grand Canyon sequence (McKee and Resser, 1945), and the Mount Whyte formation of Alberta and British Columbia (Deiss, 1939, 1940) can be considered the time equivalent of the beds with this zone in the Mexican sections.

**MIDDLE CAMBRIAN FAUNAS**

**FAUNAL ZONES**

Two faunal assemblages of the early Middle Cambrian are well represented in the Mexican section, and the highest formation contains elements of a fauna of the later Middle Cambrian. Study of the Mexican sequences and a careful examination of the descriptions of other Cordilleran Middle Cambrian sections have convinced the author that errors and misconceptions are present in the early zones of the Middle Cambrian as indicated in the Cambrian correlation chart (Howell et al., 1944). The difficulty seems to have arisen from two causes. The Middle Cambrian workers have attempted to maintain the details of local sections as regional zones, and they have not fully appreciated the great influence of facies upon the appearance and abundance of certain early Middle Cambrian genera. *Albertella, Zacanthoides*, and *Anoria* are especially good examples, as they occur as quite striking fossils in a shale facies and consequently were readily noticed. The faunal zones as indicated in the Cordilleran sections measured by Wheeler (1943) and Deiss (1938, 1939, 1940) illustrate this feature very clearly.

The author believes that the earliest complete Middle Cambrian faunal assemblage is that which makes its appearance at the base of the Middle Cambrian in what is called the *Kochaspis illiana* zone and continues as a unit through the so-called *Albertella* zone. She proposes that this lowest Middle Cambrian faunal zone and faunal assemblage be known as the *Albertella* fauna, and that the entire faunal assemblage
of this zone be taken into consideration when locating it in a section (see chart 2). At present the following genera are restricted to and diagnostic of this assemblage: Albertella, Strotocephalus, Provededoria, Mexicella, Mexicaspis. As the fauna is studied in more detail throughout the Cordilleran sections, it is to be expected that a more complete list of restricted genera may be established.

The term Kochaspis liliana zone has little if any exact value because the species is not everywhere present in these basal Middle Cambrian beds, and the genus Kochaspis apparently ranges through most of the Middle Cambrian. Kochaspis does appear in the earliest Middle Cambrian beds in many Cordilleran sections, sometimes in such abundance as to attract the immediate attention of stratigraphers; at other places in more moderate numbers associated with other trilobite genera, recognized members of the Albertella fauna. These genera continue to be associated together throughout what has been called the Albertella zone. Albertella itself is capable of appearing anywhere within the range of the zone as recognized by Lochman, but is a genus which, either because of original environmental preference of the living animal or some detail of preservation of the test, occurs most commonly in a shale matrix. Hundreds of shale specimens of Albertella have been obtained to date from this zone, but the author knows of only about 20 limestone specimens. This peculiarity has led to some confusion in the position of Albertella, as only when the fossils occur in abundance in the shales are they noted by stratigraphers. However, the stratigraphic position of shale beds is known to vary in the Cordilleran sections.

In two of the Mexican sections there is an indication of a transitional horizon between the characteristic assemblage of the Albertella zone and that of the overlying Glossopleura-Kootenia zone. The genera Pachyaspis and Glossopleura make their appearance in association with Mexicella, Mexicaspis, and Albertella, and continue into the succeeding beds after these three genera have disappeared. The author has drawn the arbitrary boundary line between the two zones in the Mexican sections after the disappearance of Albertella and Mexicaspis. It must be recognized, however, that there is an interval of time represented here during which the characteristic genera of the Albertella zone were dying out and the characteristic genera of the Glossopleura-Kootenia zone were migrating into the region. Thus when a collection is made from this particular horizon a truly transitional faunal assemblage will be obtained. Such a transitional assemblage is represented also by the fauna of the Ptarmigania strata of the Langston limestone as listed by Williams and Maxey (1941).
The Utah fauna is considered by the author as representing only the very end of the *Albertella* zone because all the characteristic genera except *Albertella* are missing, and the fauna of the immediately overlying Spence shale member is a typical *Glossopleura-Kootenia* assemblage.

The second Middle Cambrian faunal zone recognized by the author contains the faunal assemblage: *Glossopleura, Kootenia, Alokistocare, Anoria, Zacanthoides, Pachyaspis*, and *Athabaskia* (the cited *Clavaspidella* of the Cordilleran region). This assemblage and zone begin in most Cordilleran sections with the appearance of *Glossopleura* and *Alokistocare*. To date *Alokistocare* appears to be fairly widespread and somewhat more restricted in vertical range than *Glossopleura*. The latter genus, while appearing in certain sections before the arbitrary beginning of the zone, is, nevertheless, an especially important member of the assemblage. It has a long stratigraphic range through the entire zone, a wide geographic range, and a valuable impartiality toward different facies.

The author does not recognize the individual identity of a faunal zone characterized by the restricted occurrence of *Anoria* and *Zacanthoides*. These two genera, like *Albertella*, occur most commonly and conspicuously in shale beds. *Anoria* may have a somewhat limited stratigraphic range, but in four widely separated localities these two genera occur with recognized members of the *Glossopleura-Kootenia* fauna. In locality 801-O of the Puerto Blanco section, *Zacanthoides* occurs with *Alokistocare althea* (Walcott), although represented by only a few small, rare specimens, as the matrix is limestone. In the Grand Canyon section (McKee and Resser, 1945) at locality 19 *Anoria* occurs with *Glossopleura* and *Alokistocare althea* (Walcott), and at U.S.N.M. locality 11 *Zacanthoides* occurs with *Kootenia* and *Pachyaspis*. In Utah the Spence shale member of the Langston contains *Zacanthoides, Glossopleura, Alokistocare*, and other genera (Williams and Maxey, 1941). In the British Columbia sections Deiss (1939a, pp. 1017-1018) suggests that *Anoria* and *Athabaskia* are within the *Glossopleura* fauna. The association of all these genera in a single assemblage must be recognized. On chart 2 the author proposes the single faunal zone, *Glossopleura-Kootenia*, to succeed the *Albertella* zone.

No further evidence concerning Middle Cambrian faunal zones could be obtained from the Mexican sections, as the highest formation, the nearly 2,000-foot Tren dolomite, is almost entirely unfossiliferous. Three fragmentary cranidia were obtained from it, and two of them were tentatively referred to *Parehmania*. This genus is a member of
the *Elrathia* stock which becomes prominent in the later half of the Middle Cambrian. It is considered indicative of the presence of the *Elrathiella-Clappaspis* zone (Howell et al., 1944), but no details of the fauna of this zone can be contributed from the Mexican sections. In this connection it should be mentioned that the species referred to *Ehmaniella* from the *Ptarmigania* fauna (Resser, 1939) and most of the species referred to *Parchmania, Ehmania, Elrathia,* and *Elrathiella* from the Grand Canyon sections (McKee and Resser, 1945) do not appear to belong to those genera as defined. They were all examined in the course of this study as it was assumed that there should be some faunal connections between the two regions. A careful revision of the Grand Canyon generic identifications should be made before the faunal lists can be used accurately for correlation purposes.

**COMPOSITION**

The genera of the *Albertella* faunal assemblage in the Mexican sections are: *Kochaspis, Strotocephalus, Albertella, Proveedoria, Mexicella, Mexicaspis,* and *Ptarmigania.* Of these, *Kochaspis* has such a long stratigraphic range as to be unimportant except for the fact that, as usual, it makes its appearance in the earliest recognized Middle Cambrian fauna. *Albertella* is the guide fossil for the zone. *Mexicaspis* is closely related to *Albertella,* and well represented by individuals of two species. It will be interesting to watch future discoveries of *Mexicaspis* to see if it is a southern variant of the *Albertella* stock. It seems much more prominent than *Albertella,* but as the Mexican section is largely limestone at this horizon, it is not possible to draw any definite conclusions from poor representation of *Albertella* in these sections. *Strotocephalus* was previously recognized only from the *Albertella* fauna of the Gordon formation of Montana (Deiss, 1939, p. 38). The genus *Mexicella* will probably prove to be one of the most valuable guide fossils of this zone. It was established for the old "*Agraulos stator* Walcott," more recently "*Alokistocare stator* (Walcott)," which occurs so abundantly in the Ross Lake shale member of the Cathedral dolomite (Deiss, 1939a, p. 1004), and also occurs in a sandstone from Montana. A closely related species occurs abundantly in the Mexican sections. Apparently the individuals of *Mexicella* had no facies preference. The occurrence of a few specimens of *Ptarmigania* in locality 801j, approximately in the middle of the *Albertella* zone, and in association with *Mexicella,* extends the stratigraphic range of this genus down at least to this position. It is possible that *Ptarmigania* may be another genus limited to and diagnostic of the
Albertella zone. Apparently its highest known occurrence is in the Ptarmignania fauna of Utah and Idaho. It is listed (Williams and Maxey, 1941) as being restricted to this horizon and not occurring in the immediately overlying, closely related Glossopleura-Kootenia faunal assemblage of the Spence shale member. Two other genera, Glossopleura and Pachyaspis, make their appearance near the top of the Albertella zone in the Mexican sections. Their significance is mentioned below.

During this discussion of faunas several comparisons with the Middle Cambrian faunas of the Canadian Rockies and Montana have already been made and more will be made in discussing later faunas. In order to avoid misunderstanding, it should be definitely stated that the making of comparisons with northwestern Cordilleran areas does not necessarily indicate that the Mexican sections are most closely related faunally to that region. The necessity of making such comparisons is caused by the fact that only from that region (with the exception of the Grand Canyon sections) have the early Middle Cambrian faunas been even partially described. In the case of the Grand Canyon region some comparisons can be made, but more detailed comparisons are hampered by the rather incomplete faunal representation from that region.

The genera of the Glossopleura-Kootenia assemblage found in the Mexican sections are fortunately many of the common, distinctive, and wide-ranging genera of this zone: Glossopleura, Pachyaspis, Athabaska, Zacanthoides, Kootenia, Alokistocare, and Alokistocarella. Inglefieldia, Kistocare, and Arellanella are also present. In several sections Glossopleura and Pachyaspis, having first appeared at the top of the Albertella zone, continue on after the disappearance of all Albertella zone genera, and together constitute a very early subfaunule before the appearance of the rest of the Glossopleura-Kootenia assemblage. Besides the two above-mentioned genera, Kootenia, Athabaska, Alokistocare, Alokistocarella, and the related zone genus Kistocare appear to be widespread, valuable guide fossils for this zone in all types of facies. Kistocare tontoensis (Resser) is now known both from the Grand Canyon region and the Mexican sections. Zacanthoides can only be expected in noticeable abundance when shale is present. Anoria does not appear in the Mexican sections, though its occurrence in the shales and sandstones of the Grand Canyon region suggests that it could range this far south. Arellanella has not been noted in any previously described fauna. Its close affinities to Pachyaspis are probably significant. Inglefieldia at present has little stratigraphic value, as the only valid species recorded to date are, in the
author's opinion, those from the Cape Kent formation of Greenland and the Mexican species. The single small cranidium identified by Resser as *Inglefieldia idahoensis* from the Langston is clearly a species of *Alokistocare*.

Brief mention should be made at this time of the stratigraphic status of *Kootenia*. Both the zone and faunal assemblage are called *Glossopleura-Kootenia*, and in the Cordilleran sections the appearance and abundance of *Kootenia* are undeniably a valuable aid in recognizing this zone. Yet a tabulation of the various species referred to this genus shows a reported stratigraphic range from the Lower Cambrian nearly to the end of the Middle Cambrian. Two factors seem to be responsible for some, and possibly all, of this confusion. One factor is known to be misidentification of the pygidia, the part most frequently found, with the pygidia of *Olenoides*, a late Middle Cambrian genus. An example is *Kootenia tetonensis* (Miller), so placed by Resser, which is really an *Olenoides*. While this specimen is well-enough preserved that its true identification can be made, many stratigraphers have attempted to assign fragments of pygidia to one or the other genus. Because of the general similarity of pygidia of the two genera, the author does not believe that accurate identification can be made on such fragments. A second factor is the need for a recognition of finer subgeneric distinctions within the genus itself. All the recorded Lower Cambrian specimens are from the Appalachian trough, and, as recently noted by Rasetti (1948), the pygidia of these species always have seven pairs of marginal spines, whereas no Middle Cambrian species is known with more than six pairs. It thus appears that at least in the Cordilleran region the genus *Kootenia* has some stratigraphic value.

Little can be said about the faunal assemblage of the *Elrathiella-Clappaspis* zone as found in the Tren dolomite because only the genus *Parchmania* has been tentatively recognized. This genus was described by Deiss (1939) from what was called by him the *Elrathia-Elrathina* zone in the Pentagon shale. It has since been identified from several other Cordilleran sections, but most of these assignments are incorrect and cannot be depended upon for stratigraphic conclusions.

**Correlation**

The Puerto Blanco section is regarded by the author as the most complete and the only unbroken Middle Cambrian sequence in this region. The faunal succession, as revealed by the collections from this section, indicates that the Arrojos formation is apparently the time equivalent of all the early Middle Cambrian, and the Tren dolomite is
the equivalent of at least the lower half of the later Middle Cambrian.

The lowest Middle Cambrian fauna obtained from this section contains *Strotocephalus* and *Kochaspis*. The beds with these fossils occur just above the top of the Cerro Prieto limestone, the position at which the Lower–Middle Cambrian boundary was drawn on lithologic evidence. There is no indication in this section of any bed or beds carrying an abundance of *Kochaspis liliana* (Walcott). If such a bed were very thin, it might possibly have been covered. The succeeding collections from localities 80ii, 80ij, 80ik, 80ika, and 80iL all carry genera that are typical of the *Albertella* zone. *Kochaspis* also continues to be present. All the beds from the base of the Arrojos formation through 80iL are considered to belong to one faunal zone, the *Albertella* zone. An examination of the Cambrian correlation chart (Howell et al., 1944) will give a general idea of North American correlation. On chart 1 a few of the more important and exact correlations in the Cordilleran region are shown. The lower part of the Arrojos formation can confidently be correlated with the lower half of the Bright Angel shale of the Grand Canyon region, the lower part of the Gordon shale of Montana, and the Ptarmigan formation and lower part of the Cathedral dolomite of British Columbia.

Collections from localities 80im, 80in, and 80i-O of the Arrojos for-
formation all are representative of the *Glossopleura-Kootenia* zone, as indicated on chart 2 and discussed on page 77, the range of the common genera of this part of the section indicates that we are dealing with a single faunal assemblage of which *Zacanthoides* and *Anoria* are regular members. In chart 2 only the Mexican genera are tabulated, but a consideration of the genera of the Spence shale member alone would nearly double the genera of the assemblage. This assemblage will probably become known as one of the richest and most widely distributed of Middle Cambrian faunas when more complete studies in the Cordilleran region have been made. All evidence to

<table>
<thead>
<tr>
<th>Faunal zones recognized in this paper</th>
<th>Puerto Rico Section</th>
<th>Mexico</th>
<th>Eastern Grand Canyon</th>
<th>Arizona (Millard)</th>
<th>Northwestern Montana (P. Ericks and W. M. Desmou)</th>
<th>Sooke Range, B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eriathella-Claparède</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolopus-Glyphaeus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glossopleura-Kootenia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albertella</td>
<td></td>
<td></td>
<td>Bright Angel Shale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anagnostus-Oriochelus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omelloides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophiella</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Cambrian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Chart 2.—Known stratigraphic range of Mexican Middle Cambrian trilobite genera.**

date, with one exception (McKee and Resser, 1945), indicates that *Zacanthoides* is a normal member of the *Glossopleura-Kootenia* fauna. This exception is the occurrence of *Zacanthoides* cf. *Z. walapai* Resser at locality 40, in the Bright Angel shale, 34 feet above the Tapeats transition beds. This position would place it down in the *Albertella* zone, and has not yet been satisfactorily explained as the specimen cannot be found at the United States National Museum. The upper part of the Arrojos formation with the *Glossopleura-Kootenia* faunal assemblage is correlated with the upper part of the Bright Angel shale and a lower portion of the Muav limestone of the Grand Canyon, the highest part of the Gordon shale, the Dam-
nation and the Dearborn limestones of Montana, and the lower part of the Stephen formation of British Columbia.

The Tren dolomite consists of nearly 2,000 feet of beds from which only three poorly preserved cranidia were obtained near the top of the formation. This portion of the Middle Cambrian Mexican section occurs in the Arrojos Hills section which is very much disturbed in the lower half as indicated by the collection from locality 800d of the Albertella zone overlying beds carrying a diagnostic assemblage of the Glossopleura-Kootenia zone, and being in turn overlain by beds with the same faunal assemblage of the Glossopleura-Kootenia zone. However, the uppermost beds of the Arrojos formation and the overlying Tren dolomite appear to be an undisturbed sequence. The tentative identification of Parehmania for two of the cranidia affords a possible correlation with the Elrathiella-Clappaspis zone. There is no evidence of the intervening Bolaspis-Glyphaspis zone, but its presence in the lower portion of the Tren dolomite is quite possible. It is likewise impossible to say whether the rest of the Middle Cambrian time equivalent above the Elrathiella-Clappaspis zone is present in the Mexican sections. Present indirect evidence suggests that all the latest Middle Cambrian is missing from this region.

SYSTEMATIC DESCRIPTIONS

LOWER CAMBRIAN FAUNAS

PROBLEMATICA I AND II

Plate 15, figures 1-3

Two poorly preserved cone-shaped specimens occur in collection 801b in the Olenellus zone assemblage. The specimens might tentatively be referred to an early cap-shaped gastropod except that the poor preservation leads to considerable uncertainty concerning many of the features. One of the specimens appears to have shell fragments adhering to the internal mold which have medium-sized puncta on the inner shell surface. Another difficulty arises from the fact that the preservation is so poor that a distinct outer edge or aperture cannot be determined. As it is impossible to be sure whether these specimens truly belong to any known phylum of animals, or even whether they both represent the same phylum, they have been left unnamed but are figured for stratigraphic reference.

Figured specimens.—Internal mold with shell fragments, U.S.N.M. No. 115660; worn and crushed shell, U.S.N.M. No. 115661.

Formation and locality.—Lower Cambrian, Puerto Blanco formation, 801b.
POSITION UNCERTAIN

HYOLITHES aff. H. PRINCEPS Billings

Plate 15, figures 9-13

Hyolithes princeps Billings, Can. Nat., n.s., vol. 6, p. 216, figs. 4a, b of page 213, 1872.


Original description.—“Shell large, sometimes attaining a length of three or four inches, tapering at the rate of about three lines to the inch. In perfectly symmetrical specimens, the transverse section is nearly a semicircle, the ventral (dorsal) side being almost flat, usually with a slight convexity, and the sides and the dorsum (ventrum) uniformly rounded. In many of the individuals, however, one side is more abruptly rounded than the other, in consequence of which the median line of the dorsum (ventrum) is not directly over that of the ventral (dorsal) side, and the specimen seems distorted. This is not the result of pressure, but is the original form of the shell. Sometimes, also, there is a rounded groove along the median line of the dorsum (ventrum). The latter is somewhat more narrowly rounded than the sides. Lower (upper) lip uniformly convex and projecting about three lines in a large specimen. Surface with fine striae and small subimbricating ridges of growth. These curve forward on the ventral (dorsal) side. In passing upwards on the sides, they at first slope backwards from the ventral (dorsal) edge, and then turn upwards and pass over the dorsum (ventrum) at a right angle to the length.

“When the width of the aperture is seven lines, the depth is about five. The operculum has not been identified.”

Discussion.—A number of specimens of Hyolithes from two different localities have been tentatively assigned to this species. Unfortunately, all the material is in a poor state of preservation so that none of the details of the outer surface can be determined in any of the specimens, nor is it possible to determine whether any of the Mexican specimens have the curved apical tip as in the types. The identification is based particularly on the large size, the character of the transverse section which is exactly like that shown for H. princeps Billings, and the apical angle which averages about 15°.

Walcott also identified this species from the Olenellus zone in the Silver Peak group of Nevada. These specimens, in the author’s opinion, surely represent the same species as the Mexican ones, but their
preservation is also too poor to justify the erection of a new species. It should be noted that this large Hyolithes appears to occupy about the same stratigraphic position at all three localities.

The specimens consist of one 6-inch weathered slab from locality 801b which consists entirely of Hyolithes shells of all sizes. The slab is a very deeply weathered limestone. In this, pieces of shells up to 50 mm. (2 inches) in length can be seen, and transverse sections up to 15 mm. across. Also from locality 801b a number of large but very fragmentary shells have been etched out of limestone. This material is interesting because the shells were covered with a sandy lime ooze which was deposited in very fine cross-bedded laminae. This material sifted into the shell and filled the interior at various angles. Subsequently the original shell material was lost, and this laminated sandy material now forms the fossil specimen. A single piece of fresh limestone from locality 801b was sectioned, and shows on its surface a number of Hyolithes tubes. These are smaller (30 mm. in length) than the others, but appear to have a similar transverse section and are thus tentatively placed here.

**Figured specimens.**—Large etched specimens, U.S.N.M. Nos. 115664, 115665, 115666a; sections in weathered slab, U.S.N.M. No. 115667.

**Formation and locality.**—Lower Cambrian, Puerto Blanco formation, 801b; Lower Cambrian, 801q.

**HYOLITHES WHITEI** Resser

Plate 16, figures 2-6

*Hyolithes primordialis*? (Hall) White, Geogr. Geol. Expl. Surv. West 100th Merid., Preliminary Report Invertebrate Fossils, p. 6, 1874; idem, vol. 4, pt. 1, p. 37, pl. 1, figs. 5a-e, 1875.


**Original description.**—"H. whitei is a rather small species with a thick shell. The posterior side is nearly flat; the anterior is angular giving the tube a nearly equilateral triangular outline. The lateral corners are rounded."

**Discussion.**—Four specimens are tentatively referred to this species. They consist of a very poorly preserved internal mold from one locality and four specimens from a second locality. From among the
latter are two showing a well-preserved outer surface with growth lines and on one the suggestion of two equally spaced longitudinal grooves. The other two are internal molds, one of which has been partially freed from the matrix to show the typically triangular outline. However, it should be noted that neither in *H. whitei* types nor in these specimens does the transverse section form a true equilateral triangle, because by actual measurement the dorsoventral diameter is approximately one-half (a little over) the length of the dorsal side. The lateral angles on the freed internal mold are fairly sharp, but on the more weathered specimen from horizon 809a they are quite rounded. The edge of the dorsal aperture rises 1-2 mm. above the level of the side and ventral margins. The apical angle appears to be about 15° to 17°.

*Hypotypes.*—Three well-preserved specimens (807b), U.S.N.M. Nos. 115670, 115671a,b; weathered shell (809a), U.S.N.M. No. 115669.

*Formation and locality.*—Lower Cambrian, Buelna formation, 807b, 809a.

**ORTHOTHECA BUELNA** Lochman, new species

Plate 15, figures 4, 5

Shell a narrow conical tube, averaging 18-19 mm. in length by 3 mm. in width at the aperture; tapering to a sharp point at apex; apical angle 8°; transverse section perfectly circular with aperture a smooth horizontal circle; internal mold marked by closely spaced, fine concentric grooves, all approximately of the same strength, and very faint thin longitudinal lines running the length of the shell.

*Discussion.*—This species is represented by two specimens, both internal limestone molds, lying close together on the same piece of rock. They have been referred to *Orthotheca* rather than *Hyolithes* because of their apparently circular cross section, more tapered shape, and horizontal aperture. They cannot, however, be identified with any of the described species of *Orthotheca* from the Lower Cambrian, all of which occur in the Atlantic Province. These species differ from *O. buelna* in their less-tapered shape and much smaller apical angle.

*Types.*—Holotype, U.S.N.M. No.115662a; paratype, U.S.N.M. No. 115662b.

*Formation and locality.*—Lower Cambrian, Buelna formation, 807b.
Phylum MOLLUSCA  
Class GASTROPODA  
SCENELLA cf. S. RETICULATA Billings  
Plate 15, figures 6-8

A single specimen of a young Scenella was found in collection from locality 809a associated with an Antagmus-Onchocephalus faunal assemblage. The shell is a small oval cone, with a well-defined aperture, but with the apex of the cone broken and the surface worn so that the concentric rugae and radiating lirae are only faintly suggested. The shape, size, and aperture definitely indicate a juvenile specimen of Scenella but an accurate specific determination does not seem possible with this limited material.

Figured specimen.—Juvenile shell, U.S.N.M. No. 115663.
Formation and locality.—Lower Cambrian, Buelna formation, 809a.

Class CEPHALOPODA  
SALTERELLA MEXICANA Lochman, new species  
Plate 15, figure 14; plate 16, figures 7-11; plate 17, figures 1-5

Shell a small, sharply pointed, perfectly straight cone; the largest complete specimen measuring 8 mm. in length by 2 mm. in width at aperture; most shells average 6 mm. by 1.8 mm. Cross section of shell circular from the apex to the aperture, which is perfectly circular, smooth and horizontal. Apical angle approximately 16°.

Outer surface covered with fine concentric grooves alternating with narrow concentric ridges, which are about two to three times the width of the fine grooves; in the larger shells certain of the concentric grooves about every .25 mm. appear to be slightly deeper, especially near the aperture. The markings appear to be in the nature of growth markings, each ridge marking the addition of a new internal cone. Outer shell layer very thin.

Siphuncle central, small, with circular cross section, wall complete, diameter about one-fourth width of shell measured at bottom of living chamber. Septa thin, steeply inverted cones, arranged very close together, the space between each septum being approximately the same as the width of the septum; living chamber occupying almost but not quite one-half the length of the shell.

Discussion.—The specimens representing this species occur in very large numbers at several localities and several horizons throughout the Olenellus zone. According to the kind of preservation, several different
aspects of the shells are presented and these have been very useful in elucidating the structure. Those with well-preserved exterior surfaces present the annulled appearance as described above, while many weathered specimens appear to be quite smooth. The well-known cone-in-cone effect, from which *Salterella rugosa* Billings derived its name, is clearly caused by the removal of the outer shell layer and the exposure of the internal septal structure. Frequently the siphuncle and living chamber have been filled with extraneous material so that on weathered surfaces this internal mold and the hollow external mold are all that remain. In another type of weathering a longitudinal section is produced which shows a single cone within the shell. This appears to the author to be the wall of the living chamber that has been replaced by calcite. The best specimens for study are some artificial sections made at all angles, simply by cutting pieces of the rock containing innumerable specimens. In most of these sections the siphuncle and living chamber show up very well, but the numerous septa are less common in occurrence, as in many specimens they appear to have been subsequently replaced entirely by a crystalline calcite, which shows little or no structure.

This species is similar to *Salterella rugosa* Billings of which only weathered cone-in-cone interiors are known. Poulsen referred the extremely abundant specimens from Greenland to Billings’s species and from his Greenland specimens described the internal structures of siphuncle and septa. The discovery of the Mexican specimens indicates that Billings’s types from Anse du Loup, Canada, do not show any features of real specific significance, as weathered specimens from all three localities will show the same cone-in-cone effect. Poulsen reports the exterior surface of his specimens to be smooth, but, unfortunately, the exterior is not known of any of Billings’s types. Certainly the Mexican specimens show distinct differences as compared to the Greenland specimens: (1) Concentric grooves and ridges on the exterior surface; (2) the living chamber is much larger, nearly one-half the length of the shell as compared to one-third to two-fifths; (3) the septa are thin, closely packed, and show no branching at the outer walls; (4) the siphuncle is a definite tube wider in proportion to the width of the shell. At present no certainty exists as to whether the types of *Salterella rugosa* Billings have an internal structure like that of the Mexican specimens or the Greenland specimens, so actually doubt must remain as to the specific assignment of both these species.

The Mexican species can be definitely said to show no real relationship to *Salterella expansa* Poulsen or *S. conulata* Clark, if the internal
structure given for these species is correct. Nor does it show any striking similarity to the primitive orthoceroid and hyolithid internal structure as depicted by Kobayashi (1937).

The shell coquinas which the Mexican specimens form suggest accumulation of the shells by wave action. In nearly all collections the Salterella shells occur in separate beds, and only at locality 807b do they occur mixed with trilobite carapaces. Otherwise, while the Salterella coquinas may be interbedded with trilobite-bearing limestone, the two types of beds are generally mutually exclusive.

Types.—Holotype, small section showing septa and siphuncle (807g), U.S.N.M. No. 115677a; paratype: sections showing living chamber and siphuncle (807g), U.S.N.M. No. 115677b; piece showing longitudinal and transverse sections with many septa (807g), U.S.N.M. Nos. 115674a-c; specimens with external ornamentation (809a), U.S.N.M. Nos. 115675a, 115678; specimens showing weathered cone-within-cone effect (807b), U.S.N.M. Nos. 115672a, 115673a; specimens showing internal mold of living chamber and siphuncle and external mold of shell (801t), U.S.N.M. No. 115676.

Formation and locality.—Lower Cambrian, Buelna formation, 807, 807f, 807g, 809a, 809d, 801t; Puerto Blanco formation, 801q.

SALTERELLA cf. S. PULCHELLA Billings

Plate 16, figure 1


Original description.—"Elongate, conical, gently curved, from six to eight lines in length and from one to one and a half in width at the aperture. Surface ornamented with small encircling striae just visible to the naked eye.

"This species is larger than S. rugosa, always a little curved, not so abundant, and when weathered does not present the sharp imbricating annulations of that species."

Discussion.—A single shell occurs among the innumerable specimens of Salterella mexicana, new species, which shows a slight curvature instead of the perfectly straight cone. It has the exterior surface preserved, and shows the same fine concentric grooves alternating with concentric ridges. It measures approximately 7 mm. in length, and is thus comparable in size to the specimens of Salterella mexicana. In
view of the rareness of this form, the author suspects that the curvature may be either a feature of preservation or an unusual individual variation. It should be noted that the examples of *Salterella pulchella* Billings were recorded by Billings as occurring with his specimens of *Salterella rugosa* but being fewer in number.

_Hypotype._—U.S.N.M. No. 115668.

_Formation and locality._—Lower Cambrian, Buelna formation, 809a.

**SALTERELLA**, species undetermined

Plate 17, figures 6, 7

Two pieces of limestone from different localities have, because of their preservation, been so identified. It is considered highly probable that they represent the same species as *S. mexicana* Lochman, as they agree with that species in general size and shape. However, their preservation is poor and positive specific identification really cannot be made. One piece is a highly baked limestone which contains on its weathered surface several sections of *Salterella*; one shows a single cone within the shell which is interpreted by the author as being the wall of the living chamber replaced by calcite. This specimen is from locality 812a.

The second piece of rock is a small weathered limestone slab which was picked up loose on the slope west of the saddle in the Puerto Blanco section in such a position that it must come from the lower part of the Middle Cambrian just above the Cerro Prieto limestone. In spite of the weathered condition, it is clearly a *Salterella*.

_Figured specimens._—Sections in metamorphosed limestone (812a), U.S.N.M. No. 115680; section in weathered limestone, U.S.N.M. No. 115679.

_Formation and locality._—Lower Cambrian, 812a, and loose on slope on west side of Cerro Prieto limestone ridge and saddle between highest hills, Proveedora Hills.
Phylum ARTHROPODA
Class TRILOBITAE
Family OLENEllIDAE Vogdes, 1893
Genus OLENEllUS Hall, 1862
OLENEllUS (OLENEllUS) TRUEMANI Walcott

Plate 18, figures 6-12


Original description.—"This species differs from Olenellus thompsoni (Hall) and O. gilberti Meek in having shorter palpebral lobes and eyes, smaller and shorter plural [sic] lobes of the third thoracic segment, and in having a more coarsely reticulated outer surface of the test, in the latter character resembling O. reticulatus Peach. It differs from the latter and O. lapworthi Peach in having a stronger rim about the cephalon, the anterior glabellar lobe closer to the frontal rim, and a broader thorax and smaller, shorter pleural lobe on the third segment. The third thoracic segment is distinctly larger than the others in all specimens; proportionally it decreases in size from the young to the largest adults . . . .

"The hypostoma has a denticulated posterior margin similar to that of Paederumias transitans and Wanneria halli. It appears to have been attached to the doublure by its anterior margin and not by a process as in Paederumias transitans.

"The specimens of this species are abundant and usually well preserved. The largest cephalon collected had a width of 50 mm. and a length of 22 mm., and the entire dorsal shield has a length of 56 mm. exclusive of the spine-like telson."

Supplementary description.—Cephalon semicircular, moderately convex in profile; glabella slightly hourglass-shaped; first, or anterior lobe, moderately convex, vertical in front, broadest at base of palpebral lobes, tapering inward to rounded front; second lobe wide, increasing in length at sides which are bent backward; third lobe shorter, chevron-shaped; fourth lobe longer and wider, chevron-shaped; occipital ring same size as fourth lobe, with small median posterior node. First glabellar furrow broad and faint across base of palpebral lobes, then more distinct and sharply curved; second glabellar furrow very faint under bent ends, then deepening into diagonal slits, and disappearing along median line; third glabellar furrow straight, diagonal, well defined laterally, nearly obsolete on median line; occipital furrow
straight, diagonal, deep at sides, nearly obsolete across middle; dorsal furrow present posterior to third glabellar furrow, then absent, re-appearing faintly around front of anterior lobe. Palpebral lobes strong, slightly arcuate, running from base of anterior lobe to very slightly posterior to occipital furrow; palpebral furrow well defined in front, faint posterior. Eye vertical, apparently extending full length of lobe. Fixed-cheek area small, slanting upward from dorsal furrow to palpebral furrow except end of eye where slope is downward to posterior marginal furrow. Free-cheek area of medium width, increasing posteriorly from a narrow, flat brim; marginal furrow narrow, continuous around cephalon; marginal border narrow, convex, rimlike, with short slender genal spines; a faint posterior facial suture ridge running from base of eye out laterally, then curving back to posterior margin two-thirds of length out from dorsal furrow; in immature cephalon this length is one-half and a small intergenal spine is present at this position.

Thorax with 15 segments having small axial nodes on 7 to 14 and large spine on fifteenth; segments broad and flat with a broad, shallow pleural furrow; falcate terminations of second and third progressively enlarged.

Pygidium not observed.

Outer surface of immature cephalon finely granulated; of mature cephalon covered by fine interrupted wavy ridges conforming to contours of cephalon; inner surface of free cheek covered with heavy radiating, anastomosing ridges, with one especially heavy one two-thirds of the way back on eye running outward and branching once (this heavier ridge is of common occurrence on the Olenellidae and is a feature which early authors frequently mistook for a trace of the posterior facial suture).

Discussion.—The Mexican material referred to this species consists of several nearly complete adult cephalon, a number of fragments of cephalon and some complete immature cephalon. The immature cephalon have the preglabellar area wider, the anterior glabellar lobe slightly wider and the position of the intergenal spines different as compared to the adult cephalon. However, these three features appear to be characters of immaturity. These cephalon are referred to the Canadian species after the following considerations. O. truemani Walcott is established upon the cotypes U.S.N.M. Nos. 60084-60091, all of them preserved flattened in a fine black shale, and some of the specimens obviously distorted. As a result the Mexican and Canadian specimens cannot be compared as to convexity. Of the cotypes, U.S.N.M. No. 60089 (Walcott 1913, pl. 54, fig. 8) although flattened, has a
cephalon, 7 mm. in length, which agrees in every specific detail with that of the Mexican adult. Also the larger cephalon, U.S.N.M. No. 60087 (Walcott 1913, pl. 54, fig. 6), although both crushed and distorted, has the same narrow anterior glabellar lobe and very narrow brim. But the other specimens, U.S.N.M. No. 60084, which are both interior impressions, and U.S.N.M. No. 60088, a crushed dorsal view, show the anterior glabellar lobe as appearing wider and reaching to the marginal furrow. After consideration of all these specimens the author has concluded that the discrepancies in the last two mentioned are features of the shale preservation and that the first two cotypes which are conspecific with the Mexican cephalon represent the true specific features of *O. triemani* Walcott. It is interesting to note that on the same piece of shale with the complete thorax, U.S.N.M. No. 60089, a number of smaller cephal a occur which are like those referred to the Mexican form, the smallest of them preserving the small intergenal spines in the one-half length position.

**Hypotypes.**—U.S.N.M. Nos. 115687, 115689, 115690a, b, 115691, 115692.

**Formation and locality.**—Lower Cambrian, Buelna formation, 807b, 807c, 807e.

**OLENELLUS (FREMONTIA) FREMONTI** Walcott

Plate 18, figures 4, 5

*Olenellus fremonti* Walcott, Smithsonian Misc. Coll., vol. 53, No. 6, p. 320, 1910 (see for complete previous synonymy).


**Original description.**—"The cephalon of *O. fremonti* differs from that of *O. gilberti*: (a) in having a more expanded anterior glabella close to the rounded frontal border; (b) in having a shorter palpebral lobe, both in the young and the adult; and (c) in having an unusually expanded pleural lobe to the third thoracic segment. A comparison of the young cephalons . . . with those of *O. gilberti* . . . shows some of the differences between the two species.

.................................................................

"The species that is most nearly related appears to be *O. thompsoni*, but we find that the latter differs from *O. fremonti* in having: (a) a space between the glabella and the marginal rim; (b) a less expanded frontal glabellar lobe and longer palpebral lobes; (c) *O. fremonti* also has a peculiarly expanded pleural lobe of the third segment of the thorax."
"The same differences exist in relation to *O. lapworthi*. It differs from *O. logani* in details mentioned under that species.

The hypostoma is very rarely preserved. It is much like that of *O. gilberti* in having a denticulated posterior margin, and both are much like the hypostoma of *Paedeumias transitans*.

The outer surface is similar to that of *O. gilberti* and other species of the genus."

*Supplementary description.*—Cephalon semicircular, moderately convex in profile; glabella slightly hourglass-shaped; anterior glabellar lobe rounding out slightly in front of eyes, extending to marginal furrow, front vertical in young, broader and lower with 45° slope in old adults; second glabellar furrow longest with lateral ends bent backward; third lobe chevron-shaped, shorter than second; fourth lobe chevron-shaped, wider, and slightly longer than third; occipital ring straight, same width as fourth glabellar furrow but a little longer, with a small posterior median node; dorsal furrow present along posterior glabellar sides, interrupted by palpebral lobes, then continuing around anterior lobe to coalesce with marginal furrow in front, very faint in larger cephalas. First glabellar furrow deepest at sides, starting in a short distance, curving backward and becoming fainter across center; second glabellar furrow very faint at sides, curving up and in to be deep and diagonal, then faint across center; third glabellar furrow deep at sides, diagonal, absent through middle third; occipital furrow straight, diagonal, deep at sides, absent through center. Palpebral lobes strong, short, curving to opposite center of fourth glabellar lobe. Eye vertical, full length of lobe; palpebral furrow curved, well defined; fixed-cheek area lowest at anterior extremity opposite third glabellar lobe, widening and sloping upward posteriorly into a low knoll opposite end of eye, then sloping downward in all directions to posterior margin. Free-cheek areas of medium width, increasing posteriorly; marginal furrow well defined, continuous; border narrow, rimlike in young, flattening out a bit and widening posteriorly into base of long genal spines in larger cephalas; a 45° angle in posterior margin approximately one-third distance in from the genal spine to dorsal furrow and at this angle in small cephalas is a minute intergenal spine and from it a faint posterior facial suture ridge runs into base of eye.

Only known thorax (Walcott, 1910, pl. 37, fig. 7) shows 15 segments with a strong fifteenth axial spine, and a very extreme macropleural development of the third segment; first and second segments
have short falcate terminations but remainder are not well preserved; pygidium not known.

Outer surface of cephalon covered by low crowded imbricating ridges warped around and conforming to contours of cephalon; inner surface of free-cheek area covered with heavy anastomosing ridges radiating outward from eye.

Discussion.—Two cephalae, one a large adult estimated as measuring 66 mm. in width by 32 mm. in length, and a smaller one, 23 by 13 mm., represent this species. Both are fragmentary, but supplement each other quite well. They are clearly conspecific with O. fremonti Walcott, and it is interesting to note that after observing such features as the low knoll on the fixed-cheek area and the minute intergenal spine on the limestone Mexican specimens, the author was surprised to find these same details on the flattened specimens of the type lot, though neither feature had been mentioned by Resser or Walcott. Following Resser's discussion of the species (1928, pp. 6-7), the author has considered as the cotypes the specimens figured by Walcott from loc. 52, with special emphasis on the adult cephalon, U.S.N.M. No. 56819a, which shows all the critical features including the fixed-cheek knoll which crushing has displaced slightly posteriorly. This feature is also shown on U.S.N.M. No. 56819i (Walcott, 1910, pl. 37, fig. 13), a small cephalon which was sketched by Walcott. Also on a small immature cephalon from locality 52, which is not figured, the author found minute intergenal spines in the same position as on the small Mexican cephalon. This feature appears to be characteristic only of the young.

The author has used basically the cephalon, U.S.N.M. No. 56819a, for the detailed description, supplementing the note on convexity from the Mexican limestone specimens. The specimen, U.S.N.M. No. 56822a, has been used for the description of the thorax, but the specimen is not well preserved and it will be noted that the anterior lobe of the glabella is much more expanded than in the main cotype, but how much is real and how much due to crushing cannot be determined; therefore, its position in the species should be considered doubtful. No thorax is associated with the cephalon from locality 52.

It should be noted that the specimen, U.S.N.M. No. 56819a, represents actually a form of the species in which the base of the genal spines is in a somewhat forward position, lying opposite the posterior end of the eyes. The California specimens described by Resser represent this same variety. However, the Mexican specimens appear to have the genal spines directly at the posterolateral corners and in this respect are actually the normal form for the species. The specimens,
U.S.N.M. No. 15416, from locality 30, likewise show the genal spine in normal position, and are considered *Olenellus fremonti* Walcott by the author, although Resser (1928) would exclude them.

_Hypotypes._—U.S.N.M. Nos. 115685, 115686.

_Formation and locality._—Lower Cambrian, Buelna formation, 809a.

**Olenellus**, species undetermined

Two very fragmentary cephalas of *Olenellus* which show a narrow brim similar to that of *Olenellus truemani* Walcott occur at the base of the *Obolella* beds, and thus represent the first appearance of *Olenellus* in the Mexican Lower Cambrian section. However, they are so fragmentary that many important details of the cephalon, including the length of the eyes, cannot be determined, and consequently it is impossible to identify the species.

_Formation and locality._—Lower Cambrian, Puerto Blanco formation, 801b.

**Genus Paedeumias Walcott, 1910**

**Paedeumias puertoblancoensis** Lochman, new species

_Plate 19, figures 9-16_

Cephalon semicircular, with low convexity; holotype 10 mm. in width by 6 mm. in length; glabella low, slightly hourglass-shaped, tapering to a broad point anteriorly; anterior lobe of low convexity, narrow at base of palpebral lobes, widest just in front of lobes, then tapering forward to a broad, blunt point; second glabellar lobe short and flat in center, at sides curving forward, then bent backward; third glabellar lobe short, narrow, merging at sides with second lobe; fourth glabellar lobe apparently chevron-shaped, longer and wider than second. Occipital ring straight, as wide as and longer than fourth lobe; dorsal furrow narrow, faint but distinguishable along sides to first glabellar furrow. First glabellar furrow forming deep, arcuate slits at sides, absent across center; second glabellar furrow in form of deep, straight slits just below inner ends of first glabellar furrow, then becoming straight, broad, and very faint across the center; third glabellar furrow arcuate posteriorly, deep at sides, becoming progressively fainter at center; occipital furrow arcuate posteriorly, well defined at sides, faint across center. Palpebral lobes strong-based, wide, curving to opposite center of occipital ring; palpebral furrow arcuate, wide and clear along anterior half, then disappearing and reappearing again near end of eye lobe; eye vertical, extending full length of lobe. Fixed-cheek area small, sloping up from palpebral and
dorsal furrows into a low knoll opposite end of fourth glabellar lobe, sloping downward posteriorly to marginal furrow. Free-cheek area starting with a narrow brim in front of anterior lobe, increasing in width posteriorly; brim crossed on median line by a low narrow ridge extending from center of anterior lobe and interrupting marginal furrow; marginal furrow very narrow, distinct at front and sides, fainter posteriorly; border narrow, rimlike. Genal spine relatively short and intergenal spines very short in adult.

Thorax and pygidium not known.

Outer surface covered by fine wavy interrupted ridges, crossing test transversely and conforming somewhat to contour of cephalon.

Discussion.—This species is represented by protaspids and metaspids, and fragmentary cephalia from six localities. The holotype is a young, nearly complete cephalon. A larger cephalon is fragmentary. An additional paratype is fairly well preserved but has had the front of the cephalon pushed back and up so that the brim is abnormally short and the anterior lobe of the glabella appears somewhat broader.

The species is very close to *P. transitans* Walcott. It appears to differ from that species only in the more rounded anterior lobe of the glabella and the straight posterior margin of the cephalon. As the type of *P. transitans* is a flattened, somewhat crushed shale specimen, the author is unable to determine how much the difference in matrix has affected these details of the cephalon. She considers it feasible for the present to describe the Mexican material as a new species but to call attention to its close relation to *P. transitans*.

In studying the species of *Paedeumias* the author concluded that nearly all the same features listed for *Olenellus* constitute features of specific value in *Paedeumias*, i.e. (1) length of eye, (2) shape of anterior glabellar lobe, (3) width of brim and structure of median anterior ridge. In *Paedeumias*, however, there appears to be no variation in the width of the border, the narrow, rimlike border being apparently a generic character.

Types.—Holotype, U.S.N.M. No. 115703; paratypes: cranidia, U.S.N.M. Nos. 115705a, 115706-115708; protaspids, U.S.N.M. No. 115708; fragments, U.S.N.M. Nos. 115709, 115710.

Formation and locality.—Lower Cambrian, Buelna formation, 801e, 801f, 807c, 809a, 807b, 807e.
Genus WANNERIA Walcott, 1910

WANNERIA MEXICANA, new species, and W. M. PRIMA Lochman, new variety

Plate 18, figures 1-3

Cephalon semicircular; small cephal a with strong convexity, but larger cephal a appearing to have only moderate convexity. Glabella parallel-sided posteriorly, expanding anteriorly; anterior lobe of low convexity, with vertical front, reaching to marginal furrow, its greatest width at a bulge just in front of bases of palpebral lobes; second glabellar lobe of medium length, arcuate; third glabellar lobe chevron-shaped, slightly longer, but narrower; fourth glabellar lobe chevron-shaped, a little shorter and narrower than fourth lobe; occipital ring straight across, same length and width as fourth lobe, with a short median posterior spine. Dorsal furrow faint, running forward and outward to second glabellar furrow, curving in and around second glabellar lobe, disappearing across palpebral lobes, then continuing faintly around anterior lobe and coalescing with marginal furrow. First glabellar furrow well defined, slightly arcuate, running from palpebral lobes; second glabellar furrow curving in and back from dorsal furrow, nearly obsolete in center; third glabellar furrow well-defined, curving in, back and across center. Occipital furrow nearly straight across, deep at sides, faint in center. Palpebral lobes thick with strong base at anterior glabellar lobe, extending in a low arc to opposite third glabellar furrow; palpebral furrow not seen. Eye vertical, extending full length of palpebral lobe; fixed-cheek area very small, starting opposite second glabellar furrow, the part opposite third glabellar furrow rising almost vertically to palpebral lobe, posteriorly only a gentle rise, then the surface slopes down to marginal furrow; free-cheek area of medium width, widening posteriorly to equal width of anterior lobe, strongly convex in small cephal a; marginal furrow wide, well defined around cephalon; border of medium width, convex, widest at base of genal spines and narrower around front and also noticeably narrower along posterior margin. In this species it is presumed that the long, medium-sized genal spines would lie at the posterolateral angles, and the intergenal spines would be small and in a short distance on the posterior margin.

Fragmentary hypostoma shows a large circular, strongly convex anterior lobe with a large macula at each posterior corner; a narrow, flat, crescent-shaped posterior border with six small teeth on each side.

Thorax and pygidium not known. Surface of test not known.

Description of variety.—The cephalon of the variety is like that of the species in all proportions and details except for the position and
size of the genal and intergenal spines which are placed as follows: At the posterolateral angle at the end of the strong posterior facial suture ridge lie medium-sized intergenal spines, projecting somewhat laterally; the long, heavy genal spines lie on a line with the first glabellar furrow, and the spine projects nearly straight outward at the side of the cephalon, with a slight upward flexure at the base.

Discussion.—This striking form is represented by a number of cephalas of various sizes, but all the material has weathered out on the surface of a dense limestone from which it is impossible to break out any specimens. Unfortunately all the cephalas have been quite deeply weathered, so that not only is the surface gone or badly worn, but in most the weathering has reached down to the limestone underneath the specimen. As a result it is hard to judge many of the details and the original convexity.

The species is most closely related to the other two Cordilleran Wanneria species, W. rowei (Walcott) and W. occidens Walcott, but in so far as comparison can be made it differs from them in (1) the sudden bulge of the anterior lobe just in front of the palpebral lobes, (2) the very short occipital spine, and (3) the somewhat shorter eyes. The author recognizes this form as a species differing from described ones as noted above; and this particular form as a variety of that species in which the intergenal and genal spines are placed as noted.

In association with this variety from locality 801c on the same weathered slabs are a number of small cephalas, ranging from 2 mm. to 9 mm. in length. All specimens are so deeply weathered that their positive identification is difficult, but it can be seen that on them the genal spines lie at the posterolateral angle of the cephalon. While the preservation of the glabella and eyes is so poor that they cannot positively be placed in Wanneria, the author believes it possible that they may represent the normal form of the species, Wanneria mexicana. It should also be mentioned that in the United States National Museum material from locality 61k, Hota shale, Mumm Peak, British Columbia, several cephalas occur which have never been described, but which represent the same species and variety as W. mexicana prima. They are associated with specimens of Wanneria occidens Walcott, and an undescribed variety of that species which has the intergenal and genal spines in the same position as the Mexican species and variety.

The occurrence of both this species of Wanneria and Olenellus truemani Walcott together in the Hota shale and the Mexican section suggests a close relationship between the faunas.

Types.—Holotype, U.S.N.M. No. 115681; paratypes, U.S.N.M. Nos. 115682, 115683; unfigured paratypes, U.S.N.M. No. 115684.
Formation and locality.—Lower Cambrian, Puerto Blanco formation, 801c.

WANNERIA WALCOTTANA BUELNAENSIS Lochman, new variety

Plate 19, figures 1-6

Description of variety.—The cephalon of the variety is like that of the species in all proportions and details except for the position and size of the genal and intergenal spines; the intergenal spine is quite small on the two cephalas where it is preserved and lies at the posterolateral corners of the cephalon. From it the border slopes forward and outward bringing the base of the medium-sized genal spine a short distance anterior to the posterior end of the eye. The straight genal spine projects backward and slightly outward. On the holotype, a low knoll occurs on the posterior limb back of the end of the eye. All other specimens are too poorly preserved to show this part of the carapace, therefore it is not certain whether this is a feature of preservation or of constant varietal importance.

Discussion.—The holotype of this variety is a cephalon 24 mm. in length, and though not complete, does permit specific determination. It is most interesting to find the occurrence of this variety of the common Appalachian species in the Cordilleran trough. It agrees with Wanneria walcottana (Wanner) and differs from all other described species in the following features: (1) A regular and smooth expansion of the anterior lobe of the glabella; (2) the presence of a row of pits along the inner edge of the border; (3) the eyes and palpebral lobes reaching just to the center of the fourth glabellar lobe; (4) an occipital node rather than spine; (5) a very small intergenal spine, apparently aborted in large adults; (6) a medium-sized genal spine.

The material contains a number of large fragments consisting of broken glabellae and free-cheek areas. These are believed to represent the same species and variety, though they are specifically undeterminable. These fragments have the network ornamentation of the surface beautifully preserved, and indicate that the individual adults of this variety reached as large a size as the Appalachian specimens. Several associated hypostoma show the same network ornamentation on their ventral surface.

A number of associated metaspids are well preserved and show that the genal spine is in advanced position even at this stage.

Types.—Holotype, U.S.N.M. No. 115695; paratypes: fragmentary glabellas and free cheeks, U.S.N.M. Nos. 115696, 115697; protaspids,
U.S.N.M. No. 115700; small cephalu, U.S.N.M. No. 115699; hypostoma, U.S.N.M. No. 115698.

Formation and locality.—Lower Cambrian, Buelna formation, 807b.

WANNERIA? species undetermined
Plate 19, figures 7, 8

A small collection from quartzite beds at an isolated locality consists of five fragmentary cephalu, a large broken hypostoma, and a protaspid, all belonging to an olenellid genus. However, the specimens are only broken internal molds of quartzite and the preservation is so poor as to make identification uncertain. Generic reference to Wanneria is made because the specimens show short eyes, the ends of the palpebral lobes reaching not quite to the center of the fourth glabellar lobe. In this respect they are comparable to those of Wanneria mexicana prima. However, on the posterior margin two-thirds the distance out from the dorsal furrow there is a noticeable bend, but no intergenal spine can be seen. The genal spine is at the posterolateral corner of the cephalon. They may represent the normal form of the species, Wanneria mexicana, but until more complete material is obtained, nothing definite can be determined.

Figured specimens.—U.S.N.M. Nos. 115701, 115702.

Formation and locality.—Lower Cambrian quartzite, Proveedora formation, 807j.

Family CORYNEXOCHIDAE Angelin, 1854
Genus BONNIA Walcott, 1916

BONNIA SONORA Lochman, new species
Plate 21, figures 1-7

Single known cranidium small, 1.8 mm. in length by 2 mm. across the eyes; glabella occupying central half of cranidium, convex, becoming steep and vertical anterior to palpebral lobes, expanding somewhat forward to a nearly flat, broad front (some distortion to left in cranidium may cause a greater than true expansion); faint coloration indicates a posterior, slightly curved glabellar furrow extending practically across, and another glabellar furrow in front of it, very short and at sides only. Dorsal furrow well defined at sides forward to a clear rounded pit on each side of glabella opposite anterior end of palpebral lobe, then much narrower and shallower around front of glabella. Occipital furrow wide and deep. Occipital ring narrow, nearly flat, possibly with a low median node; no brim; fixed cheeks slope regularly to broad, very shallow marginal furrow which merges
into dorsal furrow. Border a narrow, convex, vertical rim; anterior margin rounded. Fixed cheeks approximately one-half width of glabella, very slightly convex, downsloping; palpebral lobes medium size, just back of midline of glabella; palpebral furrow narrow, well defined; ocular ridge obsolete; posterior limbs of medium width, starting opposite third glabellar furrow, same length as occipital ring, crossed by a narrow, shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin just within genal angle. Outer surface apparently smooth, but definitely worn; a few minute transverse ridges distinguishable on border.

Thorax not known.

Pygidium semicircular, convex; axis of medium width, convex, sides subparallel to a broadly rounded end which does not quite reach border, divided into three segments and a long terminal portion by three broad shallow furrows; dorsal furrow broad, well defined at sides only; pleural platforms slightly wider than axis, flat near dorsal furrow, then curving down steeply to narrow, well-defined marginal furrow; border of medium width, slightly convex, continuing slope of pleural platforms; a very small anterior marginal spine at each side; posterior margin smoothly rounded; surfaces poorly preserved.

Discussion.—This species is described from a single small cranidium and seven pygidia ranging from 4 mm. by 2½ mm. to 8 mm. by 4¾ mm. All the pygidia are poorly preserved; only one specimen shows the very small marginal spine. The species is close to three described species but differs from them as indicated. *Bonnia tensa* Resser and *Bonnia fieldensis* (Walcott) have all proportions and convexity practically the same, but both differ in that the glabella merges into the border as the marginal furrow is almost obsolete; and *B. tensa* Resser also has a steeper frontal slope of the glabella. A small cranidium in the *B. fieldensis* lot, which is the same size as the Mexican specimen, differs from it in exactly the same features as the larger *B. fieldensis* cranidia. This indicates that the specific features are already established in cranidia of this small size. Pygidia of the same size as *B. fieldensis* and *B. sonora* do not show any differences. The Mexican species is closest of all to *B. columbensis* Resser from the Mount Whyte formation. The cranidium differs in (1) the steep slope of the front part of the fixed cheeks, and (2) the nearly flat profile of the glabella. In the pygidium of *B. columbensis* the marginal furrow is more distinct, especially around the back, and the posterior border tends to flatten out. With the present limited material representing both species, it is possible that, when more material is obtained, the Mexican species can be shown to be the same as *B. columbensis* Resser.
Types.—Holotype, U.S.N.M. No. 115736; paratypes, pygidia, U.S.N.M. Nos. 115737, 115738, 115739.

Formation and locality.—Lower Cambrian, Buelna formation, 809a.

Family INCERTAE SEDIS

Genus ANTAGMUS Resser, 1936

ANTAGMUS BUTTSI (Resser)

Plate 21, figures 15-21


Original description.—“This species is characterized by the width of the cranidium at the anterior end of the eyes. The thorax has 15 segments, and this is one of the few specimens of the genus which preserves the pygidium. It is small, well fused, and the rear portion is turned down so that it stands vertically.”

Supplementary description.—Cranidium nearly square, slightly wider than long; glabella broadly conical, with nearly straight front, moderately convex; profile highest posteriorly, sloping anteriorly; three pairs of short faint glabellar furrows at sides only; first and second glabellar furrows apparently straight, third slightly arcuate. Occipital furrow broad, well defined, slightly deeper at sides. Occipital ring narrow at sides, expanding to medium in center, slightly convex; dorsal furrow broad, well defined at sides, shallow across front. Brim of medium width, gently convex, sloping steeply at sides but nearly flat at center; marginal furrow broad, shallow at sides, apparently fading at center to form a broad, but slight, indentation. Border of medium width, very slightly convex, horizontal; anterior margin rounded. Fixed cheeks two-thirds width of glabella, slightly convex, horizontal. Palpebral lobes small, prominent, on midline of glabella; palpebral furrow narrow, faint. Ocular ridge narrow, well defined, curving to just behind front of glabella; posterior limbs same width as occipital ring, crossed by a broad, well-defined marginal furrow. Free cheek triangular with small eye at inner angle; ocular platform of medium width, with moderate slope; border somewhat narrower, slightly convex, horizontal, with short anterior projection and short slender genal spine; marginal furrow narrow, shallow. Facial suture cutting anterior margin well out at sides, curving back to marginal furrow, then straight back, into, and around palpebral lobes, thence curving out and back to cut posterior margin within genal angle.
Thorax of 15 narrow segments; axis and pleural lobes of same width; pleural segments with short pointed falcate ends and crossed by shallow, medium-wide pleural furrows.

Pygidium small, narrow, transverse in outline; axis broad, slightly convex, sides tapered very slightly to broadly rounded end, not quite reaching margin; segments not distinguishable; dorsal furrow narrow, apparently at sides only; pleural platforms somewhat narrower than axis, gently sloping; two or three segments may be present; marginal furrow not preserved; border narrow, gently sloping at sides, vertical in position posteriorly.

Outer and inner surfaces of test not known.

Discussion.—This species is represented in the Mexican material by 10 cranidia ranging in length from 3 mm. to 6.5 mm.

The holotype of Antagmus buttsi (Resser), U.S.N.M. No. 94771, though a complete carapace, is only a mold in fine yellow sandy shale, and the cephalon as a whole is distorted and poorly preserved. The glabella is flattened and worn off on top and the entire border is broken off, but the approximate width can be estimated from a trace of the anterior margin running along the right side. Likewise, the preservation has rendered a complete description of the pygidium impossible. In trying to compare the Mexican specimens with this material, all the cranidia in the type lot were examined, and while they showed all sorts of distortion, several are better preserved than the holotype. The cranidia which had received only slanting lateral pressure were best preserved, and showed a brim and border of the same width, convexity, and slope as the Mexican specimens.

The species differs from A. solitarius Lochman in its much wider brim, somewhat more convex fixed cheeks, and the slight divergence of the anterior facial suture. It differs from all other described species of Antagmus except A. perola (Walcott) in the much greater width of the brim. The proportions and width of the brim and border are the same in the two species, and the only difference noted is the convex and sloping condition of the brim, and (in some specimens) of the border in A. perola (Walcott). As this species is preserved in shale, it is impossible to be sure which feature is the true one, but it seems as if the brim, at least, were moderately convex and regularly sloping in the normal condition. A. perola (Walcott) is the only other species of Antagmus in which the thorax of 15 segments is known, but only two of the specimens in the type lot have the pygidium, which is not well preserved. What can be determined of it would certainly indicate a congeneric relation, but more detailed analysis cannot be made.
Hypotypes.—U.S.N.M. Nos. 115743a, b, 115744, 115745; unfigured hypotypes, U.S.N.M. No. 115746.

Formation and locality.—Lower Cambrian, Buelna formation, 809a.

ANTAGMUS SOLITARIUS Lochman, new species

Plate 21, figures 8-11

Cranidium square, largest specimen 5 mm. by 5 mm.; glabella conical with straight front, moderately convex, with posterior highest, sloping anteriorly; three pairs of short, faint glabellar furrows at sides only; first pair straight, second and third pairs slightly arcuate. Occipital furrow of medium width, deep at sides, shallow through center. Occipital ring slightly convex, narrow at sides, expanding to center, with a small median node. Dorsal furrow broad, well defined at sides, shallow across front of glabella. Brim narrow, flat, sloping gently at center, steeper at sides; marginal furrow broad, well defined for nearly entire length, fading at center with a very slight V-shaped indentation, border medium wide, strongly convex, horizontal; anterior margin rounded. Fixed cheeks two-thirds width of glabella, slightly convex, horizontal. Palpebral lobes small, on midline of glabella; palpebral furrow narrow, shallow; ocular ridge low, narrow, curving slightly to just behind the front of the glabella; posterior limbs narrow, approximately same length as occipital ring, crossed by a broad shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin well out at sides, curving out to furrow, then running straight back to and curving around palpebral lobes, thence curving out and back to cut posterior margin within genal angle. Outer surface of test finely granulated.

Thorax and pygidium not known.

Discussion.—This species is known from one small adult cranidium of which the brim is somewhat crushed, and a smaller cranidium, under 3 mm. in length, which is broken at the edges of the cheeks, palpebral lobes, and posterior limbs. It corresponds closely in all preserved parts to the larger cranidium, and has an undamaged brim.

The species is very close to A. typicalis Resser in the very narrow brim but differs in the convex border and the straight anterior facial suture. From A. tennesseensis it differs in the wider brim and the diverging facial suture of the latter species, although the preservation of both species makes it difficult to determine the true course of this suture. In the type lot of A. tennesseensis several cranidia show a straight suture while others have a slight divergence. In the cranidia of A. solitarius it appears to go straight forward, but this portion of the specimens is not well preserved.
Types.—Holotype, U.S.N.M. No. 115740; paratype, U.S.N.M. No. 115741.

Formation and locality.—Lower Cambrian, Buelna formation, 809a.

Genus **ONCHOCEPHALUS** Resser, 1937

**ONCHOCEPHALUS BUELNAENSIS** Lochman, new species

Plate 20, figures 5, 18-29

Cranidium subquadrate, average dimensions $\frac{5}{2}$ mm. across the eyes by $\frac{4}{3}$ mm. in length; glabella conical with a nearly straight front, moderately convex, with greatest elevation in posterior and sloping regularly to quite low anteriorly. Three pairs of glabellar furrows at sides only, first pair straight, very faint; second pair well defined, slightly arcuate; third pair well defined, arcuate. Occipital furrow distinct, broad, deep at sides, shallower through middle. Occipital ring narrow at sides, expanding at center with a minute median node; dorsal furrow broad, deep at sides, shallow around front; brim nearly flat, slightly sloping, of medium width at sides, narrowing in front of glabella. Marginal furrow broad, shallow at sides, becoming very shallow on median line and bending into a broad V. Border narrow, with median expansion, horizontal posteriorly, then curving downward anteriorly; anterior margin rounded. Fixed cheeks three-fourths width of glabella, slightly convex, slightly downsloping. Palpebral lobes small, on midline through glabella; palpebral furrow narrow, shallow; ocular ridges narrow, curving slightly into dorsal furrow behind front of glabella. Posterior limbs short, same width as occipital ring, crossed by a broad, shallow marginal furrow. Free cheek narrow, elongate with small eye at inner angle; ocular platform of medium width, flat and sloping slightly. Marginal furrow narrow, very faint; border narrow, horizontal on inside, curving down on outside, with a short-pointed anterior projection and a short slender genal spine. Facial suture cutting anterior margin about halfway from center, curving out to marginal furrow, then back, into and around the palpebral lobes, thence out and back to cut posterior margin within genal angle. Outer surface of test finely granulated; inner surface showing coarse venation on brim, and scattered fine punctations. Thorax not known.

Pygidium small, transverse, only moderately convex, $3\frac{1}{2}$ mm. wide by $1\frac{1}{2}$ mm. in length; axis broad, slightly convex, sides subparallel to broadly rounded end, not quite reaching marginal furrow. Anterior half segment well defined by furrow; second segment set off by a very faint broad furrow with a low oval bulge on each side of
center; third segment broad, set off by a broad faint arcuate furrow with two low oval bulges halfway in on each side; terminal portion narrow. Dorsal furrow narrow, faint. Pleural platforms three-fourths width of axis, sloping gently with two anterior segments and a terminal portion divided by narrow interpleural grooves running clear to margin, well-defined pleural furrows. Marginal furrow faint. Border narrow, flat, horizontal at sides, steeply sloping at back; posterior margin with a distinct indentation at median line; outer surface finely granulated; inner surface not known.

Remarks.—This species is known from a number of cranidia and some free cheeks and pygidia. The holotype cranidium and some of the paratypes are from locality 807c, and while they have a clear outline and are fresh, the outer surface has invariably been torn in breaking them out. Therefore, all the furrows are slightly deeper and the ocular ridges stronger than in specimens preserving the outer surface. This feature can be readily demonstrated by partially peeled cranidia in collection from locality 809a.

In so far as the type, *Onchocephalus thia* (Walcott), can be compared accurately, because of its poor preservation, it appears to be very similar to *O. buelnaensis*, but differs from it in having the brim narrower, flat, and definitely horizontal in position. In *O. leuka* (Walcott) the wider, flat, slightly ascending border is quite different. *O. buelnaensis* seems quite close to *O. virginicus* (Resser), but the preservation of the single holotype cranidium of that species is so poor that specific characters are not really distinguishable.

Types.—Holotype, U.S.N.M. No. 115724; paratypes: cranidia, U.S.N.M. Nos. 115725, 115727, 115733; free cheeks, U.S.N.M. No. 115726; pygidia, U.S.N.M. Nos. 115729, 115731, 115732; unfigured paratypes, U.S.N.M. Nos. 115728, 115730, 115734-115735.

Formation and locality.—Lower Cambrian, Buelna formation, 809a, 807c, 801f.

**ONCHOCEPHALUS MEXICANUS** Lochman, new species

Plate 20, figures 6-17

Cranidium rectangular, average dimensions 6 mm. across the eyes by 5 mm. in length; glabella moderately convex, highest posteriorly, sloping to low anteriorly; conical with a nearly straight front. Three pairs of faint short glabellar furrows, first and second pairs straight, third pair arcuate; dorsal furrow broad, distinct at sides, shallow across front of glabella. Occipital furrow of medium width, deep at sides, very shallow across center. Occipital ring narrow at sides, expanding in center with probably a small median node. Brim of medium
width, moderately convex at sides, only slightly convex in front of glabella, continuing downslope of glabella. Marginal furrow broad, distinct at sides, faint in center where it appears to bend slightly back to form V. Border narrow, expanding backward on midline, slightly convex, descending; anterior margin rounded. Fixed cheeks three-fourths width of glabella, slightly convex, downsloping; palpebral lobes small, on midline through glabella; palpebral furrow narrow, shallow; ocular ridges practically obsolete, slightly curved to just back of front of glabella; posterior limbs short, only slightly wider than occipital ring, crossed by a broad, shallow marginal furrow. Free cheek narrow, elongate, with small eye at inner angle. Ocular platform of medium width, flat, gently sloping; marginal furrow very faint; border narrow, slightly convex, descending regularly, with a short anterior projection and a short slender genal spine. Facial suture cutting anterior margin on line with dorsal furrow, curving out to marginal furrow, then straight back and around palpebral lobes; then curving out and back to cut posterior margin within genal angle. Outer surface of test finely granulated; inner surface appears smooth.

Pygidium small, transverse, 2½ mm. wide by 1 mm. long, convex, axis broad, moderately convex, sides subparallel to broadly rounded end, not quite reaching marginal furrow. Three faint axial furrows, anterior one nearly across, others only at sides, marking off three segments and a terminal portion; dorsal furrow narrow, faint; pleural platforms one-half width of axis, flat near dorsal furrow, then dropping down very steeply to a very faint marginal furrow. Interpleural grooves narrow, running out across the border, dividing two anterior segments, crossed by pleural furrows, and a terminal portion; border narrow, flat, sloping down slightly at sides but becoming vertical at posterior median line. Outer surface finely granulated; inner surface not known.

Remarks.—This species is extremely abundant in locality 809a, but is only sparsely represented at the other localities. The cranidia are numbered in the hundreds, but only 12 pygidia were obtained, a fact probably due to their small size. In trying to determine which pygidium to associate with which cranidium in these two species of *Onchocephalus*, the author decided to assign the more convex type of pygidium to the more convex cranidium. Likewise, the free cheek with the more convex ocular platform was associated with the more convex cranidium.

*Onchocephalus mexicanus* Lochman as here recognized differs from *O. buelnnaensis* in the steeper descent of the brim and continued downslope of the border of the cranidium, and the steep slope of the pleural
platforms of the pygidium. The species are definitely close, but the cranidia from each locality can be separated into the two types. The author was not able to demonstrate a gradational series between the two types, but if a hundred or more specimens are cleaned, it may be possible to show such a feature. This would afford a very interesting problem as plenty of material is available.

Types.—Holotype, U.S.N.M. No. 115713; paratypes: cranidia, U.S.N.M. Nos. 115714, 115717, 115719; free cheeks, U.S.N.M. No. 115718; pygidia, U.S.N.M. Nos. 115715, 115716; unfigured paratypes, U.S.N.M. Nos. 115720-115723.

Formation and locality.—Lower Cambrian, Buelna limestone, 809a, 809b, 807c, 801f.

Genus SOMBRERELLA Lochman, 1948

SOMBRERELLA MEXICANA Lochman

Plate 20, figures 1-4


*Original description.*—Cranidium subquadrate, 4 mm. across eyes by 4½ mm. in length; glabella narrowly conical with straight front, strongly convex with appearance of a median ridge, profile highest posteriorly, sloping steeply down to a very low anterior; three short, extremely faint glabellar furrows; occipital furrow narrow, present at sides but nearly obsolete across center; occipital ring flat, narrow at sides, expanding rapidly to center with a node on posterior margin, in profile continuing upward slope of back of glabella; brim narrow, flat, sloping at sides, horizontal at center; marginal furrow broad, shallow, narrower toward center with a suggestion of a medium indentation; border of medium width, moderately convex, horizontal; anterior margin rounded. Fixed cheeks approximately one-half width of glabella, horizontal; palpebral lobes small, slightly forward of center but not on anterior one-third of glabella; palpebral furrow shallow, faint; ocular ridge narrow, well defined, slightly curved to just behind front of glabella; posterior limbs same width as occipital ring. Free cheek not known. Facial suture cutting anterior margin well out at sides, running out and back to marginal furrow, then back and in to and around palpebral lobes; thence curving out and back to cut posterior margin well within genal angle. Outer surface not known; inner surface with coarse punctations on brim and medium-sized punctations on fixed cheeks and posterior limbs.

Thorax and pygidium not known.

*Discussion.*—Only two small cranidia represent this genus and
species. The broken glabella on the paratype suggests that this exposed portion of the cranidium was especially subject to damage. Although the top is broken, the glabella in the paratype does not seem quite so narrow and steep as in the holotype, so that some question still remains as to whether the extreme appearance of the holotype may not be due to some slight distortion of the specimen which cannot now be detected.

Types.—Holotype: cranidium, U.S.N.M. No. 115712; paratype: broken cranidium, U.S.N.M. No. 115711.

Formation and locality.—Lower Cambrian, Buelna formation, 809a.

GENUS AND SPECIES UNDETERMINED 1

Plate 21, figures 13, 14

Cranidium wide, subquadrate, $7\frac{1}{2}$ mm. across eyes by 6 mm. in length; glabella narrow, conical with nearly straight front, moderately convex, high posteriorly with steep slope anteriorly; three pairs of short straight glabellar furrows at sides only, becoming slightly longer posteriorly; occipital furrow broad, deep; occipital ring narrow, expanding to medium at center, slightly convex; dorsal furrow broad, well defined all around glabella; brim of medium width, flat, sloping moderately at sides, very slightly in center; marginal furrow narrow, very shallow at sides, apparently obsolete in center; border damaged but appearing at least medium in width. Fixed cheeks wider than glabella by one-fourth more than the width of glabella, very gently convex, horizontal; palpebral lobes small, prominent, on midline through glabella; palpebral furrow shallow, very faint; ocular ridge narrow, well defined, curving to near front of glabella; posterior limbs $1\frac{3}{4}$ times the width of occipital ring, crossed by a broad, well-defined marginal furrow. Free cheek not known. Facial suture at anterior margin not known from marginal furrow running straight back and slightly in to and around palpebral lobes, then curving out and abruptly back to cut posterior margin within genal angle (most of width of limb is caused by the wide fixed cheeks, and the limb itself actually extends only a short distance beyond the palpebral lobe). Outer surface finely granulated; inner surface not known.

Thorax and pygidium not known.

Discussion.—Only a single cranidium, which appears fairly well preserved except for the loss of the border and slight damage to the brim and right fixed cheek, is known. The author can detect no evidence of distortion, yet the cranidium presents a combination of generic characters which is not known in any described Lower Cambrian genus. However, the one cranidium is not specifically determinable.
because of the damage, and the author will not erect a new genus on such a specimen.

The combination of generic characters which makes the cranidium unique is:

1. The palpebral lobes small, on midline of glabella.
2. Glabella narrow, conical with straight front, regularly convex; with three pairs of short glabellar furrows.
3. Fixed cheeks \( \frac{1}{4} \) the width of the glabella.
4. Fixed cheeks horizontal.
5. Posterior limbs \( \frac{1}{4} \) width of the occipital ring.

The generic characters are listed and the specimen described and figured so that its affinities may be recognized when other cranidia like it are found.

*Figured cranidium.—* U.S.N.M. No. 115742.

*Formation and locality.—* Lower Cambrian, Buelna formation, 809a.

### MIDDLE CAMBRIAN FAUNAS

#### PROBLEMATICUM III

Plate 28, figures 8-11

A collection from the Arrojos formation contains four small cone-shaped, apparently broken shells. They are composed of a thin black phosphatic material. Not enough can be determined from the specimens to make any accurate determination even of their phylum. The surface ornamentation at first glance suggests the Archaeostracan genus *Bradoria* of which one species, *B. rugulosa* Matthew, has similar concentric ridges on the surface. *Bradoria* is described from the Lower Cambrian of Nova Scotia and the test is also of dark phosphatic material. However, *Bradoria* has no central apex to the carapace. None of the Mexican specimens, even though broken, give any suggestion of an ocular tubercle, a straight hinge line, or even the general shape of the *Bradoria* carapace.

The author believes that the specimens show some resemblance to the type of small cone-shaped shells described as *Kinsabia varigata* Lochman from the early Upper Cambrian. However, the shells of *Kinsabia* have a very distinct calcareous composition quite unlike the phosphatic material of these Mexican specimens. Therefore, it seems unwise to assign them to any named Cambrian genus at present because their affinities are clearly not determinable. A brief description covering the salient characters of the shells is given below and they are figured for future reference.

*Shell a low, elongate cone composed of a thin layer of calcareo-
phosphatic material, none of the specimens showing a complete outline, as all have ragged outer edges; center of cone nearly central or slightly excentric in position; surface ornamentation quite distinctive consisting of (1) a nearly smooth apical area marked by only a few puncta, (2) surrounded by a long series of concentrically arranged ridges which make about a half turn and then bifurcate, (3) toward the outer half of the cone the ridges anastomose so closely as to produce a coarse reticulate pattern.

The largest specimen measures 3 by 2 mm.

Figured specimens.—U.S.N.M. Nos. 115920, 115921.

Formation and locality.—Middle Cambrian, Arrojos formation, 800d.

Phylum PORIFERA
Order HEXACTINELLIDA
Family CHANCELLORIDAE Walcott, 1920
Genus CHANCELLORIA Walcott, 1920

CHANCELLORIA EROS Walcott

Plate 28, figures 1-7

Chancelloria eros Walcott, Smithsonian Misc. Coll., vol. 67, No. 6, p. 329, pl. 86, figs. 2, 2a-c; pl. 88, figs. 1, 1a-f, 1920.

Original description.—“General form tubular, finger-shaped or in fronds of varying outline; there are twelve of the elongate and four frond-like specimens in the collection, all of which are flattened in the shale; that they were hollow or filled with very soft tissue is indicated by a specimen in which the greatly reduced space between the walls is filled with a thin layer of shale between the dermal spicular layers of the former opposite walls.

"Reticulum.—The skeletal spicules are not united to form a connected framework but occur more or less irregularly in the walls of the sponge. In specimens preserving the dermal layer intact only the outlines of the spicular rays are to be seen, the spicules being embedded in the compact skin-like layer; when the dermal layer has been partially removed, either before or after being embedded in the sediment, two of the rays of each spicule are exposed with their points extending upward, and it is only when the spicules have been displaced in relation to the dermal layer that their structure is revealed; the two exposed rays diverge at an angle of from 80 to 90 degrees, and the first impression is that they represent two actines of a triaene spicule, but displaced spicules in the outer layer (extosome) and flat-lying
spicules in the inner layer (endosome) prove that the spicules have a
definite body formed of a small disk hollowed out on one side and
slightly convex on the other side; some show a tubercle that in one
spicule appears as though it might have been the base of a vertical ray
with a central canal; there are from 4 to 9 rays, each of which is
truncated at its inner end where it joins the central disk, it is then
expanded and fitted closely to the adjacent rays for a short distance;
a clearly defined line delimits the inner end and sides of each ray
within the disk; the base of each ray is swollen and has a shallow
round pit on the upper side corresponding in appearance to the hollow
on the central disk; the rays taper rapidly from where they join the
body of the spicule and each one forms a slender, straight or curved
accicular ray; the rays may be nearly on a plane or may curve down-
ward into an umbrella-like form; apparently there are some two or
three rayed spicules with a swollen central body, but these may be
portions broken off from many-rayed spicules. The presence of a
vertical or axial ray on the larger stellate spicules is not readily proven
for, if present, they have been crushed down into the mud and con-
cealed or broken off; it is the presence of an apparently broken-off
base in the center of the body that leads to the conclusion that a ver-
tical ray existed; there is also a strong probability of its presence as
it occurs on similar spicules in Chancelloria drusilla.

“The central body of the spicules appears to have been embedded in
the outer wall (ectosome) with its convex side towards the base and
the transverse axis horizontal or nearly at right angles to the vertical
axis of the sponge, two of its rays turned upward just beneath this
dermal outer covering and the others were embedded in the cortex
within; an inner wall of flat-lying spicules is indicated by one speci-
men. Tufts of fine slender spicules occur along the upper margin
that appear to be pressed down with the rays of the longer spicules.

“Dimensions.—The largest specimen has a length of 95 mm., with
a width as flattened on the shale of 20 mm. at its upper end and 5 mm.
where broken off at the basal end. A frondlike specimen is 38 by 41
mm., and is broadly rounded at the top and almost transverse at the
base. The two exposed rays of the spicules in the elongate specimen
average from 2.5 to 3 mm. in length in the upper half and from 1.5
to 2 mm. in the lower part; a small-sized, six-rayed spicule, 3 mm.
in diameter from the tips of the rays, has the following proportions;
body of spicule 0.5 mm., central disk or node 0.25 mm., length of ray
from where it joins the body to its tip 1.25 mm.; some large detached
spicules have rays 10 mm. in length but these may belong to a separate
and as yet unrecognized species.”
Discussion.—Hundreds of detached sponge spicules occur in locality 800c and a few have been obtained from localities 801n and 800a. All are readily referrable to the genus *Chancelloria*, and are for the present identified as *C. eros* Walcott from the Burgess shale. All details of spicular structure mentioned by Walcott under that species can be matched by specimens in the Mexican material, but the shape or dimensions of the body of the sponge are not known from these specimens. Since the individual spicules are so similar to those of *C. eros* Walcott, the author has preferred to assign them thus rather than describe a new species which could not, on the basis of the spicules, be differentiated from *C. eros*.

The best-preserved spicules show the individual rays with the inner end truncated where they fit against the central vertical ray and the flat edges where they fit against each other. The rays frequently separate along these sutures. Several spicules are illustrated in which the rays reach a length of 3 to 4 mm. but in all the blunt ends suggest that the ray is not now its full length. In a few spicules from locality 800c the vertical ray is still present or a clean break demonstrates its position, but in many the vertical ray appears to have been worn off. However, all four silicified spicules from locality 800a have it in place. Several broken spicules from locality 800c show a low knob with a central pit at the base of each ray.

The majority of the spicules in the collection from locality 800c show considerable wear and appear simply as six- or seven-rayed stars in which the central ray or disk is not separable from the side rays. The author believes that secondary deposition of calcite has taken place along the sutures and this has held the rays together. Many of these badly worn specimens show a pit in the central disk. Comparison with the silicified specimens in the collection from locality 800a, in which such a pit is indicated on the base of the vertical ray, suggests that such specimens are being viewed from the lower surface.

The side rays of the Mexican spicules number 4 to 7, with spicules of 6 or 7 side rays being commonest. The most complete side rays are slightly curved (pl. 28, fig. 4). In all the Mexican spicules in which the feature can be accurately observed, the side rays appear to slant or curve upward from the base of the vertical ray at approximately a 30° angle.

Hypotypes.—U.S.N.M. Nos. 115912-115916, 115918, 115919a.

Formation and locality.—Middle Cambrian, Arrojos formation, 800a, 800c, 801n.
INCERTAE SEDIS

HYOLITHES SONORA Lochman, new species

Plate 27, figures 17-25

Shell conical, straight, with a nearly flat (very slightly convex) dorsal surface and a strongly convex ventral surface; transverse section with sharp lateral angles, the dorsoventral diameter on the midline measuring two-thirds the length of the dorsal side so that lateral angles are approximately $50^\circ$-$52^\circ$. Estimated length of average shell between 25 and 30 mm., with 11-12 mm. the width at the aperture. Large fragments suggesting a length of 50 mm., with a width at aperture of 15 mm.

Outer surface of dorsal side crossed by regular, closely spaced, arcuate growth lines which indicate an upcurved lip at the dorsal aperture; outer surface of ventral side not known.

Surface of the internal mold crossed by innumerable very fine, concentric striations (approximately 20 in a millimeter); several narrow longitudinal ridges appearing along the outer edges in smaller shells; in the large fragment five narrow, well-defined, regularly spaced longitudinal ridges cross the dorsal surface, and 12 mm. from the aperture one additional narrow longitudinal ridge appears by implantation on each side of the median ridge; the appearance on the specimens suggests that these longitudinal ridges are caused by longitudinal grooves on the interior of the shell; the arcuate growth lines of the exterior cross the ridges without interruption.

A fragmentary operculum has a triangular shape with semicircular base; the surface is crossed by three or four semicircular grooves paralleling the base.

Discussion.—This species is represented by 10 or more specimens from the Kootenia-Glossopleura zone. The holotype is a small, broken internal mold which is free from the matrix and shows the very characteristic transverse section. The paratypes consist both of other well-preserved internal molds and three specimens showing the external surface. All are more or less still in the matrix. Several other badly weathered internal molds are also referred to this species, although their preservation is so poor that only the characteristic transverse section can be made out. Two opercula are known, but both are very fragmentary.

It is hard to compare *H. sonora* Lochman, new species, with the other described Middle Cambrian species of *Hyolithes* because of the usual poor preservation. *H. prolixus* Resser is represented by free specimens which have a different transverse section. *H. comptus*
Howell and *H. cercops* Walcott from the Spence shale are both flattened in shale, so that nothing can be told of the transverse section. The same condition plus quite poor preservation holds for *H. idahoensis* Resser from the Rennie shale. Consequently it is impossible to compare the various specimens accurately, though none of them shows the longitudinal ridges which can be seen on some of the specimens of *H. sonora* Lochman.

**Types.**—Holotype, U.S.N.M. No. 115902; paratypes, U.S.N.M. Nos. 115903-115910.

**Formation and locality.**—Middle Cambrian, Arrojos formation, 800a, 800c, 801L, 801n, 801-O.

**Plyum MOLLUSCA**

**Class GASTROPODA**

**HELCIONELLA, species undetermined**

Plate 28, figures 23-25

One small (2 mm.) specimen of *Helcionella* was obtained from 800c. It is an internal limestone mold, much worn and showing the many cracks which appear to characterize the worn organic pellets so common in this collection. The preservation is really too poor to warrant an exact specific identification, but it seems most closely to resemble *H. burlingi* Resser from the Langston formation, Bear River Range, Idaho. The apex curves forward but probably not far downward and five well-defined concentric ribs cross the anterior profile and die out on the lateral surfaces.

**Figured specimen.**—U.S.N.M. No. 115936.

**Formation and locality.**—Middle Cambrian, Arrojos formation, 800c.

**Phylum ARTHROPODA**

**Class TRILOBITA**

Family **ALOKISTOCARIDAE** Resser, 1939

**ALOKISTOCARE ALTHEA** Walcott

Plate 27, figures 3-8


**Original description.**—“This species is represented by casts of several specimens of the cranidium that are preserved in a fine sandstone
matrix. Nothing is known of the surface of the test, and only indistinct traces of the glabellar furrows are to be seen. The most nearly related cranidium is that represented by figures 4, 4a, plate 25, which differs in details of frontal rim and boss. The two forms are, however, closely related and may belong to the same species, the apparent differences being caused by the condition of preservation of the specimens. Alokistocare althea occurs in a fine sandstone matrix and the variety in a sandy shale; the two beds are separated stratigraphically by 200 to 300 feet in thickness of sandy shale.”

Supplementary description.—Cranidium slightly elongate; glabella conical, with broadly rounded front, only slightly convex, highest posterior to low anteriorly; three pairs of short, faint glabellar furrows, first pair short, straight, second and third arcuate; dorsal furrow narrow, well defined at sides, fainter across front; occipital furrow narrow, deep and slitlike at sides, shallower across center; occipital ring narrow, flat, with a small median node; brim of medium width, descending at sides, but rising in front of glabella into a broad triangular median boss extending across the narrow marginal furrow (nearly blotting it out at center), onto the posterior part of border which is of medium width, flat at center, concave at sides, and upturned; anterior margin broadly curved. Fixed cheeks three-fifths width of glabella, slightly convex, very slightly upsloping; palpebral lobes medium, arcuate, back of midline of glabella but not on posterior third; faint curved ocular ridge extending to anterior corners of glabella; palpebral furrows shallow, narrow; posterior limb of medium width, same length as occipital ring. Free cheek a slender triangle with medium eye at inner angle; ocular platform of medium width, convex, strongly descending; marginal furrow narrow, well defined; border narrow, flat, horizontal, with a short pointed anterior projection and a medium-length, slender flat genal spine. Facial suture cutting anterior margin well out at sides, curving out and back to marginal furrow, then running straight in to and curving around palpebral lobes, thence curving out and back to cut posterior margin well within genal angle.

Thorax of 19 narrow segments; axis low, narrower than pleural lobes; pleural segments crossed by broad and very shallow pleural furrows and ending in short pointed falcate terminations.

Pygidium triangular in shape; axis wide, strongly convex, with nearly parallel sides, extending to posterior margin with broadly rounded end, divided by two narrow furrows into two segments and a broad terminal portion; dorsal furrow obsolete; pleural platforms approximately one-third width of axis, slightly convex, downsloping; no interpleural grooves or segments seen; no marginal furrow or border seen.
Outer surface coarsely granulated; inner surface punctate with heavy anastomosing veins crossing ocular platform and brim.

Discussion.—This species is represented by two immature and three adult cranidia, several free cheeks and a pygidium. All are quite fragmentary but are identifiable specifically. The largest cranidium, though very broken, is interesting as it shows the size which can be reached by the species and also the stronger glabellar furrows in the larger individual. The two immature cranidia are important also. They agree in every feature with the adults except that the median boss is not developed yet. These cranidia are about 3 mm. in length.

McKee and Resser (1945) demonstrated that both the shale and sand specimens come from the same stratigraphic position and not as stated by Walcott in his description. At this time Resser chose U.S.N.M. No. 61574, a complete carapace in shale, as the lectotype. This specimen is somewhat flattened, but except for this distortion is obviously the same species as the sand specimen.

Hypotypes.—U.S.N.M. Nos. 115887-115892.

Formation and locality.—Middle Cambrian, Arrojos formation, 801-O.

ALOKISTOCARE MODESTUM Lochman, new species

Plate 27, figures 11-16

Cranidium quadrate, average specimen 6 mm. across the eyes by 6 mm. in length; glabella short, conical, length and width practically same, with broadly rounded front, convexity low, highest posteriorly to quite low anteriorly; three pairs of medium glabellar furrows, first pair short, straight, second and third longer, arcuate; dorsal furrow well defined; occipital furrow broad, deep at sides, shallow across center; occipital ring triangular, flat, with a small median node; brim of medium width, slightly convex, descending at 45°; marginal furrow broad, extremely shallow, interrupted at center by a very low median bulge which starts on posterior edge of brim and is elongate forward to touch the border; border slightly over half the width of brim, slightly convex, descending; anterior margin evenly rounded. Fixed cheeks over one-half but not quite two-thirds width of glabella, very slightly convex, very slightly upsloping; palpebral lobes of medium size, strong, curved, situated just back of midline of glabella; palpebral furrow wide, shallow; ocular ridge wide, low; posterior limbs nearly same length as occipital ring, crossed by a broad, shallow marginal furrow. Free cheek of medium width, elongate, with medium-sized eye at inner angle; ocular platform about medium width, slightly convex, steeply sloping; marginal furrow very shallow, nar-
row; border narrow, slightly convex, horizontal with a short pointed anterior projection and a short flat genal spine. Facial suture cutting anterior margin well out at sides, curving out to marginal furrow, then curving back and into and around palpebral lobes; thence running diagonally out and curving back to cut posterior margin within genal angle.

Thorax and pygidium not known.
Outer surface covered thickly with fine granules; inner surface appearing smooth.

Discussion.—This species is represented by eight cranidia and three free cheeks in the collection from locality 8011. The granulated outer surface is quite well preserved.

The species is most similar to the genotype, A. subcoronatum (Hall and Whitfield) differing from it mainly in the weaker development of the median bulge and the steeper descent of the border. In the genotype the border is essentially horizontal in position.

The single small cranidium (4 mm. in length) from the Langston formation of Idaho, identified by Resser as Inglefieldia idahoensis, is clearly a species of Alokistocare, and is very close to A. modestum, showing the same type of low median bulge. Additional and better-preserved specimens from both localities may demonstrate the synonymy of the species, but at present the holotype of A. idahoensis (Resser) (not A. idahoense Resser) differs from A. modestum Lochman in having the brim and border of practically the same width, and the border apparently somewhat more convex.

Types.—Holotype: cranidium, U.S.N.M. No. 115897; para-types: cranidia, U.S.N.M. Nos. 115898, 115899, 115901c,d; free cheeks, U.S.N.M. Nos. 115900, 115901a,b.

Formation and locality.—Middle Cambrian, Arrojos formation, 8011.

ALOKISTOCARE cf. A. MODESTUM Lochman, new species

Plate 27, figures 9, 10

Three cranidia in the collection from locality 800a are given this tentative identification. None is very well preserved, the surface being weathered and the edges of the cranidia broken. The measurements seem to fit Alokistocare rather than Kistocare. The specimens appear to resemble A. modestum Lochman, new species, in the weak development of the median bulge and in the width and proportions of the brim and border. They do show, however, three pairs of well-developed glabellar furrows, a feature more characteristic of Kistocare tontoensis (Resser) of this same fauna. The author considers that
there may be a possibility that these cranidia are actually the same as those representing that species, but that poor preservation or some slight distortion has blurred their true characters. Therefore their identification as Alokistocare modestum Lochman, new species, should remain tentative.

Figured specimens.—U.S.N.M. Nos. 115894, 115895.

Formation and locality.—Middle Cambrian, Arrojos formation, 800a.

Genus ALOKISTOCARELLA Resser, 1938

ALOKISTOCARELLA MEXICANA Lochman, new species

Plate 27, figures 1, 2

Cranidium nearly quadrate; glabella broadly conical, rounded in front, slightly convex, with greatest convexity posterior, sloping down rapidly anteriorly; three pairs of faint glabellar furrows, first pair short, straight, second short, curved, third longer, arcuate, all furrows mainly distinguished by absence of granules; a medium-wide, well-defined dorsal furrow around glabella; occipital furrow narrow, slitlike at sides, shallow and wider across center; occipital ring of medium width, slightly convex; rim of medium width, convex, regularly downsloping; marginal furrow broad, shallow, clear at sides, becoming fainter across center; border three-fourths width of limb, flat, slightly downsloping, with a low, transversely oval bulge on median line in posterior half; anterior margin evenly curved. Fixed cheeks not quite two-thirds width of glabella, slightly convex and slightly downsloping; palpebral lobes just under medium, curved, slightly posterior to midline of glabella; palpebral furrow shallow, well defined; a broad, low, gently curved ocular ridge; posterior limbs narrow, same length as occipital ring, crossed by a medium-wide, deep marginal furrow. Free cheek not known. Facial suture cutting anterior margin well out at sides, curving out and back to marginal furrow, then running diagonally into and curving around palpebral lobes, thence curving first nearly straight out, then sharply back to cut posterior margin within genal angle.

Thorax and pygidium not known.

Outer surface thickly covered with medium-sized granules, except the smooth furrows and bulge on the border. Inner surface not known.

Discussion.—This species is represented by three cranidia 6½ mm. in length and a fourth one somewhat smaller from locality 801n, and a broken, deeply weathered cranidium, 7 mm. in length, from 800c.

It is interesting to find a species of Alokistocarella in the Mexican
material so close in all features to the genotype from the southern Appalachian region. It may be distinguished from *A. typicalis* Resser by the descending nature of the narrow border as contrasted to the distinct upcurve in the latter species. The Mexican species also has a less convex glabella and a shallower dorsal furrow. It is doubtful how much importance should be put on these features, because all the types and duplicates of *A. typicalis* are internal molds in a punky yellow sandy leached limestone. Such preservation tends to emphasize the depth of furrows and convexity of glabella.

*A. mexicana* differs from *A. brighamensis* Resser in the flat horizontal border of the latter species, but as the types are crushed and flattened in shale this may be only a feature of preservation.

The preservation of *A. typicalis* and *A. brighamensis* fails to show the low median bulge although some cranidia of the former species have a suggestion of it.

**Types.**—Holotype, U.S.N.M. No. 115884; paratypes, U.S.N.M. Nos. 115885a, b, 115886.

**Formation and locality.**—Middle Cambrian, Arrojos formation, 800c, 801n.

Genus *KISTOCARE* Lochman, 1948

**KISTOCARE CORBINI** Lochman

Plate 28, figures 12-22


**Original description.**—“Cranidium subquadrate, largest specimen 8 mm. across the eyes by 7 mm. in length; glabella conical, slightly longer than wide, broadly rounded in front, convexity low, regular; three pairs of moderately deep glabellar furrows, first pair short, diagonal forward, second short, straight, third pair longer, arcuate; dorsal furrow narrow, deep at sides, shallow across front; occipital furrow narrow, deep at sides, broad and very shallow across center; occipital ring of medium width, slightly convex, with a small median node; brim and border nearly subequal, brim just a bit narrower, flat, sloping downward; marginal furrow narrow, shallow, becoming faint on median line; border narrow, flat, nearly horizontal (very slight descent can be seen); anterior margin evenly curved. Fixed cheeks slightly over one-half width of glabella, slightly convex, very slightly upsloping; palpebral lobes wide, raised, medium size, on posterior one-third line of glabella; palpebral furrow broad, shallow; ocular ridge wide, prominent, strongly curved; posterior limbs narrow, same
length as occipital ring, crossed by a broad, well-defined marginal furrow. Free cheek narrow, elongate, with medium eye at inner angle; ocular platform of medium width, one and one-half times the border, flat, gently descending; marginal furrow narrow, shallow; border narrow, very slightly convex, almost horizontal, with a slender pointed anterior projection and a short, slender genal spine. Facial suture cutting anterior margin far out at sides, curving out to marginal furrow, then curving back and into and around palpebral lobes; thence running diagonally outward and curving abruptly back to cut posterior margin within genal angle.

"Thorax not known.

"Pygidium broadly transverse; axis wide, strongly convex, very slightly tapered to a broadly rounded end, apparently extending to posterior margin, divided by two broad faint furrows into two narrow segments and a long terminal portion; dorsal furrow obsolete; pleural platforms slightly more than half the width of axis, flat, then steeply descending, two very faint narrow interpleural grooves distinguishable; marginal furrow obsolete; no border distinguishable; a long, narrow facet turns abruptly back at a 45° angle so that the lateral and posterior margins form a single gentle curve.

"Outer surface covered thickly with fine granules; inner surface apparently smooth."

Discussion.—This species is represented by a number of cranidia, three free cheeks, and a pygidium in the collection from locality 800c and six cranidia from locality 801n. The best-preserved specimens are unfortunately the smaller cranidia so that the holotype and best paratypes are about 3 mm. in length. Most of the larger cranidia are broken and crushed and so do not afford a perfect picture of the species.

This species differs from Kistocare tontoensis (Resser) in the somewhat wider proportion of the brim to the border, and the nearly horizontal position of the border.

Types.—Holotype, U.S.N.M. No. 115923; paratypes: cranidia, U.S.N.M. Nos. 115926-115928, 115931-115934; free cheeks, U.S.N.M. Nos. 115924, 115925; pygidium, U.S.N.M. No. 115929; unfigured paratype, U.S.N.M. No. 115930.

Formation and locality.—Middle Cambrian, Arrojos formation, 800c, 801n.
KISTOCARE Tontoensis (Resser)

Plate 28, figures 26-31


Original description.—"A cranidium has been segregated to represent this species. It occurs in micaceous sandstone and is coated with limonite.

"Glabella occupies a little more than half cranidial length; tapers normally to truncated front; several pairs of furrows and a keel faintly outlined. Brim consists of the usual rim and preglabellar area. In certain light, rim appears to be wider than preglabellar area, whereas light from the other direction gives the opposite impression. This indicates width and shallowness of anterior furrow. Fixigenes equal to about three-fourths glabellar width. Eyes situated behind central point, so that eyelines swing backward sharply. Postero-lateral limbs narrow and small. Owing to slight compression, the convexity cannot be determined, although the specimen shows considerable relief both as a whole and in its various parts.

"Measurements: Holotype (cranidium), length 5.5 mm., width at eyes 6.2 mm., length of glabella 3.4 mm., anterior width of glabella 2.2 mm., width at base of glabella 2.5 mm."

Supplementary description.—Cranidium subquadrate; glabella conical, very slightly longer than wide, front broadly rounded, convexity low, regular; three pairs of moderately deep glabellar furrows with a pair of faint anterior pits which may represent another vestigial pair; first pair short, straight, second and third longer, arcuate; dorsal furrow narrow, well defined; occipital furrow broad, deep at sides, very shallow across center; occipital ring of medium width, flat with a small median node; brim narrow, slightly less than border in front of glabella, flat, gently descending; marginal furrow broad, quite shallow on outer surface, deeper on internal mold (as in holotype), with suggestion of a very slight median inbend; border narrow, slightly convex, continuing downslope of brim; anterior margin evenly curved. Fixed cheeks slightly over half the width of glabella, slightly convex, almost horizontal; palpebral lobes wide, raised, of medium size, on posterior one-third line of glabella; palpebral furrow broad, shallow; ocular ridge wide, prominent, strongly curved; posterior limbs narrow, same length as occipital ring, crossed by a broad, well-defined marginal furrow. Free cheek not known. Facial suture cutting anterior margin far out at sides (on line with outer third of fixed cheek), curving out to marginal furrow, then diagonally back and into and
around palpebral lobes; thence curving outward and strongly backward to cut posterior margin within genal angle.

Thorax and pygidium not known.

Outer surface thickly covered with fine granules; inner surface not known.

Discussion.—This species is represented by five cranidia, most of them partly broken but they check in every detail available with the sandstone-mold holotype from the Grand Canyon region. The supplementary description is based primarily on the holotype cranidium with the character of the outer surface of the test added from the hypotypes. It should be noted that the original description erred especially in the width of the fixed cheeks.

This species was described by Resser in 1945 as *Parehmania ton-toensis* but it differs from *Parehmania* Deiss, 1939, in the following diagnostic features:

1. The palpebral lobe in *Parehmania* is just back of the midline of the glabella, not on the posterior one-third line.
2. The fixed cheeks in *Parehmania* are definitely one-half width of glabella and not more.
3. The posterior limbs in *Parehmania* are slightly less than the length of the occipital ring.

It is interesting to find this Arizona species in the Mexican section as its faunal association in both localities is the same. It apparently maintains the same stratigraphic position throughout this region.

Hypotypes.—U.S.N.M. Nos. 115937-115940.

Formation and locality.—Middle Cambrian, Arrojos formation, 800a.

Family CREPICEPHALIDAE Kobayashi, 1935

Genus KOCHASPIS Resser, 1935

KOCHASPIS COOPERI Lochman, new species

Plate 25, figures 33, 34

Cranidium and free cheek not known.

Thorax not known.

Pygidium transversely rectangular; axis of medium width, strongly convex, tapering posteriorly, with a low extension on the border, divided by narrow furrows into three segments and a terminal portion; dorsal furrow narrow, shallow, extending all around axis; pleural lobes two-thirds width of axis; pleural platforms slightly convex, tapering posteriorly, divided into four segments by broad, shallow interpleural grooves which curve backward and fade into base of spines; a narrow,
flat border delimited only along posterior margin, laterally forming bases of spines; at posterolateral corners a slender flat spine leaves border and curves very slightly inward for a distance slightly more than length of body of pygidium; lateral margin from anterior to tip of spines is gently convex; posterior margin moderately convex. Outer surface thickly covered with fine granules.

Discussion.—Eight pyidia from locality 801k include a number which are broken and small, but several fairly well preserved. No cranidium can be associated with them. They definitely belong to Kochaspis but are not like any previously described species. It is most like the pygidia assigned to K. dispar Resser (K. maladensis Resser) but differs from them in the slight convexity of the pleural platforms and the direction of the marginal spines. In the holotype pygidium, chosen because of its completeness, the convexity is probably somewhat lower than that attained in the larger adult specimens.

Types.—Holotype, U.S.N.M. No. 115853; paratypes, U.S.N.M. Nos. 115854, 115855.

Formation and locality.—Middle Cambrian, Arrojos formation, 801k.

**KOCHASPIS aff. K. CELER** (Walcott)

Plate 24, figures 27-30


*Ptychoparia clusia* Walcott (the cranidium), Smithsonian Misc. Coll., vol. 67, No. 3, p. 85, pl. 11, fig. 3, 1917.


Original description.—"Glabella a little more than two-thirds as long as the cranidium, quite strongly elevated along a subacute medial ridge which disappears gradually toward the front; outline trapezoidal, the broadly rounded anterior extremity not more than half as broad as the base; dorsal furrows rather wide, deeply impressed, converging quite rapidly anteriorly and rounding sharply into the more shallow, transverse anterior furrow; glabellar furrows also broad and deep, though not persistent across the crest; posterior pair inclined to the axis of the shield at an angle of a little more than 45°, almost completely isolating the tumid posterior lobe; medial pair neither so broad nor so deep as the posterior and nearly at right angles to the axis; anterior pair a little shorter than the medial, slightly inclined toward the front and placed nearer to the medial pair than to the anterior furrows; occipital groove broad and deep, completely dissecting the crest of the
glabella, very slightly sinuous; occipital ring rather narrow, expanded medially, obtusely angulated at the medial posterior margin, and bearing a rather prominent median node. Fixed cheeks plump and quite wide, the distance from the palpebral lobe to the dorsal furrow a little more than half the width of the medial portion of the glabella; postero-lateral lobe narrow and probably extended laterally; posterior furrow conspicuously broad and deep, its inner terminus in line with both the occipital furrow and ring; posterior margin narrow and sharply elevated. Palpebral lobe short, narrow, crescentic, set opposite the lobe between the posterior and medial furrows. Palpebral ridge rather prominent, cordate, arching across the fixed cheeks and intercepting the dorsal furrows directly in front of the anterior glabellar furrows. Frontal limb rather narrow, inflated laterally, gently declining medially. Frontal border wider medially than the limb, sharply upturned. Facial sutures imperfectly preserved.

"Exterior surface very finely and closely granulated or roughened by an irregular pitting with broken, depressed ridges that give the effect of obscure granulation.

"Pygidium rudely quadrate in outline exclusive of the posterior constriction, the lateral margins approximately parallel to the axis; anterior margin broken by the forward curve of the axial lobe; posterior margin very broadly and deeply insinuated. Axial lobe large and coarse, broadly conic in outline, acutely tapering posteriorly; axial annulations probably very distinct in perfectly preserved individuals, including apparently 6 component segments and a terminal section. Pleural lobes flexuous, irregular in outline, the anterior lateral margin an obtuse right angle; pleural furrows following the same general direction as the outer margin but less angulated, disappearing abruptly along an imaginary arc of about 180°; extremities of pleural lobes produced into cuneate appendages, acutely tapering."

Discussion.—This species is represented by four immature cranidia, 1.5 mm. to 2 mm. in length, and several small adult cranidia, none of which are complete enough to warrant positive specific identification. The determinable details of the adult cranidia suggest close affinities with Kochaspis celer (Walcott). This, unlike most species of Kochaspis, shows the same type of narrow brim and border with a similar slope and convexity. However, the incompleteness of the Mexican material does not warrant positive identification with this species or description as a new species.

Several of the cranidia show features of immaturity, as (1) in the smallest cranidium an additional pair of anterior glabellar furrows appears as small pits, and (2) the glabella has a square rather than
rounded front as it is just transitional from the straight-sided rectangle of the protaspid stage to the conical type of glabella of the adult. Several cranidia of Kochaspis celer (Walcott) show this feature through a length of 3-4 mm.

*Figured specimens.*—U.S.N.M. Nos. 115824, 115825, 115826, 115827.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 802b.

**Kochaspis? species undetermined**

Plate 25, figures 23, 24

Three very incomplete and poorly preserved cranidia were obtained from two collections in the Puerto Blanco section. They show a strongly convex glabella, broader at base than long, with three pairs of deep, well-defined glabellar furrows, and the outer surface covered with coarse granules. The specimens are, however, so broken that even certain generic identification is not possible. The cranidia are noted because of their possible bearing on the position of the Lower–Middle Cambrian boundary, and because more complete material may demonstrate that they are the cranidia which should be associated with the pygidia of Kochaspis cooperi Lochman, new species.

*Figured specimens.*—U.S.N.M. Nos. 115852a, 115851.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 801h, 801i.

Family Kootenidae Resser, 1939

Genus *Kootenia* Walcott, 1889

**Kootenia exilaxata** Deiss

Plate 26, figures 1-20


*Kootenia fragilis* Deiss, Geol. Soc. Amer. Spec. Pap. 18, p. 100, pl. 17, figs. 18-20, 1939.


*Kootenia scapegoatensis* Deiss, Geol. Soc. Amer. Spec. Pap. 18, p. 102, pl. 18, figs. 1-4, 1939.

*Original description.*—“Species known from several associated cranidia and pygidia.

“Cranidium similar to that of *Kootenia scapegoatensis*, but glabella relatively more slender, and fixed cheeks wider. Width of glabella one-
half length, including occipital ring. Dorsal furrows narrow, rounded, deep.

"Pygidium similar to that of Kootenia erromena, but slightly more transverse, and possesses a narrower and more parallel-sided axis."

Supplementary description.—Cranidium subquadrate in outline; glabella broad with parallel sides, rounding in at front; convexity relatively low but regular; suggestion of a faint short posterior pair of glabellar furrows; dorsal furrow narrow, well defined along sides and front, deepening to a small pit at anterolateral corners of glabella; occipital furrow broad, deep, especially at sides; occipital ring of medium width, convex, with a short, stout, upward-projecting median spine; brim a narrow, elongate, steeply sloping triangle in front of fixed cheeks; marginal furrow narrow, shallow, continuous with dorsal furrow in front of glabella; border narrow, inner part flat and slightly wider at sides, outer part downcurved; anterior margin evenly curved. Fixed cheeks approximately one-half width of glabella, slightly convex, downsloping; palpebral lobes medium sized, curved, on posterior one-third line of glabella; ocular ridge broad, faint, slanting diagonally forward to anterior pit; palpebral furrow very faint; posterior limbs narrow, same length as occipital ring, crossed by a well-defined marginal furrow. Free cheek short, stout, with medium-sized eye at inner angle; ocular platform of medium width, slightly convex, downsloping; marginal furrow broad, shallow; border narrow, convex, horizontal, with a short, pointed anterior projection and a short, stout broad-based genal spine. Facial suture cutting anterior margin on midline of fixed cheeks, curving steeply back to marginal furrow, then running diagonally into and curving around palpebral lobes; thence running nearly straight out and curving sharply back to cut posterior margin within genal angle.

Associated hypostoma has edges poorly preserved, no border detected; a convex, semicircular posterior lobe separated from anterior lobe by a broad, very shallow semicircular furrow; anterior lobe an elongate, convex oval not defined from rest of body of hypostoma, with a crescent-shaped ridge at each posterior corner and a very shallow macula above it; anterior lobe merging anteriorly into the very wide lappets which appear to extend outward for some distance; anterior margin curved.

Pygidium transversely semicircular in outline; axis of medium width, strongly convex, only slightly tapered to rounded end which reaches border, divided into three definite, one faint segment, and a terminal portion by furrows becoming progressively fainter posteriorly; dorsal furrow narrow, faint, along sides; pleural platforms very
slightly less than width of axis, tapered posteriorly, regularly convex, sloping down to a shallow marginal furrow, divided into three and one-half segments by interpleural grooves becoming fainter posteriorly; border flat, narrow with six short spines on each side, anterior four lying opposite the three and one-half segments of pleural lobe; spines grade in size quite regularly but slightly from longest anterior pair to shortest posterior median pair; the two posterior pairs tend to curve up, the next two lateral pairs lie more horizontally, and the two anterior pairs tend to slope down slightly.

Outer surface covered by fine granules; inner surface apparently smooth.

Discussion.—This species is represented by a number of cranidia and pygidia and a few free cheeks and hypostoma in two collections. It is to be distinguished from all other described species by the combination of the following characters: In the cranidium, the low continuous curve of the glabella from front to back; the clear separation of the front of the glabella from the border by a well-defined marginal furrow; the width of brim at sides is slightly over one-half the width of the front glabella; and a short occipital spine is present. In the pygidium, the six pairs of relatively short marginal spines showing progressive increase in length from back to front; and the variable curvature and slope of the different pairs.

In studying the Mexican species, four species of Kootenia described by Deiss from the Damnation formation of Montana proved to be synonyms. Examination and measurement of the types of these species revealed them to be similar in all features of the cranidia and pygidia, and it became clear that they were simply different-size stages of the same species. Deiss’s specimens are unfortunately all of the weathered surface-limestone type and are not well preserved. It is suggested that the specimens of K. erroshena Deiss may also represent the same species, but the types are badly crushed and weathered and give somewhat different proportions.

The entire genus Kootenia is in need of careful revision. It appears that there has been a most unnecessary duplication of species. In addition, uncertainty as to the stratigraphic range of many of these species has rendered it useless as a zone fossil. However, careful attention to identification and stratigraphic position might well reveal it as a useful form, since it appears to have definite position in the Mexican section.

Hypotypes.—Cranidia, U.S.N.M. Nos. 115869-115872, 115874, 115881; pygidia, U.S.N.M. Nos. 115873, 115876-115878, 115882; hypostoma, U.S.N.M. No. 115875; free cheek, U.S.N.M. No. 115880.
Formation and locality.—Middle Cambrian, Arrojos formation, 800c, 801n.

Family PTARMIGANIDAE Resser, 1939

Genus ATHABASKIA Raymond, 1928

Examination and analysis of the genotypes of Athabaskia Raymond, 1928, and Clavaspidella Poulsen, 1927, show that the two genera, although closely related forms, are nevertheless distinct, and Resser (1935) was in error when he placed Athabaskia in synonymy with Clavaspidella. Raymond's choice of a type species was most unfortunate as his specimens are crushed and poorly preserved in a shale matrix. In fact, the specimens of A. ostheimeri Raymond and its probable synonym, A. glacialis Raymond, are possibly the most poorly preserved of all species belonging to the genus. The analysis of the two genera reveals that all the species assigned to Clavaspidella in the Cordilleran region actually belong to Athabaskia.

The cranidium of Athabaskia differs from that of Clavaspidella in the following points:

1. The glabella is of medium width with parallel sides in posterior half while that of Clavaspidella is narrow, with slightly concave sides.
2. The fixed cheeks are two-fifths, or slightly less than one-half, the width of glabella, while those of Clavaspidella are nearly two-thirds the width of the glabella.

The pygidium of Athabaskia differs from that of Clavaspidella in the following points:

1. The axis is as wide as, or slightly wider than, the pleural platforms, while that of Clavaspidella is narrower.
2. The marginal furrow is obsolete, while it is present and distinct in Clavaspidella.

ATHABASKIA BELA (Walcott)

Plate 29, figures 1-10


Original description.—"This species attains a larger size than either B. anax or B. atossa, and differs from them in minor details of the cranidium and pygidium. There is a faint trace of pleural furrows on the lateral lobes of the pygidium, whereas in B. anax and B. atossa
they are strongly defined. The variations from *B. belesis* are mentioned under that species.

"The largest cranidium has a length of 19 mm. and the largest pygidium has a length of 22 mm. and a width of 37 mm.

"An associated hypostoma of the *Bathyuriscus* form has the surface of its central portion marked by fine, sharp, irregularly concentric ridges. None of the cranidia or pygidia appear to have the outer surface of the test. They occur as casts in a very fine, chocolate-colored, arenaceous shale."

*Supplementary description.*—Cranidium elongate-oblong; glabella of medium width, straight sides in posterior half, then expanding evenly to the broad, slightly curved front, convexity low, but regular; four pairs of glabellar furrows, first and second pairs short and straight, at sides only, third short, slightly curved, fourth pair curving diagonally backward, not quite reaching center; dorsal furrow narrow, well defined to first glabellar furrow, then very shallow and nearly obsolete around front; occipital furrow well defined at sides only, quite shallow across center; occipital ring of medium width, triangular, flat, probably with a small median node; brim a narrow, elongate, downsloping strip in front of fixed cheeks; no marginal furrow; border a concave, triangular, vertical strip in front of each brim, with an extremely narrow convex edge which continues in front of glabella as a very narrow rim; anterior margin slightly curved. Fixed cheeks very narrow in front, expanding to slightly less than one-half width of glabella, slightly convex and upsloping; palpebral lobes arcuate, long, on posterior one-third line of glabella; palpebral furrow broad, well defined; no ocular ridge; posterior limb somewhat longer than occipital ring, narrow with ends directed backward, crossed by a broad shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin extremely far out, so that with a very slight curve it turns and runs straight into and curves around palpebral lobes; thence curving straight out, then abruptly back to cut posterior margin within genal angle.

Thorax not known.

Pygidium transversely semicircular in outline; axis of medium width and convexity, tapering posteriorly onto the border, divided by narrow furrows into four segments (last one faint), and a terminal portion; dorsal furrow narrow, only along sides; pleural platforms same width as axis, tapering posteriorly, moderately convex, downsloping, divided by narrow, well-defined interpleural grooves into four wide segments, crossed by faint pleural furrows just on inside portion; no marginal furrow; border of medium width, flat, forming a concave
upcurve from pleural platforms and crossed halfway by the interpleural furrows.

Outer surface apparently smooth except for a few narrow parallel ridges on border of cranidium and border of pygidium; inner surface not known.

Discussion.—This species is distinguished from all those described by the wide, strongly upturned border of the cranidium, and the four segments of the axis and quite faint development of the pleural furrows of the pygidium. On many specimens with poorly preserved outer surface they may appear to be missing.

The species is represented by three cranidia and a number of fragmentary pyidia in two collections. This is the second species from Mexico faunas which also occurs in the Gordon formation of Montana.

Hypotypes.—Cranidia, U.S.N.M. Nos. 115941, 115942, 115945; pygidia, U.S.N.M. Nos. 115943, 115946-115948.

Formation and locality.—Middle Cambrian, Arrojos formation, 800c, 801n.

ATHABASKIA MINOR (Resser)

Plate 31, figures 1-3


Original description.—"A number of specimens in the Lakeview limestone evidently belong to Clavaspidella. This species is much smaller than any other thus far described; also, both the pygidial axis and the eye lobes are longer."

Supplementary description.—Cranidium elongate-oblong; glabella oblong, posterior half of medium width with parallel sides, expanding gradually anteriorly to a low rounded front; convexity low, regular; four pairs of short, shallow glabellar furrows, first pair slanting forward, second pair straight, third and fourth slanting backward; dorsal furrow of medium width, well defined all around glabella; occipital furrow broad and shallow; occipital ring of medium width, triangular, flat with a tiny median node; brim a narrow, gently descending rectangular area in front of each fixed cheek; no marginal furrow; border a very narrow, flat, slightly sloping band, narrowest on median line; anterior margin very slightly curved. Fixed cheeks approximately one-half width of glabella, slightly convex, horizontal; palpebral lobes long, wide, arcuate, on posterior one-third line of glabella; palpebral furrow wide, well defined; ocular ridge short, very faint; posterior limbs somewhat longer than occipital ring (crushed), crossed by a broad, shallow marginal furrow. Free cheek not known. Facial suture
cutting anterior margin far out, on line with dorsal furrow, curving back a short distance, then running diagonally inward to and around palpebral lobes, thence curving far out, then back abruptly to cut posterior margin within genal angle.

Thorax not known.

Pygidium transversely semicircular; axis of medium width, convex, tapering slightly to a broad pointed expansion extending onto the border, divided by four narrow, progressively fainter furrows into four narrow segments and a terminal portion; pleural platform very slightly wider than axis, slightly convex and descending gently, divided by four broad interpleural grooves which curve back onto the border; pleural furrows narrow, faint, fading out before reaching the border; no marginal furrow; border narrow, concave, upturned, posterior margin evenly curved.

Outer surface apparently smooth; inner surface also appears smooth.

Discussion.—The occurrence of this species in Mexican material affords another interesting tie with the Northwestern Middle Cambrian sections. It is represented by a small cranidium, and two somewhat larger pygidia, but none of the specimens is complete or very well preserved.

The redescription was written from the holotype and paratypes from the Lakeview limestone at Pend Oreille Lake, Idaho. The diagnostic characters of this species appear to be a combination of the following features:

1. In the cranidium the low convexity of the glabella and the flat, horizontal to very slightly descending position of the border, and
2. In the pygidium the narrow width and upturned position of the border and the faint impress of the pleural furrows.

Neither the long eyes, which are proportionately no longer than those of any other species of the genus, nor the small size, which simply means that only small specimens were found—features cited by Resser as diagnostic specific features—are regarded by the author as valid features.

_Hypotypes._—Cranidium, U.S.N.M. No. 115988; pygidia, U.S.N.M. Nos. 115987, 115989.

_Formation and locality._—Middle Cambrian, Arrojos formation, 80og.

Genus _PTARMIGANIA_ Raymond, 1928

Considerable confusion has arisen as to the distinctions between _Ptarmigania_ and _Dolichometopsis_, especially as a result of Resser's (1939) emendation of the genus. Consequently a complete restudy of the Langston material referred to both these genera and the plasto-
types of *Dolichometopsis resseri* Poulsen at the United States National Museum had to be made and points of interest were discovered.

The following distinctions can be recognized between the cranidia of *Dolichometopsis* and *Ptarmigania* when dealing with specimens at least 10 mm. or over in size. In *Dolichometopsis* (1) the palpebral lobes are large and (2) are situated on the posterior one-fourth line through the glabella, (3) the fixed cheeks are less than one-half and nearly one-third the width of the midline of the glabella, (4) the anterior end of the palpebral lobe and palpebral furrow run into and touch the dorsal furrow so that at this position the fixed cheek has no separate width, and (5) the anterior corners of the glabella tend to round in, the rounding becoming more pronounced with increase in size. In *Ptarmigania* (1) the palpebral lobes are just over medium size and (2) are situated on the posterior one-third line through the glabella, (3) the fixed cheeks are between three-fourths and three-fifths the width of the midline of the glabella, (4) there is always an appreciable width of fixed cheek crossed by a well-defined ocular ridge opposite the anterior end of the palpebral lobe, and (5) the anterior corners of the glabella always remain squared and generally expanded.

An examination of the small holaspid cranidia in the Langston material referred arbitrarily by Resser to either *Dolichometopsis* or *Ptarmigania*, the small cranidia from Greenland and those referred to *Dolichometopsis*? by Rasetti (1948) from Canada reveals that certain of the adult distinctions are lost. The anterior end of the glabella in both genera is expanded and somewhat squared, and the palpebral lobes in *Dolichometopsis* assume more nearly the one-third posterior line position. However, in none of the small Langston cranidia does the fixed cheek assume the narrower proportions and only in one form, described as *Dolichometopsis lepida* Resser, does the fixed cheek almost disappear opposite the anterior end of the palpebral lobe. Even in this form the palpebral furrow does not run right into the dorsal furrow as in *Dolichometopsis resseri* Poulsen. This general similarity of all the small cranidia of what I would consider to be only one genus, *Ptarmigania*, in the Langston material to the small cranidia of *Dolichometopsis* very probably was the original cause of the confusion. In view of the fact that all the large holaspid cranidia are definitely congeneric with *Ptarmigania rossensis* (Walcott), the author can see no reason why the smaller holaspid cranidia should not be considered to be *Ptarmigania* also. The similarity between the small holaspid cranidia of the two genera is interpreted as indicating that *Ptarmigania* is the early Middle Cambrian descendant of the late Lower Cambrian *Dolichometopsis*. 
Concerning the pygidia of the two genera the following items should be noted: (1) There are no complete specimens in the Langston material at the United States National Museum in which cranidium, thorax, and pygidium are connected as Resser would imply (1939, p. 33). The specimen of Dolichometopsis poulsoni Resser is just as figured on plate 5, figures 5, 6, consisting only of pygidium and seven broken thoracic segments. (2) The suite of type material of P. rossensis (Walcott) shows that in this species there is one well-developed anterior pair of marginal spines, almost always a second pair of spine nubbins opposite the second interpleural grooves, and on one specimen the inception of a third pair of spine nubbins opposite the third interpleural grooves. Such a condition indicates that marginal spines are inherent in the genus, and the forms described by Resser from the Langston show all the possible gradations up to four pairs of well-developed spines. The Langston material is thought to contain only three or four distinct species (one of them P. rossensis (Walcott)) and affords an excellent opportunity for a study of specific variation and growth stages within this genus.

(3) In view of the above-mentioned evidence from the specimens, the author agrees with Rasetti's opinion (1948, p. 20) that it is more plausible to accept Poulsen's assignment of a Lower Cambrian pygidium to his Lower Cambrian Dolichometopsis cranidium.

Genus PTARMIGANIA Raymond, 1928

PTARMIGANIA BISPINOSA Lochman, new species

Plate 22, figures 1-9

Cranidium subquadrate; glabella broad, elongate, with parallel sides and a very slight anterior expansion, rounded anterior corners, convexity low but regular; four pairs of glabellar furrows, first and second very short, straight, first very faint, third short, slightly curved, fourth longer, arcuate; dorsal furrow narrow, well defined all around glabella; occipital furrow narrow, well defined; occipital ring triangular, flat, with a small node on posterior midline; brim a narrow steeply sloping rectangle on sides; a faint narrow marginal furrow running into corners of glabella; border narrow, flat, widening slightly in front of brim, but rimlike in front of glabella. Fixed cheeks very narrow anteriorly, approximately one-third width of glabella on midline of palpebral lobes, very slightly convex, upsloping; palpebral lobes long, arcuate; palpebral furrow broad, well defined; ocular ridge obsolete; posterior limbs narrow, slightly shorter than occipital ring, lower than cheeks, crossed by a narrow well-defined marginal fur-
row. Free cheek too poor to describe. Facial suture cutting anterior margin far out at sides, curving out, then running straight back to and curving around palpebral lobes, then curving outward and straight backward to cut posterior margin within genal angle.

Hypostoma triangular with prominent broad convex lappets; a tumid elongate anterior lobe with a low, short ridge at each posterior corner and a shallow macula just anterior to it; posterior lobe apparently convex, narrow, semicircular, very poorly preserved; anterior border crushed, apparently regularly convex and downsloping; no marginal furrow; anterior margin a flat curve; lappets quite wide, extending hornlike at sides but full length not known.

Thorax not known.

Pygidium semicircular; axis wide, strongly convex, only slightly tapered to a broadly rounded end, extending nearly full length of pygidium, divided by three broad well-defined and one faint furrow into four segments and a terminal portion, first and second anterior segments with short stout axial spines and on third an axial node; dorsal furrow obsolete; pleural platforms practically same width as axis, moderately convex, downsloping steeply at sides, divided by broad, shallow interpleural grooves into four segments; where these grooves meet the border they form a shallow oval pit, otherwise no marginal furrows; flat, narrow border with four stout marginal spines on each side, lying opposite each pleural segment and directed nearly straight backward; length of spines not known.

Outer surface of smallest cranidium apparently smooth, but preservation poor; inner surface not known.

Discussion.—This species is described from a number of cranidia of varying sizes and a number of pygidia. Unfortunately, all the material occurs at one horizon and is crushed and the surface weathered so that the preservation is quite poor and no one specimen shows all features clearly and accurately.

The Mexican species is very similar to *P. rossensis* (Walcott) in the structure of the cranidium, showing only an occipital node rather than the usual strong spine. In the pygidium it appears that the four pairs of marginal spines were of medium length, and the species differs from all other described forms in the possession of two axial spines and the axial node on the third segment of the pygidium.

Types.—Holotype, U.S.N.M. No. 115760; paratypes: cranidia, U.S.N.M. Nos. 115764, 115765a; pygidia, U.S.N.M. Nos. 115761, 115762, 115765b; hypostoma, U.S.N.M. No. 115763.

Formation and locality.—Middle Cambrian, Arrojos formation, 801j.
Genus GLOSSOPLEURA Poulsen, 1927

GLOSSOPLEURA LEONA Lochman, new species

Plate 25, figures 1-21

Cranidium narrow, elongate-oblong; glabella of medium width, expanding very slightly forward to a wide, flatly curved front, low, regular convexity; four pairs of faint glabellar furrows, first and second short, slanting forward, third short, straight, fourth longer, diagonally backward; dorsal furrow narrow, well defined along sides to a small pit opposite first glabellar furrow, a faint suggestion continues to corner, but is obsolete across front (demarcation between glabella and border determined by a slight change in convexity); occipital furrow broad, well defined, deeper at sides; occipital ring of medium width, slightly convex; brim a narrow, flat, descending area in front of fixed cheeks, merging into border; no marginal furrow; border a narrow flat band continuing slope of glabella in front; anterior margin evenly curved. Fixed cheeks extremely narrow in front, slightly more than one-third width of glabella at midline of palpebral lobes, slightly convex and downsloping; palpebral lobes long, arcuate, situated on posterior third of glabella; palpebral furrow broad, well defined, running to dorsal furrow; ocular ridge faint, short; posterior limbs narrow, same length as occipital ring, crossed by narrow, well-defined marginal furrow. Free cheek narrow, elongate, with large eye at inner angle; ocular platform slightly convex, descending, narrow anteriorly, expanding posteriorly; a narrow, well-defined marginal furrow; border convex, narrow, downsloping, with a short anterior projection and a slender, medium-length genal spine. Facial suture cutting anterior margin on line with dorsal furrow, curving out and back and then straight into and around palpebral lobes; thence curving evenly out and back to cut posterior margin within genal angle.

Associated hypostoma subtriangular in outline; an extremely narrow border and marginal furrow along posterior half; marginal furrow deepening at each side; a narrow, slightly convex posterior lobe separated from anterior lobe by a broad, shallow furrow which joins marginal furrow at sides; anterior lobe tumid, broadly triangular, merging anteriorly into anterior margin and lappets, marked at each posterior corner by an elongate ridge with a broad, shallow macula just anterior to it; no anterior furrow or border distinguishable; lappets wide, length not known.

Thorax not known.

Pygidium semicircular; axis of medium width, moderately convex, tapering posteriorly to and onto marginal border, divided into five
or six narrow segments and a terminal portion by narrow, progressively fainter furrows; dorsal furrow very shallow, only along sides; pleural platforms approximately same width as axis, convex, descending steeply, divided by very faint interpleural grooves into four or five broad segments; no distinct marginal furrows; marginal border narrow, somewhat concave, descending slightly; posterior margin with a slight median inbend.

Outer surface covered thickly with fine granules with some narrow imbricating ridges on border of cranidium, free cheek, and pygidium; inner surface coarsely punctate.

Discussion.—This species is represented in several collections by a number of cranidia, pygidia, free cheeks, and hypostoma. The specimens in collections from localities 802b and 802c are medium-sized adults, but the rest of the specimens are quite small, a condition which has made comparison with the usually large specimens of Glossopleura difficult.

This species appears to differ from all described ones in (1) the gentle expansion and low convexity of the front of the glabella, and (2) the narrow, descending border of the pygidium. In fact, only two other species show a similar narrow border—G. belesis (Walcott), preserved in shale, and with the border apparently horizontal in position, and the paratype U.S.N.M. No. 62695 of G. mcekei Resser. On this specimen also the narrow border apparently lies in horizontal position and so is not comparable to the Mexican species. Attention should be called to the fact that the holotype of G. mckeei has a pygidial border of medium width and so could not represent the same species as the above-mentioned paratype. Two other paratypes referred to this species by Resser have also been misidentified—U.S.N.M. No. 62691 and U.S.N.M. No. 62690—the free cheeks and pygidium respectively of Anoria tontoensis (Walcott).

Types.—Holotype, U.S.N.M. No. 115830; paratypes: cranidia, U.S.N.M. Nos. 115832, 115833, 115839, 115843, 115845, 115847, 115848; pygidia, U.S.N.M. Nos. 115835, 115838, 115841, 115842, 115844, 115846, 115849; free cheeks, U.S.N.M. Nos. 115831, 115834; hypostoma, U.S.N.M. Nos. 115836, 115837.

Formation and locality.—Middle Cambrian, Arrojos formation, 802b, 802c, 801m, 801m', 801n.
GLOSSOPLEURA species

Plate 31, figures 8-14

A number of specimens of a large species of Glossopleura was obtained from the shales in the upper part of the Arrojos formation in the Arrojos Hills. Some of the specimens are of the entire carapace, but all are unfortunately crushed and flattened in the shale, and, for some reason, the cephalon is poorly preserved. The absence of the free cheeks from most of the specimens suggests that they are actually molts of the animal. The cephalon and pygidium appear to be specifically similar to those of Glossopleura mckeei Resser from the Bright Angel shale of the Grand Canyon section. However, complete carapaces of the latter species show consistently seven segments in the thorax, regardless of size, whereas the Mexican species consistently shows eight segments in the thorax. The author is at a loss to explain the true significance of this difference, as certainly the cephalon and pygidia cannot be separated specifically. It must be admitted that the poor shale preservation in both groups of specimens makes it very difficult to judge the value of small specific features.

Figured specimens.—Cranidia, U.S.N.M. Nos. 115995, 116336; carapaces, U.S.N.M. Nos. 116333, 116334, 116335; pygidium and part of thorax, U.S.N.M. No. 115996.

Formation and locality.—Middle Cambrian, Arrojos formation, S0oc, S0oc', S0of, S01m'.

Family ZACANTHOIDAE Swinnerton, 1915

Genus ALBERTELLA Walcott, 1908

ALBERTELLA PROVEEDORA Lochman, new species

Plate 23, figures 1-8

Cranidium oblong-elongate; glabella oblong, slowly expanding to a broadly rounded front, moderately and regularly convex; four glabellar furrows extending about one-third in on each side, first and second short, straight, third and fourth longer, arcuate; dorsal furrow well defined along sides, deepening to small pit at first glabellar furrow, very narrow and faint across front; occipital furrow broad and shallow; occipital ring of medium width, flat, probably a tiny posterior median node; brim a small rectangle in front of fixed cheek, sloping

2 The collections studied by Dr. Lochman included some species also studied by Dr. Stoyanow. The latter regards the species as a new genus, Sonoraspis. Dr. Lochman, on the other hand, refers the specimens submitted to her to Glossopleura.—G. A. C.
steeply, then flattening out; no marginal furrow; border convex, narrow, rimlike; anterior margin a flat curve. Fixed cheek just a little more than one-third width of glabella, slightly convex, downsloping; palpebral lobes of medium length, posterior to midline of glabella, continuing forward into low, broad diagonal ocular ridges; palpebral furrow broad, shallow; posterior limbs of medium length and width with a very broad shallow furrow. Free cheek elongate, of medium width; medium-sized eye at inner angle; ocular platform of medium width, steeply sloping anteriorly, lower posteriorly; marginal furrow narrow, well defined; border of medium width, flat, with a short anterior projection and a medium-length, flat genal spine. Facial suture cutting anterior margin far out at side, curving around, then running straight back to and curving around palpebral lobes; thence curving out and back to cut posterior margin within genal angle.

Hypostoma roughly triangular in outline; anterior lobe oval, strongly convex, with a shallow crescentic furrow near posterior end; this furrow runs into a slitlike macula on each side; posterior to each macula is a low ridge; posterior lobe small, crescent-shaped, convex, separated from anterior lobe by well-defined furrow; marginal furrow very narrow; posterior border narrow, rimlike, marked by narrow ridges; anterior marginal furrow broad, very shallow; anterior border narrow, flat, extending laterally into flat lappets.

Thorax not known.

Pygidium semicircular; axis strongly convex, only slightly tapered, extending to border, divided by narrow shallow furrows into four segments, a faint fifth segment and a terminal portion; dorsal furrow obsolete, only as pits opposite first and second furrows; pleural platforms approximately one-half width of axis, tapering rapidly posteriorly, only three segments delimited by broad shallow interpleural grooves, anterior half segment and first segment extending laterally into a heavy marginal spine diverging out and back at 45°; posterior to spines a narrow, nearly flat border separated by a faint, shallow marginal furrow; posterior margin convex.

Outer surface covered thickly with fine granules; inner surface apparently smooth.

Discussion.—This species is represented by a small number of cranidia, pygidia, hypostoma, free cheeks, and associated protaspids in collections from one section. It is associated with the very widespread _Mexicella mexicana_ Lochman. The matrix is a dirty limestone, and the restricted occurrence of _Albertella_ in the various Cordilleran sections strongly suggests that this genus favored a muddy environment.
The species appears quite close to *Albertella bosworthi* Walcott both in the forward expansion of the glabella and the five segments of the axis of the pygidium. The pygidium of *A. proveedora* Lochman differs, however, in greater width of the pleural lobes in proportion to the axis, and the apparent absence of the median nodes on the axis. The cranidium differs in the medium length of the palpebral lobes. Those of *A. bosworthi* Walcott appear to have been somewhat longer even though the lengthening due to crushing of the shale matrix is discounted. This situation presents a problem which should receive further study as it appears that in all limestone specimens of the cranidium the palpebral lobes are of medium length, whereas in all shale specimens they appear to be larger.

*Types.*—Holotype, U.S.N.M. No. 115776; paratypes: cranidia, U.S.N.M. Nos. 115778, 115783; pygidia, U.S.N.M. Nos. 115777, 115781, 115782; free cheek, U.S.N.M. No. 115779; hypostoma U.S.N.M. No. 115780.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 801i, 801k.

**ALBERTELLA** aff. **A. PROVEEDORA** Lochman, new species

Plate 23, figure 9

*Remarks.*—A single fairly well-preserved hypostoma which is identical in every feature with the hypostoma associated with *Albertella proveedora* Lochman, new species, occurs in the collection from locality 802a. However, as no cranidium or pygidium of *Albertella* have been obtained from this locality, the specific assignment must be considered tentative.

*Figured specimen.*—U.S.N.M. No. 115784.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 802a.

**Genus MEXICASPIS** Lochman, 1948

**MEXICASPIS DIFUNTOSENSIS** Lochman, new species

Plate 22, figures 10-23

Cranidium oblong-elongate; glabella oblong, parallel-sided posteriorly, expanding very slightly anteriorly, moderately convex; four pairs of broad, shallow glabellar furrows, first and second short, straight, third and fourth longer, arcuate; dorsal furrow broad, shallow at sides, deepening into a small pit opposite first glabellar furrow, narrow and shallow around front; occipital furrow broad, well defined; occipital
ring of medium width, flat, triangular with a flat, short posterior median spine; brim a small square, steeply sloping area in front of fixed cheeks; narrow, shallow marginal furrow at sides merging into dorsal furrow; border narrow, flat, rimlike, crossed by several narrow ridges; anterior margin a flat curve. Fixed cheeks one-half width of glabella, slightly convex, horizontal; palpebral lobes of medium length, strongly curved, slightly back of midline of glabella; ocular ridge very faint in adult; palpebral furrow narrow, shallow; posterior limbs of medium length and width with a minute node on posterior margin near suture, and crossed by a broad shallow marginal furrow. Free cheek elongate, narrow; medium-size eye at inner angle; ocular platform convex, downsloping, narrow anteriorly, expanding posteriorly; marginal furrow shallow, wide, turning posteriorly; border of medium width, outer edge crossed by narrow ridges, flat, with a short, pointed anterior projection and a slender, medium-length genal spine. Facial suture cutting anterior margin far out at sides, curving out, then running straight back to and curving around palpebral lobes, thence curving out and back to cut posterior margin. Hypostoma subtriangular, expanded anteriorly into short, broad, downcurved lappets; anterior lobe oval, widening anteriorly, moderately convex, with a strong crescentic ridge on each posterior corner just below a shallow, slitlike macula; posterior lobe crescentic, of medium width, separated by well-defined furrow; narrow posterior marginal furrow; narrow, rimlike posterior border; anterior marginal furrow well defined through whole length; anterior border narrow, slightly convex.

Thorax not known.

Pygidium subquadrate; axis strongly convex, very slightly tapered, extending to border, divided by narrow furrows into four segments (posterior two faint) and a terminal portion; anterior first and sometimes second segment with a small median axial node; dorsal furrow broad, shallow; pleural platforms slightly narrower than axis, sloping gently down, divided into one anterior segment and triangular posterior area by one broad interpleural groove; anterior segment extending into a short, sharp marginal spine; pleural area extending posteriorly into another longer, heavier marginal spine, directed backward and somewhat laterally; flat border extending around back of pygidium, separated by a shallow marginal furrow which fades out across base of large marginal spine; posterior margin curving back from base of spine a short distance, then running straight across middle.

Outer surface covered with fine granules; inner surface minutely punctate.
Discussion.—This species is represented by a number of cranidia, free cheeks, hypostoma, and pygidia from the Difuntos Hills section. Some were broken freshly from the fine-grained limestone, and these specimens are the main types for the description; but there are many more specimens scattered over the surface of weathered slabs. On these the details of the structure are poorly preserved, and it should be noted that the posterior margin of the pygidium appears to be curved, whereas the two unweathered pygidia show the middle part actually to be straight.

The species is readily distinguished from *Mexicaspis stenopyge* Lochman, by (1) posterior part of glabella wider so that forward expansion appears less, (2) glabella moderately convex, (3) dorsal furrow in front of glabella and marginal furrow distinct on outer surface, (4) pygidium with broader proportions, and (5) the lateral direction of the posterior pair of marginal spines.

Types.—Holotype, U.S.N.M. No. 115766; paratypes: cranidia, U.S.N.M. Nos. 115768a,b, 115771, 115775c; pygidia, U.S.N.M. Nos. 115767, 115770, 115772, 115775a-c; hypostoma, U.S.N.M. No. 115769; free cheek, U.S.N.M. No. 115774.

Formation and locality.—Middle Cambrian, Arrojos formation, 802a, b.

**MEXICASPIS STENOPYGE** Lochman

Plate 23, figures 10-27


Original description.—“Cranidium oblong-elongate; glabella oblong, parallel-sided posteriorly, expanding moderately forward, slightly convex; glabellar and dorsal furrows practically obsolete on outer surface, well-defined on inner; four pairs of broad shallow glabellar furrows, first and second straight, very short, third arcuate, short, fourth arcuate, longer; dorsal furrow broad, shallow, deepening into small pit opposite first glabellar furrow, shallow across front of glabella; occipital furrow broad, shallow; occipital ring broadly triangular, flat, no median node; brim a narrow sloping rectangle in front of fixed cheek; marginal furrow of medium width, very shallow, merging with dorsal furrow; border narrow, very slightly convex, band-like; anterior margin a flat curve. Fixed cheeks one-half width of glabella, slightly convex, horizontal; palpebral lobes of medium length, slightly arcuate, situated a little back of midline of glabella; ocular ridge broad, very faint; palpebral furrow broad, only on inner surface; posterior
limbs of medium width and length, with a very broad shallow marginal furrow. Free cheek narrow, elongate, medium-size eye at inner angle; ocular platform narrow, flat anteriorly, becoming wider and steeply sloping posteriorly; marginal furrow broad, shallow; border of medium width, slightly convex, crossed by narrow ridges, with a short anterior projection and a long, slender genal spine. Facial suture cutting anterior margin far out at sides, curving out, then straight back to and around palpebral lobes, thence curving out and back to cut posterior margin within genal angle.

"Hypostoma subtriangular with broadly expanded anterior border and short, broad, curved lappets; anterior lobe oval, expanding anteriorly, moderately convex, with a prominent curved ridge at each posterior corner just below a shallow, slit-like macula; posterior lobe a small, convex crescent, separated from anterior lobe by a well-defined furrow which coalesces with the narrow posterior marginal furrow at the sides; narrow, rim-like posterior border; anterior border convex, narrow at center, expanding laterally into lappets, separated whole length from anterior lobe by anterior marginal furrow, deep and broad at center, shallow across lappets.

"Thorax not known.

"Pygidium elongate-oblong in outline; axis strongly convex, practically parallel-sided with bluntly rounded end, extending to border, divided into four or five segments and a terminal portion by furrows, anterior two broad and deep, others faint and narrow; a median axial node may be present on first two segments; dorsal furrows shallow; pleural platforms two-thirds width of axis, divided by one broad, deep interpleural groove into one broad anterior segment extending backward into a long slender marginal spine, and an unmarked triangular area continuing posteriorly into a short, stout marginal spine; the lateral margins converge posteriorly so that the posterior pair of spines are quite close together and extend straight back; a medium-wide flat border set off by a faint, shallow marginal furrow around posterior half; posterior margin very short, straight to slightly concave.

"Outer surface thickly covered with fine granules; inner surface minutely punctate."

Discussion.—This species is represented by a large number of cranidia and pygidia, and some hypostoma and free cheeks in collection from locality 801L, but the limestone matrix is coarse and crumbly and there has been some leaching by ground water so that the preservation of the surface and the spines is not good. The species has been chosen as the genotype because the greater numbers of specimens
afford a better concept of the size range to be expected. Several poorly preserved cranidia occur in the collection from locality 8ood.

The species differs from *Mexicaspis difuntosensis* Lochman in (1) the narrower posterior part of the glabella, (2) the slight convexity of the glabella, (3) the very faint dorsal and marginal furrows on the outer surface, and (4) the narrower proportions of pygidium and backward direction of the posterior pair of marginal spines.

_Types._—Holotype, U.S.N.M. No. 115785; paratypes: cranidia, U.S.N.M. Nos. 115787, 115792, 115794, 115796, 115798, 115799; pygidia, N.S.N.M. Nos. 115788-115790; hypostoma, U.S.N.M. Nos. 115786, 115793; free cheeks, U.S.N.M. No. 115791.

_Formation and locality._—Middle Cambrian, Arrojos formation, 8ood, 8o1L, 8o1ka.

**Genus ZACANTHOIDES WALCOTT, 1888**

**ZACANTHOIDES aff. Z. HOLOPYGUS Resser**

Plate 30, figures 11-17


_Zacanthoides holopygus* RESSER, Smithsonian Misc. Coll., vol. 97, No. 12, p. 10, pl. 2, figs. 10-12, 1939.

_Original description._—“At first it was thought this small species was merely a young stage of one of the larger forms, but careful sorting shows that such is not the case. *Z. holopygus* varies in length from less than one-eighth of an inch to more than 2 inches. As a whole this trilobite has a more even oval shape than most species of *Zacanthoides*, which is due to the fact that the thoracic terminations are relatively broader. It is the most common Spence shale species.

“*Z. holopygus* has rather large eyes, and the anterior facial suture diverges sharply, leaving rather long anterior angles. The pygidium is fused into a solid shield, including all marginal spines except the outer pair, the other spines being reduced to a serrated border. The long thoracic spine is not on the fifth but the last segment.”

_Discussion._—Seven poorly preserved and fragmentary specimens in shale from locality 8o0e’ and a poorly preserved cranidium, two pygidia, and a hypostoma in limestone from locality 8o1n are so tentatively identified. The specimens are all so poorly preserved that specific identification is doubtful at best. Enough of the structure of these parts can be made out, however, to suggest (1) that they all represent the same species, and (2) that the limestone cranidium is practically
identical with the uncrushed cranidia of \textit{Z. holopygus}, and the pygidia resemble the pygidium of that species in the poor development of the marginal spines. Only a single large marginal spine, derived from the anterior segment, is present; the pleural lobes are extremely narrow, but the posterior margin is so poorly preserved in all specimens that its structure cannot be made out.

Attention should be called to the fact that a number of errors occur in Resser's original description, and the author wishes to make the following additions and corrections after a study of the type material. The serrate border of the pygidium has two small marginal spines on each side back of the big anterior spine. The large thoracic spine is on the eighth or next-to-last segment, as is well shown in a small paratype. Especially important is the fact that among the types the largest specimen showing the specific characters of \textit{Z. holopygus} is the holotype carapace, 15 mm. in length. The 2-inch-long paratype carapace mentioned by Resser has a pygidium with four strong marginal spines as in \textit{Z. idahoensis} Walcott. Therefore, it must be admitted that Walcott's early conclusion that these smaller forms represented the young of that species has not yet been disproved. Certainly all the Mexican material is small in size also. It would be most interesting to find what type of pygidium a large specimen from the same Mexican horizon would have.

\textit{Figured specimens.—Cranidia, U.S.N.M. Nos. 115984, 115979; carapace, U.S.N.M. No. 115985; pygidia, U.S.N.M. Nos. 115983, 115978; free cheeks, U.S.N.M. Nos. 115981, 115982.}

\textit{Formation and locality.—Middle Cambrian, Arrojos formation, 800e, 801c, 801n.}

Family \textit{INCERTAE SEDIS}

Genus \textit{ARELLANELLA} Lochman, 1948

\textit{ARELLANELLA CABORCANA} Lochman

Plate 29, figures 23-29

\textit{Arellanella caborcana} Lochman, Journ. Paleontol., vol. 22, p. 460, pl. 70, figs. 22-26, 1948.

\textit{Original description.—"Cranidium nearly square, very slightly wider than long; glabella broadly conical—truncato-conical—with very broadly rounded front; convexity low; three pairs of glabellar furrows, well-defined on inner surface, faint on outer surface, in front of first pair on inner surface is an elongate slit at each side which may represent traces of another pair, first pair short, straight, second}
pair longer, slightly curved, third longer, arcuate; dorsal furrow broad, shallow at sides, narrower and fainter across front; occipital furrow of medium width, deeper at sides, shallower across center; occipital ring of medium width, triangular (broken); brim of medium width, slightly convex, gently downsloping, merging smoothly into the narrow, flat, slightly upsloping border as marginal furrow is apparently obsolete; anterior margin evenly rounded. Fixed cheeks three-fifths width of glabella on midline, slightly convex, downsloping; palpebral lobes small, narrow, on midline of glabella; palpebral furrow narrow, faint; ocular ridge obsolete; posterior limb of medium width, same length as occipital ring, crossed by a broad, shallow marginal furrow. Free cheek of medium width, elongate, with small eye at inner angle; ocular platform of medium width, flat, gently downsloping; marginal furrow obsolete; border narrow, slightly convex, and downsloping with a long pointed anterior projection and a genal spine (broken). Facial suture cutting anterior margin on line with dorsal furrow, curving out to marginal furrow, then straight back to and around palpebral lobes; then running diagonally outward and back to cut posterior margin within genal angle.

"Thorax not known.

"Pygidium narrowly transverse, twice as wide as long; axis wide, slightly convex, only slightly tapered to broadly rounded end reaching nearly to posterior margin, divided by two very faint furrows into two narrow segments and a terminal portion; pleural platforms about one-half width of axis, convex, downsloping, divided by two very faint interpleural grooves into two narrow segments; no marginal furrow seen; very narrow border apparently present.

"Outer and inner surface of test may be smooth."

Discussion.—Five cranidia of varying sizes, a free cheek and three small pygidia are referred to this species. The holotype is the largest and best-preserved cranidium, although a peeled and somewhat worn specimen. The association of the free cheek and pygidia with the cranidium of this species rather than with those of Arellanella sonora Lochman, new species, will have to be considered open to question until more material is obtained. It is probable, in view of the general close relation of the cranidia of the two species, that the free cheeks and pygidia of the two would be very similar.

Types.—Holotype, U.S.N.M. No. 115961; paratypes: cranidia, U.S.N.M. No. 115965; free cheek, U.S.N.M. No. 115962; pygidia, U.S.N.M. Nos. 115963, 115964.

Formation and locality.—Middle Cambrian, Arrojos formation, 800a.
ARELLANELLA SONORA Lochman, new species

Plate 29, figures 15-19

Cranidium nearly square, slightly wider than long; glabella broadly truncate-conical, front broadly rounded, nearly straight; three pairs of glabellar furrows, very faint on outer surface, well defined on inner, first pair short, straight; second longer, slightly curved; third longer, arcuate; occipital furrow of medium width, deeper at sides, shallow across center; occipital ring of medium width, triangular, flat with a small median node; brim of medium width and convexity, descending; marginal furrow narrow, well defined at sides, becoming faint to obsolete across center; border narrower than brim, slightly convex, continuing descent of limb; anterior margin evenly rounded. Fixed cheek about three-fifths width of glabella, slightly convex and downsloping; palpebral lobes small, narrow, on midline of glabella; palpebral furrow narrow, faint; a very faint, narrow, curved ocular ridge; posterior limb of medium width, same length as occipital ring, crossed by a broad, shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin well out at sides, curving out to marginal furrow, then straight back to and around palpebral lobes; then running diagonally out and back to cut posterior margin well within genal angle.

Thorax and pygidium not known.

Outer and inner surface apparently smooth.

Discussion.—This species is represented by 12 or more cranidia, but most of them are small, immature specimens, 1 to 3 mm. in length, and the author hesitates to claim that they show all their specific characters well. This species differs noticeably from A. caborcana Lochman in the descending position of the border and the different proportions of the brim and border. Otherwise the two species are very close.

Types.—Holotype: cranidium, U.S.N.M. No. 115953; paratypes: cranidia, U.S.N.M. Nos. 115954-115957.

Formation and locality.—Middle Cambrian, Arrojos formation, S00a.

ARELLANELLA aff. A. SONORA Lochman, new species

Plate 29, figures 20-22

Three cranidia in a shale matrix are given this tentative identification. Two are so badly crushed and distorted as to be nearly unidentifiable, both generically and specifically. The third is an impression on which the fixed cheeks are clearly flattened and fractured, but it is
better preserved as to outline and some original convexity and suggests this identification.

*Figured specimens.*—U.S.N.M. Nos. 115958, 115959.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 800b.

**Genus CABORCELLA** Lochman, 1948

**CABORCELLA ARROJOSENSIS** Lochman

Plate 29, figures 11-14


*Original description.*—“Cranidium wider than long; glabella triangular with flatly curved front, base as wide as length, strongly convex with a steep slope to sides and in front; three moderately impressed glabellar furrows, first one short, straight; the second longer, diagonal; the third still longer, arcuate. Dorsal furrow broad, shallow; occipital furrow broad, sinuous, deep at sides; occipital ring broken; brim narrow, flat, steep in front of fixed cheeks, becoming nearly horizontal in front of glabella; marginal furrow narrow, shallow at sides, widening to a shallow pit on line with edge of glabella, then sloping up to center as a broad shallow furrow; border narrow, vertical, rounded on top, continuing down as a vertical doub lure in front; anterior margin straight in center, curved slightly at sides. Fixed cheeks approximately three-fourths width of glabella, convex, sloping up to one-half height of glabella, then flattening; palpebral lobes small, situated just posterior to midline of glabella; prominent curved ocular ridge; palpebral furrow not seen; posterior limb triangular, width one-half the length, which is nearly same as occipital ring, directed backwardly at ends, crossed by a broad, shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin about halfway out, curving out to marginal furrow, then running straight up and back to and around palpebral lobes; thence curving outward and finally backward abruptly to cut posterior margin just within genal angle.

“Thorax and pygidium not known.

“Outer surface of cranidium smooth except for a row of coarse granules on brim and a few on fixed cheek following dorsal furrow; inner surface apparently smooth.”

*Discussion.*—This species is represented by four cranidia from locality 800c. The surface is poorly preserved but otherwise they are fairly good. It should be noted that the peculiar structure of the
marginal furrow with a shallow pit on each side just in front of the dorsal furrow and then a rise of the surface of the furrow to the center could easily give the impression of an obscure or poorly developed median boss. It may actually be the inception of one, but as such, does not develop in the two known species into anything which could be considered a real boss.

*Types.*—Holotype: cranidium, U.S.N.M. No. 115950; paratypes: two larger cranidia, U.S.N.M. No. 115951, one small cranidium, U.S.N.M. No. 115952.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 800c.

**Genus INGLEFIELDIA** Poulsen, 1927

**INGLEFIELDIA IMPERFECTA** Lochman, new species

Plate 30, figures 1-10

Cranidium subquadrate, very slightly wider across the eyes than long; glabella regularly conical, tapering to a broadly rounded front, convexity apparently low, regular; three pairs of moderately well-defined glabellar furrows, first pair short, straight, second and third longer, arcuate; dorsal furrow narrow, well defined around glabella; occipital furrow of medium width, deeper at sides, shallow across center; occipital ring of medium width, subtriangular, flat, with a small median node; brim of medium width, slightly convex, descending marginal furrow narrow, clearly defined; border of medium width, practically same as brim, flat, apparently horizontal; anterior margin evenly curved. Fixed cheeks two-thirds width of glabella on midline, slightly convex, horizontal or very slightly upsloping; palpebral lobes medium-sized, arcuate, almost on posterior one-third line of glabella; ocular ridge wide, well defined, curving forward to anterior corners of glabella; palpebral furrow narrow, shallow; posterior limbs narrow, apparently same length as occipital ring, crossed by a broad, shallow marginal furrow. Free cheek narrow, elongate with medium-sized eye at inner angle; ocular platform of medium width, flat, gently sloping; a narrow distinct marginal furrow; border narrow, flat with a short pointed anterior projection and a long slender genal spine. Facial suture cutting anterior margin well out at sides, curving out to marginal furrow, then diagonally into and around palpebral lobes; thence curving gently out and back before curving down abruptly to cut posterior margin within genal angle.

Associated hypostoma small, elongate oval, consisting of only an oval tumid central lobe separated from a narrow, convex border
posteriorly by a narrow, clearly defined furrow; anterior portion of hypostoma not preserved.

Thorax apparently of 14 segments; pleural lobes slightly wider than axis; axis moderately convex, pleural lobes only very slightly convex with short, stout falcate ends; pleural segments crossed by pleural furrows which are broad and shallow at inner part and deep and narrow at outer edge.

Pygidium small, triangular in outline, convex; axis moderately convex, apparently same width as pleural lobes, apparently extending nearly to posterior margin and only slightly tapered to a broad rounded end, divided by three broad shallow furrows into three segments and a terminal portion; pleural platform slightly convex, presence of any segmentation cannot be distinguished; presence of marginal furrow and border not known.

Outer and inner surface not known.

Discussion.—This species is represented by a large number of cranidia, several complete carapaces, a few free cheeks and pygidia from the shale of 800e and the compressed limestone of the overlying collection 800f. None of the specimens is well preserved and all have undergone some distortion, whether in shale or limestone. Consequently they are most unsatisfactory for study, and in determining their generic assignment measurements were taken on as many specimens as possible in order to get an idea of the probable true proportions.

This species was one of the first to be recorded from the Mexican Cambrian, being listed by Stoyanow (1942) as Alokistocare. At first glance the general shape of the cranidium and size of the palpebral lobes and curving ocular ridge do remind one of Alokistocare, but there is no trace of a median bulge. The above-mentioned detailed measurements reveal that the species differs markedly from Alokistocare also in the width of the fixed cheeks and the position of the palpebral lobes, as well as in the apparent length of the glabella and the regular convexity. In fact, these measurements place it in Inglefieldia.

Of the described species of Inglefieldia it appears to be closest to I. discreta Poulsen, as in that species the brim and border are practically the same width, but the brim is descending, whereas in I. imperfecta Lochman, new species, it appears to have been normally horizontal in position. The poor preservation of all the specimens makes it difficult to be sure about certain features of the carapace as indicated in the description.

Types.—Holotype, U.S.N.M. No. 115966; paratypes: cranidia, U.S.N.M. Nos. 115968, 115973, 115974, 115967, 115975, 115976;
pygidium, U.S.N.M. No. 115972; carapace, U.S.N.M. Nos. 115969, 115970, 115971.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 800e, 800e', 800f.

cf. **INGLEFIELDIA IMPERFECTA** Lochman, new species

Three medium-sized cranidia occur in the limestone of collection 800g along with four cranidia readily referred to *Inglefieldia imperfecta* Lochman, new species. These are incompletely preserved and all show clear evidence from the grain of the limestone of rather severe distortion, two obviously squeezed quite strongly laterally and the other in a diagonal direction. These cranidia appear to have fixed cheeks almost as wide as the glabella, very long posterior limbs and the facial suture anterior to the eyes running far outward to the marginal furrow. However, it is impossible to take any measurements even approaching accuracy on these specimens, and rough guesses give a combination of features quite unknown and unusual.

In their present preservation these three cranidia cannot be accurately identified. The tentative assignment is given on the supposition that they are just three very badly distorted cranidia of the species which can be identified from this collection. If, however, some of the features mentioned above are real, then their affinities may be with either the genus *Kochiella* or the species from the Langston formation identified by Resser as *Ehmaniella maladensis* Resser. Their very incomplete condition does not at present warrant their reference to either of these forms.

*Described specimen.*—U.S.N.M. No. 115977.

*Formation and locality.*—Middle Cambrian, Arrojos formation, 800g.

**Genus MEXICELLA** Lochman, 1948

**MEXICELLA MEXICANA** Lochman

Plate 24, figures 1-25


*Original description.*—"Cephalon slightly oval in outline; cranidium square in outline; glabella short, squat, conical with a straight front, moderately convex posteriorly and sloping down rapidly to low anteriorly, glabella only slightly longer than brim and border; three pairs of fairly well-defined glabellar furrows, first pair narrow slits, straight
or slightly slanted, set in from dorsal furrow; second pair diagonal, third pair arcuate, both on outer third of glabella; dorsal furrow well-defined, broad at sides, narrow across front; occipital furrow broad, deep at sides, shallow across center; occipital ring of medium width, expanding slightly at median line, with a small occipital node; brim wide, convex, with a low broad median bulge (not found in cranidia under 3 mm. in length); border semicircular, narrow, convex, barely distinguished in adult by a faint narrow marginal furrow on inner surface of test; anterior margin broadly rounded. Fixed cheeks wide, slightly less than width of glabella, flat; palpebral furrow very faint; palpebral lobes small, slightly curved, situated slightly in front of mid-line of glabella; ocular ridge prominent, curved; posterior limbs short, of medium width, with a narrow marginal furrow. Free cheek triangular in outline, steeply sloping in position with small eye at inner angle; ocular platform and border indistinguishable in small cheeks, but in larger ones a faint marginal furrow separates off a narrow border with a long pointed anterior projection and a squared genal angle with a minute node at outer corner. Facial suture cutting anterior margin half way out, curving gently out to edge of border, then back and straight into and around palpebral lobes; then curving out around and slightly in to cut posterior margin within genal angle.

"Thoracic segments narrow; axis rather strongly convex with a small median axial node apparently on each segment; pleural lobes one and one-half width of axis, flat near dorsal furrow, then moderately downsloping, with a short, backward turned point on end; pleural furrow shallow, broad; number of segments not known."

"Pygidium small, strongly convex longitudinally, transverse; axis wide, nearly flat, tapering rapidly, about two-thirds length of pygidium, crossed by one or two narrow furrows forming two narrow anterior segments and a wide terminal portion; dorsal furrow narrow, clear at sides, faint around end; pleural platforms narrower than axis, strongly convex, divided into two segments by narrow interpleural grooves; border of medium width, flat, nearly horizontal at sides, becoming vertical at back.

"Outer surface of pygidium, fixed cheeks and glabella sprinkled with small granules; the heavy anastomosing venation of inner surface radiating across brim shows through on outer surface of well-preserved specimens; inner surface coarsely punctate. In immature cranidia the outer surface is smooth. One free cheek shows four or five alternating low nodes and pits along base of ocular platform."

Discussion.—This species is extremely abundant in the earliest
Middle Cambrian faunal assemblages in the Mexican section. In collection 802a it is represented by cranidia ranging from the protaspid to small holaspid stage. One fragmentary cranidium reaches 13 mm. in length and two free cheeks in collection 801j would belong to cranidia 24 mm. in length. The great abundance of smaller cranidia suggests that they represent molts. The earliest holaspid stages more resemble the species *M. stator* (Walcott) in the apparent absence of the median bulge and lessened convexity of glabella.

One cranidium in collection 801k is much worn and abraded and the glabella appears low as in *M. stator*. The author believes that in this cranidium this feature is caused by the poor preservation and that it too is an individual of *M. mexicana*.

In the National Collection *Mexicella stator* (Walcott) is represented not only by the types in shale but also by some limestone specimens, slightly worn and distorted, but from the same section. There are also some cranidia in sandstone, labeled *Agraulos*, from U.S.N.M. loc. 150d, White Creek, Powell County, Mont., which show exactly the same specific features as *M. stator* and are here considered to represent the same species.

The two species appear to be very close, but can be distinguished by: (1) in *M. mexicana* Lochman the glabella is much more convex, and the curvature of the brim is stronger near the glabella, while in *M. stator* (Walcott) the curvature is gentler and more even and continuous; (2) in *M. stator* the fixed cheeks seem to be very slightly wider in proportion to the glabella than in *M. mexicana* but this feature may be due to slight mechanical flattening in the *M. stator* specimens.


Formation and locality.—Middle Cambrian, Arrojos formation, 800d, 801j, 801k, 801ka, 801L, 802a, 802b.

Genus PACHYASPIS Resser, 1939

PACHYASPIS DEBORRA Lochman, new species

Plate 25, figures 25-32

Cranidium subquadrate, a little wider than long; glabella broadly conical, tapering to a broadly rounded front, moderately convex; three pairs of glabellar furrows, first short and straight, second and third
longer, diagonal; dorsal furrow narrow, shallow; occipital furrow narrow, deep at sides, shallow across center; occipital ring narrow, flat, with a small median node; brim relatively narrow, slightly convex, continuing downslope of front of glabella; marginal furrow narrow, well defined; border narrow, widest at center, slightly convex, horizontal; anterior margin evenly rounded. Fixed cheeks one-half width of glabella, very slightly convex, slightly downsloping; palpebral lobes small, just in front of midline of glabella; palpebral furrow very narrow, faint; ocular ridge narrow, distinct, curving to just in front of first glabellar furrows; posterior limb of medium width, same length as occipital ring, crossed by broad, well-defined marginal furrow. Free cheek not known. Facial suture cutting anterior margin about halfway from center, curving back to marginal furrow, then running straight back to and around palpebral lobes; thence curving out and down to cut posterior margin within genal angle.

Thorax and pygidium not known. Outer surface of test covered thickly with fine granules; inner surface not known.

Discussion.—This species is represented by about 12 small cranidia, none more than 5 mm. in length and one fragment of the glabella 7 mm. in length. The small size and indifferent preservation have made identification difficult, but the species appears to belong to Pachyaspis. There appears to be a slight difference among the cranidia in the slope of the fixed cheeks, some showing descent but others appearing practically horizontal. As the latter specimens appear slightly crushed, the author considers this feature to be due to preservation.

The species is close to P. typicalis Resser, differing from it mainly in the narrower and less steeply sloping brim and the narrower marginal furrow. The small Mexican cranidia also appear to have stronger glabellar furrows and stronger convexity of the glabella when compared with the larger holotype cranidium of P. typicalis Resser, but as certain of the smaller cranidia of the latter species show a more convex glabella and deeper furrows than the holotype, the author considers these differences to be caused by size and not to be specific differences.

Types.—Holotype, U.S.N.M. No. 115856; paratypes, U.S.N.M. Nos. 115857-115860.

Formation and locality.—Middle Cambrian, Arrojos formation, 802c.
PACHYASPIS ISABELLA Lochman, new species

Cranidium subquadrate, average specimen 5½ mm. across the eyes by 5 mm. in length; glabella conical, slightly longer than wide, with a broadly rounded front, regular moderate convexity; three pairs of well-defined glabellar furrows, first pair short, straight, second and third longer, arcuate; dorsal furrow narrow, well defined; occipital furrow of medium width, deep at sides and shallow across center; occipital ring of medium width, flat with a strong posterior median node (almost a small spine); brim narrow, flat, steeply descending, slightly narrower than border in center; marginal furrow narrow, well defined; border convex, narrow, slightly descending; anterior margin almost straight. Fixed cheeks approximately one-half width of glabella, very slightly convex and downsloping; palpebral lobes small, lying slightly in front of midline of glabella; palpebral furrow narrow, shallow; ocular ridge narrow, strong, nearly straight; posterior limbs of medium width, about same length as occipital ring, crossed by a broad, well-defined marginal furrow. Free cheek narrow, elongate with small eye at inner angle; ocular platform of medium width, slightly convex, sloping; marginal furrow narrow, shallow; border narrow, convex, slightly sloping with a short pointed anterior projection and a short slender genal spine. Facial suture cutting anterior margin halfway out, making a long curve back to marginal furrow, then running straight into and around palpebral lobes; thence curving out and back to cut posterior margin within genal angle.

Thorax not known.

Pygidium small, triangular, moderately convex; axis of medium width, convex, tapering slightly to a broadly rounded end reaching nearly to posterior margin, divided by faint narrow furrows into three narrow segments and a long terminal portion; dorsal furrow very faint, at sides only; pleural platforms slightly narrower than axis, convex, steeply descending, divided by three narrow interpleural grooves into three and a half narrow segments and a terminal area; no marginal furrow; a very narrow, nearly vertical border.

Outer surface of test covered with fine granules; inner surface not known.

Discussion.—This species is represented by many small cranidia, several free cheeks and two pygidia (one unfortunately lost in cleaning) from collection 801m, and one broken cranidium from collection 801n. This is the first time the pygidium and free cheek have been obtained and described. It is surprising to find this second distinct
species of Pachyaspis associated with Glossopleura leona Lochman, new species, in collection 801m, whereas Pachyaspis deborra Lochman, new species, is associated with the same species of Glossopleura in collection 802c.

The species differs from P. deborra Lochman, new species, in the narrower and more steeply sloping brim and the somewhat wider border—the brim in front of the glabella being actually slightly narrower than the border on the midline. The border is also slightly sloping as contrasted to the horizontal position in P. deborra.

Types.—Holotype: cranidium, U.S.N.M. No. 115861; paratypes: cranidia, U.S.N.M. Nos. 115862, 115865, 115866, 115868; pygidium, U.S.N.M. No. 115864; free cheeks, U.S.N.M. No. 115863.

Formation and locality.—Middle Cambrian, Arrojos formation, 801m, 801n.

PACHYASPIS, species undetermined

Plate 24, figure 26

A single worn small cranidium 1.5 mm. in length occurs with Mexicella mexicana Lochman, new species, and Mexicaspis difuntosensis Lochman, new species, in collection 802a. The cranidium appears definitely to belong to Pachyaspis but it does not appear to belong to either P. isabella Lochman or P. deborra Lochman. The brim appears extremely narrow, steeply sloping, and the border is narrow, about 1½ times the width of the brim and continues the same steep descent. This combination suggests a distinct and different species but the author is unwilling to describe a new species on a single cranidium. It is figured for future reference.

Figured specimen.—U.S.N.M. No. 115823.

Formation and locality.—Middle Cambrian, Arrojos formation, 802a.

PAREHMANIA, species undetermined

Plate 31, figures 5, 6

This identification is given to two poorly preserved cranidia from 800h, which the author cannot determine positively. The visible features indicate that the genus is certainly a member of the Etrathia stock, a group of trilobites which becomes prominent in the latter half of the Middle Cambrian. The genera of this stock are all characterized by having the fixed cheeks one-half the width of the glabella, the eyes and palpebral lobes of medium size and the glabella regularly conical in shape with nicely rounded front, and usually with three pairs of
short but clearly defined glabellar furrows. Variation in one or more of the other features determines various genera recognized in this stock, and to be absolutely certain of the identification all features must be determined.

In spite of the present generic uncertainty the recognition of a member of the *Elrathia* stock in the Tren dolomite is important as it indicates this formation is definitely younger faunally than the underlying Arrojos formation, and suggests a correlation with the *Elrathiella* zone in the lower part of the upper half of the Middle Cambrian.

The generic features which could be determined and which suggest *Parchmania* to the author are:

1. Palpebral lobes medium-sized, situated just back of midline of glabella.
2. Glabella conical, slightly longer than wide, with rounded front, convexity regular; three pairs of fairly well-defined glabellar furrows.
3. Fixed cheeks one-half width of glabella on midline.
4. Fixed cheeks horizontal.
5. Posterior limb unknown.

*Figured specimens.*—U.S.N.M. Nos. 115992, 115993.

*Formation and locality.*—Middle Cambrian, Tren dolomite, 800h.

**Genus PROVEEDORIA LOCHMAN, 1948**

**PROVEEDORIA STARQUISTAE** Lochman

Plate 21, figures 12, 22-28


*Original description.*—“Cranidium subquadrate, average specimen 5 mm. across the eyes by $4\frac{3}{4}$ mm. in length; glabella tapered conical, longer than wide with front nearly straight across, convexity low, regular with a faint median ridge; three pairs of moderately deep glabellar furrows, first very short, slit-like, second longer, slightly curved, third longer, arcuate; dorsal furrow narrow, well-defined; occipital furrow wide, deep at sides, shallow across center; occipital ring of medium width, subtriangular, flat; brim of medium width, flat, moderately downsloping; marginal furrow narrow, shallow; border slightly narrower than brim, gently downsloping, practically flat but with a very shallow median groove; anterior margin evenly curved. Fixed cheeks two-thirds width of glabella, flat, slightly downsloping; palpebral lobes of medium size, situated almost on posterior one-third line of glabella; palpebral furrow narrow, faint; ocular ridge very narrow, faint, curving to anterior corners of glabella; posterior limbs
narrow, same length as occipital ring, crossed by a narrow, well-defined marginal furrow. Free cheek short, narrow, with medium eye at inner angle; ocular platform of medium width, slightly convex, downsloping; marginal furrow narrow, shallow; border narrow, flat, horizontal, with a short pointed anterior projection and a short flat genal spine. Facial suture cutting anterior margin well out at sides, curving back to marginal furrow, then running diagonally into and around palpebral lobes; thence running straight out before curving back abruptly to posterior margin within genal angle.

"Thorax and pygidium not known.

"Outer surface of test thickly covered with fine granules, passing into short imbricating ridges on border of cranidium and free cheek; inner surface not known."

Discussion.—This species is represented by seven cranidia and four or five free cheeks from locality 801i. The fauna from this collection is small, containing this species, one cranidium of Albertella proveedorae Lochman, new species, and several cranidia referred to Kochaspis? species undetermined.

It is impossible to refer this species to any described genus, so, in spite of the limited amount of material, it was deemed best to erect a new genus for it.

Types.—Holotype, U.S.N.M. No. 115747; paratypes U.S.N.M. Nos. 115749, 115750, 115751a, 115752, 115748; unfigured paratypes, U.S.N.M. No. 115751.

Formation and locality.—Middle Cambrian, Arrojos formation, 801i.

Genus STROTOCEPHALUS Resser, 1935

STROTOCEPHALUS ARROJOSENSIS Lochman, new species

Plate 21, figures 29-34

Cranidium transverse, wider than long; glabella conical, with a broad nearly straight front, convexity low, regular; glabellar furrows very faint, posterior pair arcuate; dorsal furrow narrow, shallow, around glabella; occipital furrow medium wide, very shallow; occipital ring of medium width, flat, with a small median node; brim of medium width, convex, sloping at 45° angle; marginal furrow obsolete; border a little more than one-half width of brim, narrow, flat, slightly upturned (in small cranidia, 3 mm. in length, brim and border are subequal and separated by a narrow, just distinguishable marginal furrow); anterior margin regularly curved. Fixed cheeks almost same width as glabella on midline, very slightly convex, horizontal; palpebral
lobes arcuate, medium-sized, on posterior one-third line of glabella; palpebral lobes continuous with arcuate faint ocular ridges extending to very shallow pits at anterolateral corners of glabella; narrow, faint palpebral furrow; posterior limb narrow, little shorter than occipital ring, crossed by a shallow marginal furrow. Free cheek of medium width, elongate with medium eye at inner angle; ocular platform of medium width, flat; no marginal furrow; border flat, narrow with very short anterior projection, genal spine broken. Facial suture cutting anterior margin halfway out, curving far out to marginal furrow, then running diagonally into and around palpebral lobes; thence curving out and down to cut posterior margin within genal angle.

Thorax not known.
Pygidium not known.

Outer surface of cranidium covered thickly with fine granules; inner surface of largest cranidium showing coarse punctations with faint radiating venation across the brim, and the impress of the edge of the doublure about halfway forward on the brim.

Discussion.—The species is represented by four cranidia, three rather small, and several free cheeks. It appears to be fairly close to Strotocephalus gordonensis Resser, the genotype, differing from it only in the narrower brim.

The occurrence of a species of Strotocephalus in Mexico is interesting. The genotype is a member of the Albertella fauna of the Gordon formation of Montana, and while Strotocephalus arrojosensis Lochman occurs alone in 801h in the Puerto Blanco section, it is approximately 70 feet (21 m.) below 801h where Albertella first makes its appearance, and thus belongs to the same fauna and occurs at approximately the same position in both regions.

Types.—Holotype: cranidium, U.S.N.M. No. 115753; paratypes, U.S.N.M. Nos. 115754, 115755, 115756; unfigured paratype, U.S.N.M. No. 115757.

Formation and locality.—Middle Cambrian, Arrojos formation, 801h.

GENUS AND SPECIES UNDETERMINED 2

Plate 25, figure 22

Three small cranidia occur in collection 801h, which in spite of their very poor preservation appear to represent the same species and genus. They are, however, too small and too fragmentary to warrant a definite generic and specific determination. The best cranidium, only 1.25 mm. in length, is figured for future reference.

Figured specimen.—U.S.N.M. No. 115850a.
**Formation and locality.**—Middle Cambrian, Arrojos formation, 80th.

**GENUS AND SPECIES UNDETERMINED 3**
Plate 31, figure 7

A single broken small cranidium, estimated at 3 mm. in length when complete, shows features of the brim and border and a more strongly conical glabella with rather well-defined glabellar furrows, all of which suggest that it does not belong to the same species and probably not to the same genus as the two broken cranidia referred to *Parehmania*, species undetermined. However, the specimen is too fragmentary to afford even a single generic measurement with accuracy; consequently it cannot be identified until more complete material from the same position has been obtained.

_Figured specimen._—U.S.N.M. No. 115994.

**Formation and locality.**—Middle Cambrian, Tren dolomite, 800h.

**Cf. MIDDLE CAMBRIAN TRILOBITES**
Plate 31, figure 4

Three pieces of a thoroughly baked limy mud from Lista Blanca were collected, as each contained a very poorly preserved, but undeniable, trilobite fragment. These consisted of the distorted impression of a small cranidium, the impression of a fairly large broken free cheek, and the impression of what appears to be a medium-sized pygidium with a marginal spine, and a few thoracic segments.

None of the specimens is well enough preserved to warrant generic determination, but from their general appearance the author feels justified in suggesting that they represent a Middle Cambrian rather than a Lower Cambrian horizon.

_Figured specimen._—U.S.N.M. No. 115990.

**Formation and locality.**—Middle Cambrian, 811a.

**REFERENCES**

Arellano, A. R. V.

Cooper, G. A., and Arellano, A. R. V.

Deiss, Charles.
HOWELL, B. F., et al.
KOBAYASHI, TEICHII.
LOCHMAN, C.
LOCHMAN, C., and DUNCAN, D.
MCKEE, EDWIN D.
MCKEE, EDWIN D., and RESSER, C. E.
POULSEN, CHR.
RASSETTI, FRANCO.
RAW, FRANK.
RAYMOND, P. E.
RESSES, C. E.


Resser, C. E., and Howell, B. F.

Störmer, Leif.


Stoyanow, Alexander.

Walcott, C. D.


Wheeler, Harry E.

Williams, J. Stewart, and Maxey, G. B.
EXPLANATION OF PLATES

PLATE 1

Fig. 1.—North end of the Arrojos Hills. View looking to the southeast and showing the full section of the Arrojos formation. The dark hill on the right, of which only the base shows, is composed of the Cerro Prieto limestone. The lower Arrojos on the lower slope of the hill to the left is composed of somewhat heavy beds but the upper part is thin-bedded. The darker beds in the high part on the left is Tren dolomite. In the pass in the distance the volcanics of the Proveedora Hills are visible. The small hill on the extreme left is Tren dolomite.

Fig. 2.—Proveedora Hills. View of the Proveedora Hills taken from the high volcanic peak on the south side of the pass known as Puerto Blanco. The light-colored hills on the left side of the picture and nearly to the center are composed of Proveedora quartzite. The highest ridge in the center is the Cerro Prieto limestone and its west slope is the Buelna formation. The small fault shown in plate 4, figure 4, can be seen on this slope. The Arrojos formation occupies the deep valley between the two high ridges. The divide or saddle is visible just to the right of the high ledge that protrudes on the east slope of the ridge formed of the Cerro Prieto limestone. Albertella occurs on the slope between the high ledge and the divide. On the opposite slope near the base occur Mexicanpis and Glossopleura. Kootenia occurs about halfway up the slope. The Tren dolomite forms the massive hill on the right. On the extreme right margin of the picture can be seen the lower slope of a small hill of white dolomite which is Tren dolomite altered to marble.

PLATE 2

Aerial view of the Proveedora Hills (locality 801) showing two prominent ridges and saddle in middle of valley between them. The high ridge on the west side of the saddle is composed of Cerro Prieto limestone. The Buelna formation is adjacent to the Cerro Prieto on the west side of the ridge. Proveedora quartzite occupies the slopes next to the Buelna formation. The westernmost ridge and knob are formed of the Puerto Blanco formation. The valley between the two longest ridges is occupied by the Arrojos formation. The small high ridge just under Albertella is visible on the west side of the saddle. The easternmost ridge is Tren dolomite. Horizontal scale, 1.67 inches = 1 mile; vertical scale, 1.63 inches = 1 mile.

Photograph courtesy Bureau of Public Relations, War Department.

PLATE 3

Fig. 1.—Difuntos Hills. The small hill on the right side of the picture is composed of Buelna and Cerro Prieto limestones. The larger hills on the left consist of Arrojos limestone in the lower part and Tren dolomite in the upper part.
Fig. 2.—North end of Arrojos Hills. View of the north end of the Arrojos Hills looking north along the strike of the Arrojos beds. The low hill on the left is Cerro Prieto limestone, massive and not showing bedding; the Arrojos formation occupies the middle ground of the picture. The hill on the right is Tren dolomite.

Fig. 3.—Pleosponge reef (locality 8014). Massive limestone composed of pleosponge debris, wavy-bedded pink limestone, and oolitic limestone. Located about 0.7 mile northwest of the west end of Proveedora Hills.

**PLATE 4**

Fig. 1.—Puerto Blanco formation. Heavy ledges of limestone in the Puerto Blanco formation, west end of Proveedora Hills, 7 miles west of Caborca (locality 801b, c).

Fig. 2.—Prieto Hill (locality 809). At the left base of Prieto Hill is a low hill formed of the Proveedora sandstone. Approximately the lower half of the large hill is composed of the Buelna formation. The top of the hill is capped by a thick ledge of the Cerro Prieto limestone.

Fig. 3.—Cañedo Hill (locality 812). In the middle background the stratified but much-altered layers of Cañedo Hill are visible. To the south stretch the volcanic hills formed of the intrusive materials that altered the Cambrian sediments. The low hill on the left side of the picture is composed of Pre-Cambrian quartzite and limestone.

Fig. 4.—Proveedora Hills (Buelna and Cerro Prieto formations) (locality 801d, e). Proveedora quartzite ridges and slates on left and center. The depression in the right corner is the contact of the Buelna and Proveedora formations. The slope above the depression is Buelna limestone and the extreme right and crest of hill is Cerro Prieto limestone.

**PLATE 5**

Fig. 1.—Lista Blanca (locality 811). View looking south from south side of Caborca road. The low hill with soft contours on the left is composed of Cretaceous (?) conglomerate. The central high part is mostly of dolomitic marble. The slates that produced the poor fossils are on the right side of the observer near the darkly shadowed hill.

Fig. 2.—West Buelna Hill (locality 807). Proveedora quartzite makes up about two-thirds of the hill; the Buelna limestone with Onchocephalus and olenellid trilobites appears under the two knobs. The peaks are composed of Cerro Prieto algae-bearing massive limestone.

Fig. 3.—Girvanella on slope of Prieto Hill. Surface of the Cerro Prieto limestone on Prieto Hill, 1½ miles southwest of Caborca, showing numerous dark- and light-colored Girvanella. These may be the objects that were originally referred to Chaetetes.

**PLATE 6**

Fig. 1.—Girvanella cf. sinensis Yabe. Surface of a polished slab oriented perpendicular to the stratification showing the colonies of Girvanella, X 1.
Fig. 1.—*Ethmophyllum cooperi* Okulitch, new species, × 8.  
Holotype, U.S.N.M. No. 111814a, specimen marked O-1 “A.” Showing the thick complex inner wall and several parietes. The outer wall is missing.

Fig. 2.—*Ethmophyllum cooperi* Okulitch, new species, × 16.  
Holotype, U.S.N.M. No. 111814a, specimen marked O-1 “A.” Showing details of inner wall and vertical canals, some at the point of opening into the central cavity.

Fig. 3.—*Ethmophyllum americanum* Okulitch, new species, × 8.  
Holotype, U.S.N.M. No. 111816a, specimen marked O-8. Showing the large central cavity, narrow intervallum, numerous parietes, and complex inner wall.

Fig. 4.—*Ethmophyllum americanum* Okulitch, new species, × 56.  
Holotype, U.S.N.M. No. 111816a, specimen marked O-8. Showing details of complex inner wall and parietes.

Fig. 5.—*Ajacicyathus nevadensis* (Okulitch), × 8.  
U.S.N.M. No. 111815, specimen marked O-1 “C.” Showing regular straight parietes and simple inner and outer walls.

Fig. 6.—*Ajacicyathus nevadensis* (Okulitch), × 16.  
U.S.N.M. No. 111815, specimen marked O-1 “C” occurring with *Ethmophyllum cooperi*, new species. Transverse section showing simple walls and parietes.

Plate 8

Fig. 1.—*Syringocnemis* species, × 0.8.  
U.S.N.M. No. 111817a, specimen marked O-17. Naturally weathered-out longitudinal section showing the entire specimen.

Fig. 2.—*Syringocnemis* species, × 5.  
U.S.N.M. No. 111817a, specimen marked O-17. Enlarged view of the same specimen showing general shape, central cavity, and short tube-like canals leading from inner to outer wall.

Fig. 3.—*Ethmophyllum whitneyi* Meek, × 6.  
U.S.N.M. No. 111818a, specimen marked O-5. Photograph of a transverse thin section showing particularly well the details of structure of inner wall.

Fig. 4.—*Ethmophyllum whitneyi* Meek, × 7.  
U.S.N.M. No. 111818c, specimen marked O-11. Slightly oblique transverse section showing exceptionally well the pores of the outer wall and the crenulated inner edges of parietes.
Fig. 5.—Ethmophyllum whitneyi Meek, × 7........................... 28
U.S.N.M. No. 111818b, specimen marked O-4. Transverse section of an imperfect specimen showing pores of outer wall and variations in structure of inner wall.

PLATE 9

Fig. 1.—A portion of a fossiliferous slab from Difuntos Hills, Sonora, Mexico, showing naturally weathered-out: A, Coscinocyathus species, and B, Prototharetra species, × ½, U.S.N.M. No. 111822............. 31, 33
Fig. 2.—Coscinocyathus species, × 5.............................. 31
U.S.N.M. No. 111820, specimen marked O-3 “C.” Naturally weathered longitudinal section showing inner wall, impressions of inner-wall pores, inner edges of parietes, and upward arching tabulæ.

Fig. 3.—Cambrocyathus cf. C. occidentalis Okulitch, × 0.8............. 33
U.S.N.M. No. 111821, specimen marked O-3 “A.” Naturally weathered-out oblique fragment showing wide intervallum, numerous parietes with synapticulae.

Fig. 4.—A, Ethmophyllum cooperi Okulitch, new species, and C, Ajacicyathus nevadensis (Okulitch).......................... 29, 28
Natural-size photograph of specimens illustrated on Plate 7.

Fig. 5.—Ajacicyathus rimouski Okulitch, × 6.......................... 28
U.S.N.M. No. 111823, specimen marked O-15 “B.” Photograph of polished cross section of an imperfect specimen. Central cavity, intervallum, and some parietes can be seen.

Fig. 6.—Syringocnema species, × 1............................... 33
U.S.N.M. No. 111817b, specimen marked O-16. Arrow points to the polished longitudinal section of the specimen.

Fig. 7.—Syringocnema species, × 7................................. 33
U.S.N.M. No. 111817b, specimen marked O-16. Enlarged view of the same specimen showing part of meshlike inner wall and the radial, slightly inclined canals of the intervallum. (See also plate 8, fig. 2.)

PLATE 10

Archaeocyathus yavorskii (Vologdin), × 7............................. 31
U.S.N.M. No. 111824, thin section and specimen marked O-2. Enlarged transverse section showing the narrow central cavity, and complex taeniae, bars, and plates of intervallum resembling a spicular mesh. Outer wall visible in lower right-hand corner of the photograph.

PLATE II

A. Dictyonina minutipuncta Cooper, new species....................... 40
1, Posterior of a pedicle valve showing narrow homoeodeltidium, × 4; paratype, U.S.N.M. No. 116045. 2, Exterior of a pedicle valve, × 2; paratype, U.S.N.M. No. 116045c. 3, Posterior view of the holotype showing small homoeodeltidium, × 4. 4, Exterior of a brachial valve, × 2; paratype, U.S.N.M. No. 116045b. 5, Pedicle exterior, × 2; holotype, U.S.N.M. No. 116045a. 6, Exterior of holotype, × 4, showing pitted ornamentation. Locality 80of.
B. *Paterina* species .......................................................... 38

7, Exterior of the brachial valve, × 8; figured specimen, U.S.N.M. No. 116050a. 8, Exterior of the pedicle valve, × 8; figured specimen No. 116050b. Locality 807c.

C. *Scolithus* tubes .......................................................... 12

9, Hillside showing numerous blocks of sandstone riddled by *Scolithus* tubes. 10, Two sandstone blocks, the one on the left showing longitudinal sections of the tubes, the other showing the tubes in cross section. 11, Sandstone block showing long tubes filled with carbonaceous material. Locality 807a.

**Plate 12**

A. *Acrothele concava* Cooper, new species................................. 44

1, 5, Exterior of the conical pedicle valve, showing apex and foramen, × 2 and × 4, respectively; paratypes, U.S.N.M. Nos. 116035a and 116035c. 2-4, Brachial side, and pedicle views of an imperfect specimen preserving both valves in contact, × 2; holotype U.S.N.M. No. 116035d. 6, Brachial view of the holotype, × 4, showing ornamentation. Locality 800g.

B. *Dictyomina* species ........................................................ 41

7, Exterior of a pedicle valve with damaged beak, × 4; figured specimen U.S.N.M. No. 116044a. 8, 9, Brachial valves, × 4, showing ornamentation; figured specimens, U.S.N.M. Nos. 116044d, e. Locality 800g.

C. *Pegmatreta rara* Cooper, new species..................................... 42

10, Exterior of the pedicle valve, × 6; paratype, U.S.N.M. No. 116050a. 11, 17, Exterior of pedicle and brachial valves, ca. × 7; paratypes, U.S.N.M. Nos. 116057a, c. 12-14, Brachial, side, and pedicle views of the filling of a specimen preserving both valves, × 6; paratype, U.S.N.M. No. 116059f. 15, Another pedicle valve showing part of the pallial trunks, × 6; paratype, U.S.N.M. No. 116050g. 16, Interior of pedicle valve showing callosity indistinctly, ca. × 7; paratype, U.S.N.M. No. 116057b. 18, Interior of brachial valve showing median septum, ca. × 7; holotype, U.S.N.M. No. 116057d. 19, Brachial exterior with faint median sulcus doubtfully placed with this species, × 6; paratype, U.S.N.M. No. 116059b. Locality 800a.

D. *Obolella mexicana* Cooper, new species................................... 41

20, 21, Impression of the brachial interior and plasticine replica prepared from it, × 6; paratype, U.S.N.M. No. 116041d. 22, 23, Impression of the pedicle interior and the replica of the pedicle interior prepared from it, × 6; paratype, U.S.N.M. No. 116051c. 24, Plasticine replica of the brachial exterior, × 6; paratype, U.S.N.M. No. 116041a. 25, Plasticine replica of the pedicle exterior, × 6; paratype, U.S.N.M. No. 116041f. 26, Partially exfoliated brachial valve showing interior, × 4; paratype U.S.N.M. No. 116051e. 27, Exterior of the brachial valve preserved in a fine-grained marble, × 2; paratype, U.S.N.M. No. 116056c. 28, Exfoliated pedicle valve showing filling of foramen, × 2; holotype,
U.S.N.M. No. 116056b. 29, brachial exterior, \( \times 2 \); paratype, U.S.N.M. No. 116056a. 30, Brachial interior of exfoliated specimen, \( \times 4 \); paratype, U.S.N.M. No. 116051c. 31, Exfoliated pedicle valve, \( \times 4 \); paratype, U.S.N.M. No. 116051f. Localities 801b, 812b.

**PLATE 13**

A. *Micromitra* species .......................................................... 30

1, Exterior of the pedicle valve showing the concentric and radial ornamentation, \( \times 6 \); figured specimen, U.S.N.M. No. 116046a. 2, Exterior of a imperfect brachial valve, \( \times 6 \); figured specimen, U.S.N.M. No. 116046c. 3, Imperfect pedicle valve, \( \times 4 \); figured specimen, U.S.N.M. No. 116046b. Locality 800a.

B. *Lingulella provcedorensis* Cooper, new species .................. 37

4, Exterior of the brachial valve, \( \times 4 \); paratype, U.S.N.M. No. 116039b. 5, Exterior of the pedicle valve, \( \times 4 \); holotype, U.S.N.M. No. 116039a. 6, Another brachial valve, \( \times 4 \); paratype, U.S.N.M. No. 116040c. Locality 801b.

C. *Pegmatreta arellanoi* Cooper, new species .......................... 43

7, 8, Interior and exterior of two pedicle valves, the interior showing the callosity, \( \times 7 \); holotype and paratype, respectively, U.S.N.M. Nos. 116058g. 9, 10, Exterior and interior of two brachial valves, the interior showing the prominent median septum, \( \times 7 \); paratypes, U.S.N.M. Nos. 116058e. h. 11, Impression of the brachial interior showing the long median septum, \( \times 8 \); paratype, U.S.N.M. No. 116058c. 12, Interior impression of a pedicle valve showing pit made by callosity, \( \times 8 \); paratype, U.S.N.M. No. 116058a. Locality 800g.

D. *Wimanella* species ........................................................... 47

13, 14, Exterior of two pedicle valves, \( \times 2 \); figured specimens, U.S.N.M. Nos. 116054, 116055a. Locality 801L.

E. *Diraphora arrojosensis* Cooper, new species ........................ 47

15, Interior of the brachial valve, \( \times 3 \); paratype, U.S.N.M. No. 116042c. 16, 19, Pedicle and posterior views of the inner filling of a complete specimen showing pallial marks and posterior profile, \( \times 3 \); paratype, U.S.N.M. No. 116042f. 17, Pedicle exterior showing costellae, \( \times 3 \); paratype, U.S.N.M. No. 116042g. 18, 20, Impressions of the brachial and pedicle valves showing muscle scars and pallial marks, \( \times 2 \); paratypes, U.S.N.M. Nos. 116048a, b. 21, Partially exfoliated pedicle valve showing muscles and pallial marks, \( \times 3 \); holotype, U.S.N.M. No. 116042h. 22, Brachial interior showing notothyrial platform, median ridge and muscle scars, \( \times 3 \); paratype, U.S.N.M. No. 116042i. 23, Plasticine replica of the brachial interior showing small cardinal process, \( \times 2 \); paratype, U.S.N.M. No. 116042j. 24, Brachial exterior showing costellae, \( \times 2 \); paratype, U.S.N.M. No. 116042c. 25, Partially exfoliated pedicle valve showing pallial marks, \( \times 2 \); paratype, U.S.N.M. No. 116048c. Localities 800c, 801n.
*F. Nisusia* species .................................................. 45

26, Impression of the pedicle interior, ×2; figured specimen, U.S.N.M. No. 116037b. 27, Impression of the brachial interior, ×2; figured specimen, U.S.N.M. No. 116037c. Locality 801th.

**PLATE 14**

Figs. 1-4.—*Sonoraspis torrcsi* Stoyanow, new species .................. 53

1, Holotype. Note *Anoria*-like facial suture, absence of median tubercles, and segmented pygidial axis. ×1. U.S.N.M. No. 116348.

2, Paratype. Observe eight segments in the thorax and impression of doublure in the right side of posterior border. ×1. U.S.N.M. No. 116349.


4, Paratype. Note the absence of median tubercles on exposed thoracic segments, lack of segmentation in pygidium, and rapidly tapering pygidial axis. ×1. U.S.N.M. No. 116350.

Figs. 5, 6.—*Sonoraspis gomezi* Stoyanow, new species .................. 54

5, Paratype. Shows median tubercles on six posterior thoracic segments, smooth pygidial axis, and faint segmentation on the pygidial platform. ×1. U.S.N.M. No. 116335.


Figs. 7, 8.—*Amecephalus cf. A. piocbensis* (Walcott) .................. 55

7, Plesiotype. Shows parts of the thorax and the pygidium. ×1. U.S.N.M. No. 116351.


Fig. 9.—Incertae sedis, ×1,3. U.S.N.M. No. 116337 .................. 58

Figures 4, 5, and 6 are made from impressions with the relief reversed.

**PLATE 15**

Figs. 1-3.—Problematica I and II ........................................ 81

1-2, Problematicum I. Top and side views of internal mold retaining patches of punctate shell, ×1, U.S.N.M. No. 115660, loc. 801b.

3, Problematicum II. Top view of worn and crushed shell, ×1, U.S.N.M. No. 115661, loc. 801b.

Figs. 4, 5.—*Orthotheca buelna* Lochman, new species ............. 84

4, Holotype, detail of surface ornamentation, ×3.

5, Holotype, U.S.N.M. No. 115662a, and paratype, U.S.N.M. No. 115662b, ×3, loc. 807b.

Figs. 6-8.—*Scenella cf. S. reticulata* Billings ..................... 85

Top, side, and posterior views of the single juvenile shell, ×4, U.S.N.M. No. 115663, loc. 809a.
Figs. 9-13.—*Hyolithes* aff. *H. princeps* Billings.......................... 82
9. Largest free internal mold, × 1, U.S.N.M. No. 115664. 10, Fragment of large shell, × 1, U.S.N.M. No. 115665. 11, Transverse section of large shell, × 1, U.S.N.M. No. 115666a. 12, Transverse sections in weathered slab, × 1; longitudinal sections in same slab, × 1, U.S.N.M. No. 115667. All from loc. 80th.
Fig. 14.—*Salterella mexicana* Lochman, new species.................. 85
Reconstruction of internal structure, × 10.

**PLATE 16**

Fig. 1.—*Salterella* cf. *S. pulchella* Billings............................ 87
Hypotype, shell with slight curvature and well-preserved outer surface, × 4, U.S.N.M. No. 115668, loc. 809a.

Figs. 2-6.—*Hyolithes whitei* Resser................................. 83
2. Drawing of transverse section. 3, Hypotype, side view of partially free shell, × 3, U.S.N.M. No. 115671b. 4, Hypotype, dorsal surface of larger shell, × 2, U.S.N.M. No. 115671a. 5, Hypotype, largest shell, × 2, U.S.N.M. No. 115669. 6, Hypotype, well-preserved dorsal surface showing growth line and faint longitudinal ridges, × 4, U.S.N.M. No. 115670. Fig. 5, loc. 809a; all others, loc. 807b.

Figs. 7-11.—*Salterella mexicana* Lochman, new species............. 85
7, Paratype, shell with weathered surface, showing cone-within-cone effect, × 5, U.S.N.M. No. 115672a. 8, Paratypes, several shells showing weathered cone-within-cone effect, × 5, U.S.N.M. No. 115673a. Both loc. 807b. 9, Paratypes, transverse and longitudinal sections showing septa and siphuncle, × 8, U.S.N.M. No. 115674, loc. 807g. 10, Paratypes, typical shell coquina; shells with well-preserved annulations of outer surface, × 5, U.S.N.M. No. 115675a, loc. 809a. 11, Paratypes, weathered slab containing internal molds of living chamber and siphuncle and external molds showing outer annulations, × 5, U.S.N.M. No. 115676, loc. 801t.

**PLATE 17**

Figs. 1-5.—*Salterella mexicana* Lochman, new species................ 85
1, Paratypes, sections of three shells showing shape and proportions of siphuncle and living chamber, with camerae and septa replaced by calcite, × 8, U.S.N.M. No. 115677b. 2, Holotype, small section slightly off midline showing four thin septa, the siphuncle and the narrow camerae, × 8, U.S.N.M. No. 115677a. 3, Paratypes, typical shell coquina with well-preserved exteriors, × 5, U.S.N.M. No. 115678. 4, 5, Paratypes, sections of shells in slightly weathered rock, showing the many thin, close, steeply slanting septa in longitudinal sections, and the central siphuncle in the transverse sections, × 8, U.S.N.M. Nos. 115674b and c. Fig. 3, loc. 809a; all others, loc. 807g.

Figs. 6, 7.—*Salterella*, species undetermined.......................... 88
6, Section on weathered limestone, × 2, U.S.N.M. No. 115679, loose between top of Cerro Prieto limestone and saddle in Proveedora Hills. 7, Sections in highly altered limestone, × 4, U.S.N.M. No. 115680, loc. 812a.
NO. 1  EXPLANATION OF PLATES  171

PLATE 18

Figs. 1-3.—Wanneria mexicana prima Lochman, new species, new variety. 1, Paratype, large weathered cephalon, × 1, U.S.N.M. No. 115683. 2, Paratype, dorsal view of plasticine replica of distorted cephalon in limestone, × 1, U.S.N.M. 115682, loc. 801c. 3, Holotype, dorsal view of small, best-preserved cephalon, × 2, U.S.N.M. No. 115681.

Figs. 4, 5.—Olencllus (Fremontia) fremonti Walcott ........................................... 91 4, Hypotype, small, fairly complete cephalon, × 1, U.S.N.M. No. 115685. 5, Hypotype, fragment of a large cephalon, × 1, U.S.N.M. No. 115686, loc. 809a.

Figs. 6-12.—Olencllus (Olencllus) trucmani Walcott ........................................... 89 6, 11, Hypotype, dorsal view of two immature cephaloa, × 4 and × 5, U.S.N.M. No. 115687, loc. 807b. 7, 10, Hypotype, plasticine replica and cleaned specimen of small adult cephalon, × 2, U.S.N.M. Nos. 115690a, b. 8, Hypotype, dorsal view of small well-preserved cephalon showing genal and intergenal spines, × 5, U.S.N.M. No. 115691, loc. 807c. 9, Hypotype, dorsal view of large fragmentary cephalon, × 2, U.S.N.M. No. 115692, loc. 807c. 12, Hypotype, dorsal view of fragment of glabella, showing surface ornamentation and small occipital node, × 5, U.S.N.M. No. 115689, loc. 807b.

PLATE 19

Figs. 1-6.—Wanneria walcottiana buelnaensis Lochman, new variety. 1, Holotype, dorsal view of incomplete cephalon showing genal and intergenal spines, × 2, U.S.N.M. No. 115695. 2, 6, Paratypes, large fragmentary glabella showing surface ornamentation, × 2 and × 1, U.S.N.M. No. 115696. 3, Paratype, fragmentary cheek showing pits along marginal furrow, × 4, U.S.N.M. No. 115697. 4, Paratype, hypostoma showing serrate margin, × 4, U.S.N.M. No. 115698. 5, Paratypes, several broken cephaloa, one showing genal and intergenal spines, × 4, U.S.N.M. No. 115699, loc. 807b.

Figs. 7, 8.—Wanneria? species undetermined. ......................................................... 99 Two fragmentary cephaloa occurring in quartzite, × 2, U.S.N.M. Nos. 115701, 115702, loc. 807j.

Figs. 9-16.—Paedemunias puertoblancensis Lochman, new species. 9, Paratype, small fragmentary cephalon, × 4, U.S.N.M. No. 115707. 10, 11, Paratype, plasticine cast and fragmentary cephalon which has had brim distorted, × 1, U.S.N.M. No. 115706, loc. 807e. 12, Holotype, small nearly complete cephalon, × 3, U.S.N.M. No. 115703, loc. 807c. 13, Paratype, small broken cephalon showing intergenal spine, × 5, U.S.N.M. No. 115705a, loc. 807b. 14, Paratype, large broken cephalon showing outer surface and occipital node, × 2, U.S.N.M. No. 115708, loc. 809a. 15, 16, Paratypes, two cephaloa in meraspid stage showing genal and intergenal spines beginning to separate, × 8, × 6, U.S.N.M. Nos. 115709, 115710, loc. 809a.
Plate 20


Fig. 5.—Onchocephalus buchaensis Lochman, new species. Paratype, dorsal view of small peeled cranidium, × 4, U.S.N.M. No. 115725, loc. 807c.

Figs. 6-17.—Onchocephalus mexicanus Lochman, new species. Paratype, a peeled cranidium, × 3, U.S.N.M. No. 115714. 7, 8, Paratype, dorsal and rear views of a pygidium, × 8, U.S.N.M. No. 115715. 9, 10, Paratype, dorsal and rear views of a second pygidium, × 8, U.S.N.M. No. 115716. 11, Paratype, dorsal view of large cranidium, × 4, U.S.N.M. No. 115717. 12, Paratype, associated free cheek, × 5, U.S.N.M. No. 115718. 13, 14, Paratype, dorsal and side views of cranidium with well-preserved outer surface, × 5, U.S.N.M. No. 115719. 15-17, Holotype, dorsal, side, and front views of small, well-preserved cranidium, × 4, U.S.N.M. No. 115713. All from loc. 809a.

Figs. 18-29.—Onchocephalus buchaensis Lochman, new species. Paratype, dorsal, rear, and dorsal views of associated pygidium, U.S.N.M. No. 115731. 18, × 10; 26 and 27, × 6. 19, 23, Holotype, side and dorsal views of large well-preserved cranidium, × 4, U.S.N.M. No. 115724. 20, Paratype, associated free cheek, × 4, U.S.N.M. No. 115726. 21, 22, Paratype, large pygidium, × 6, × 5, U.S.N.M. No. 115732. 23, Holotype, side and dorsal views of large well-preserved cranidium, × 4, U.S.N.M. No. 115724. 24, Paratype, broken cranidium with well-preserved outer surface, × 5, U.S.N.M. No. 115729. 25, Paratype, dorsal view of distorted cranidium, × 6, U.S.N.M. No. 115733. 28, 29, Paratypes, side and dorsal views of two peeled cranidia, × 6, U.S.N.M. No. 115727. 18, 21, 22, 25, 26, 27, loc. 8011; 19, 20, 23, 28, 29, loc. 807c; 24, loc. 809a.

Plate 21

Figs. 1-7.—Bonnia sonora Lochman, new species. Paratype, medium-sized weathered pygidium, × 4, U.S.N.M. No. 115737. 2, 4, 6, 7, Holotype, dorsal, side, dorsal, and front views of small cranidium; 2, 7, × 10, 4, 6, × 8, U.S.N.M. No. 115736. 3, 5, Paratype, dorsal and side views of smaller pygidium, × 5, U.S.N.M. No. 115738. all from loc. 809a.

Figs. 8-11.—Antagmus solitarius Lochman, new species. 8, 9, 11, Holotype, dorsal, side, and front views of medium-sized cranidium, × 4, U.S.N.M. No. 115740. 10, Paratype, dorsal view of small cranidium, × 5, U.S.N.M. No. 115741. Both from loc. 809a.

Fig. 12.—Provecedoria starquista Lochman. Paratype, an associated free cheek, × 5, U.S.N.M. No. 115748, loc. 801l.
Figs. 13, 14.—Genus and species undetermined ............................ 108
   Dorsal and front views of broken cranidium, outer surface fairly well
   preserved, × 4, U.S.N.M. No. 115742, loc. 809a.

Figs. 15-21.—Antagmus buttisi (Resser) ..................................... 101
   15, 16, 17, Hypotype, front, side, and dorsal views of medium-sized
   cranidium, × 4, U.S.N.M. No. 115745. 18, Hypotype, small cranidium
   preserving most of outer surface, × 4, U.S.N.M. No. 115743a. 19, 21,
   Hypotype, side and dorsal views of medium-sized cranidium,
   × 4, U.S.N.M. No. 115744. 20, Hypotype, dorsal view of crushed,
   weathered cranidium, × 4, U.S.N.M. No. 115743b. All from loc.
   809a.

Figs. 22-28.—Procedoria starquistac Lochman ............................. 156
   22, 23, 24, Holotype, dorsal, front, and side views of well-preserved
   cranidium, × 5, U.S.N.M. No. 115747. 25, Paratype, a broken cranidium,
   × 5, U.S.N.M. No. 115749. 26, Paratype, plasticine squeezed of a somewhat
   distorted cast, × 5, U.S.N.M. No. 115750. 27, Paratype, a weathered cranidium,
   × 5, U.S.N.M. No. 115751a. 28, Paratype, a small cranidium, × 5, U.S.N.M. No. 115752.
   All from loc. 801i.

Figs. 29-34.—Styrocephalus arrojosensis Lochman, new species ........ 157
   29, Paratype, a fragmentary free cheek, × 4, U.S.N.M. No. 115754.
   30, Paratype, cranidium showing granules on outer surface, × 6,
   U.S.N.M. No. 115755. 31, 32, 33, Holotype, dorsal, side, and front
   views of most complete cranidium, × 3, U.S.N.M. No. 115753. 34,
   Paratype, a large fragmentary cranidium, × 3, U.S.N.M. No. 115756.
   All from 801th.

PLATE 22

Figs. 1-9.—Ptarmigania spinifosca Lochman, new species ............... 133
   1, 4, Paratype, dorsal and rear view of pygidium showing marginal
   spines, × 2, U.S.N.M. No. 115761. 2, Paratype, a more complete
   pygidium showing pits on marginal furrow, × 2, U.S.N.M. No.
   115762. 3, Paratype, associated weathered hypostoma, × 2,
   U.S.N.M. No. 115763. 5, 7, 9, Holotype, dorsal, side, and front
   views of small, well-preserved cranidium, × 4, U.S.N.M. No. 115760.
   6, 8, Paratype, dorsal and side views of large crushed and weathered
   cranidium, × 1, U.S.N.M. No. 115764. All from loc. 801j.

Figs. 10-23.—Mexicaspis difactinensis Lochman, new species ........... 139
   10, Paratype, a well-preserved pygidium, × 4, U.S.N.M. No. 115767.
   11, Paratypes, medium-sized and small cranidia, × 3, U.S.N.M. Nos.
   115768a, b. 12, Paratype, an associated hypostoma, × 5, U.S.N.M.
   No. 115769. 13, Paratype, a small free cheek, × 3, U.S.N.M. No.
   115774. 14, 16, 18, Holotype, dorsal, front, and side views of nearly
   complete cranidium; 14, 16, × 4, 18, × 3, U.S.N.M. No. 115769. 15,
   Paratype, a small pygidium, × 4, U.S.N.M. No. 115770. 17, Para-
   type, a cranidium showing all four pairs of glabellar furrows, × 5,
   U.S.N.M. No. 115771. 19, Paratype, a broken pygidium, × 5,
   U.S.N.M. No. 115772. 20, Paratype, deeply weathered pygidium,
   × 3, 21, Paratype, another weathered pygidium, × 3. 22, Paratype,
a weathered cranidium, ×3. 23, Paratypes, piece showing these cranidia and pygidia associated with *Mexicella mexicana*, ×1. 20-23, U.S.N.M. Nos. 115775a-c. 10-12, 14-18, from loc. 802a; 13, 20-23, from loc. 802b.

**PLATE 23**

Figs. 1-8.—*Albertella proveedora* Lochman, new species................. 137

1, Paratype, best-preserved pygidium, ×4, U.S.N.M. No. 115777. 2, Paratype, a middle-sized cranidium, ×3, U.S.N.M. No. 115778. 3, 7, 8, Holotype, dorsal, front, and side views of most complete cranidium, ×4, U.S.N.M. No. 115776. 4, Paratype, a free cheek, ×3, U.S.N.M. No. 115779. 5, Paratype, an associated hypostoma, ×4, U.S.N.M. No. 115780. 6, Paratype, large broken pygidium, ×4, U.S.N.M. No. 115781. All from loc. 801k.

Fig. 9.—*Albertella aff. A. proveedora* Lochman, new species........... 139

Single well-preserved hypostoma, ×4, U.S.N.M. No. 115784, loc. 802a.

Figs. 10-27.—*Mexicaspis stenopyge* Lochman......................... 141

10, Paratype, an associated hypostoma, ×4, U.S.N.M. No. 115786. 11, Paratype, a good cranidium, ×3, U.S.N.M. No. 115787. Both loc. 801L. 12, 15, Paratype, dorsal and side views of a cranidium, ×3, U.S.N.M. No. 115796, loc. 801ka. 13, Paratype, a distorted cranidium, ×6, U.S.N.M. No. 115798, loc. 800d. 14, Paratype, a large broken pygidium ×2, U.S.N.M. No. 115788. 16, 17, Paratype, side and dorsal views of best pygidium, ×2, U.S.N.M. No. 115789. 18, 23, 24, Holotype, dorsal, side, and front views of well-preserved cranidium, ×5, U.S.N.M. No. 115785. 19, Paratype, a large pygidium, ×3, U.S.N.M. No. 115790. 20, Paratype, an associated free cheek, ×5, U.S.N.M. No. 115791. 21, 22, 26, Paratype, dorsal, side, and front views of nearly complete cranidium, ×2, U.S.N.M. No. 115792. 25, Paratype, a hypostoma, ×3, U.S.N.M. No. 115793. 27, Paratype, a large fragmentary cranidium, ×3, U.S.N.M. No. 115794. 14 and 16-27 from loc. 801L.

**PLATE 24**

Figs. 1-25.—*Mexicella mexicana* Lochman............................ 150

1, 2, Paratype, dorsal and front views of a cranidium, ×4, U.S.N.M. No. 115807, loc. 800d. 3, 4, 5, Holotype, dorsal, side, and front views of a peeled cranidium, ×4, U.S.N.M. No. 115800. 6, Paratype, an associated pygidium, ×10, U.S.N.M. No. 115801, loc. 802a. 7, Paratype, a thoracic segment, ×2, U.S.N.M. No. 115811, loc. 801L. 8, 9, 10, Paratype, a complete but peeled cranidium, ×4, U.S.N.M. No. 115812. 11, Paratype, a coquina of cranidia, ×4, U.S.N.M. No. 115802. 12, Paratype, a small cranidium showing outer surface, ×4, U.S.N.M. No. 115803. 13, Paratype, an associated pygidium, ×10, U.S.N.M. No. 115804. 11-13 from loc. 802a. 14, Paratype, a meraspid cranidium, ×10, U.S.N.M. No. 115817, loc. 801k. 15, Paratype, a small cranidium, ×4, U.S.N.M. No. 115813, loc. 801L. 16, 19, 20, Paratype, dorsal, front, and side views of deeply weath-
erated cranidium, × 3, U.S.N.M. No. 115820, loc. 801j. 17, Paratype, portion of a thorax, × 10, U.S.N.M. No. 115814, loc. 801L. 18, Paratype, a small cranidium, × 5, U.S.N.M. No. 115815, loc. 801L. 21, Paratype, deeply weathered limestone mold, × 6, U.S.N.M. No. 115808, loc. 800d. 22, Paratype, a large weathered free cheek, × 2, U.S.N.M. No. 115821, loc. 801j. 23, Paratype, a distorted cranidium, × 6, U.S.N.M. No. 115809, loc. 800d. 24, Paratype, associated free cheeks, × 10, U.S.N.M. No. 115805, loc. 802a. 25, Paratype, a large peeled cranidium, × 5, U.S.N.M. No. 115818, loc. 801k.

Fig. 26.—Pachyaspis, species undetermined. 155

A small cranidium in lower left corner of piece, associated with Mexicella mexicana and Mexicaspis difuntosensis, × 10, U.S.N.M. No. 115823, loc. 802a.

Figs. 27-30.—Kochaspis aff. K. celer (Walcott) 123

27, Smallest immature cranidium, × 10, U.S.N.M. No. 115824. 28, Slightly larger immature cranidium, × 10, U.S.N.M. No. 115825.

29, Impression of broken large cranidium, × 3, U.S.N.M. No. 115826. 30, Small nearly mature cranidium, × 8, U.S.N.M. No. 115827. All from loc. 802b.

**PLATE 25**

Figs. 1-21.—Glossopleura leona Lochman, new species 135

1, Paratype, associated free cheek, × 4, U.S.N.M. No. 115831, loc. 801m. 2, Paratype, a medium-sized cranidium, × 5, U.S.N.M. No. 115843. 3, Paratype, a large pygidium, × 2, U.S.N.M. No. 115844, loc. 802b. 4, 5, 7, Paratype, dorsal, rear, and side views of nearly complete adult pygidium, × 2, U.S.N.M. No. 115846. 6, Paratype, a very small adult cranidium, × 5, U.S.N.M. No. 115847. 8, 9, 10, Paratype, dorsal, side, and front views of large broken cranidium, × 2, U.S.N.M. No. 115848. 4-10 from loc. 802c. 11, Paratype, cranidium with well-preserved surface, × 4, U.S.N.M. No. 115832, loc. 801m. 12, Paratype, a small broken pygidium, × 5, U.S.N.M. No. 115842, 801m. 13, Paratype, a distorted cranidium, × 4, U.S.N.M. No. 115833. 14, Paratype, a free cheek, × 3, U.S.N.M. No. 115834. 15, Paratype, a small pygidium, × 5, U.S.N.M. No. 115835. 16, 17, Paratypes, associated hypostoma, × 5, U.S.N.M. Nos. 115836, 115837. 18, Holotype, a small cranidium, × 4, U.S.N.M. No. 115830. 19, Paratype, an immature pygidium, × 5, U.S.N.M. No. 115838. 20, Paratype, a meraspid cranidium, × 10, U.S.N.M. No. 115839. 13-30 from loc. 801m. 21, Paratype, squeeze of ventral surface of crushed weathered pygidium, × 3, U.S.N.M. No. 115841, loc. 801m’.

Fig. 22.—Genus and species undetermined 2 158

Dorsal view of small cranidium, × 10, U.S.N.M. No. 115850a, loc. 801h.

Figs. 23, 24.—Kochaspis? species undetermined 125

23, Smaller cranidium than preceding, × 6, U.S.N.M. No. 115851, loc. 801i. 24, large, most complete cranidium, × 4, U.S.N.M. No. 115852a.
Figs. 25-32.—*Pachyaspis deborra* Lochman, new species. 152
25, Paratype, a small cranidium, X 5, U.S.N.M. No. 115857. 26, 28, Paratype, dorsal and front views of small, well-preserved cranidium, X 5, U.S.N.M. No. 115858a. 27, 31, Holotype, front and dorsal views of medium-sized cranidium, X 5, U.S.N.M. No. 115856. 29, 30, Paratype, side and dorsal views of large cranidium, X 5, U.S.N.M. No. 115858b. 32, Paratype, broken cranidium showing surface ornamentation, X 8, U.S.N.M. No. 115859. All from loc. 802c.

Figs. 33, 34.—*Kochaspis cooperi* Lochman, new species. 122
33, Paratype, deeply weathered trace of pygidium, X 1, U.S.N.M. No. 115855. 34, Holotype, dorsal view of small, most complete pygidium, X 4, U.S.N.M. No. 115853, loc. 801k.

**PLATE 26**

Figs. 1-20.—*Kootenia exilaxata* Deiss. 125

Figs. 21-29.—*Pachyaspis isabella* Lochman, new species. 154
21, Paratype, dorsal view of large crushed cranidium, X 4, U.S.N.M. No. 115862. 22, Paratype, fragmentary free cheek, X 4, U.S.N.M. No. 115863. 23, 24, 28, Holotype, front, side, and dorsal views of small, nearly complete cranidium, X 4, U.S.N.M. No. 115861. 25, Paratype, an associated pygidium, X 5, U.S.N.M. No. 115864. 26, Paratype, small cranidium, X 5, U.S.N.M. No. 115865. 27, Paratype, dorsal view of medium-sized cranidium, X 5, U.S.N.M. No. 115866. All from loc. 801m. 29, Paratype, broken cranidium, X 4, U.S.N.M. No. 115868, loc. 801n.

**PLATE 27**

Figs. 1, 2.—*Alokistocarella mexicana* Lochman, new species. 118
Holotype, dorsal and side views of well-preserved cranidium, X 3, U.S.N.M. No. 115884, loc. 801n.
Figs. 3-8.—Alokistocare althea Walcott. .................................................. 114

3, Hypotype, large fragment of cranidium, $\times 2$, U.S.N.M. No. 115887.
4, Hypotype, dorsal view of most complete cranidium, $\times 3$, U.S.N.M. No. 115888. 5, Hypotype, immature cranidium without median boss, $\times 5$, U.S.N.M. No. 115889. 6, Hypotype, small cranidium showing features of brim and border, $\times 5$, U.S.N.M. No. 115890. 7, Hypotype, an associated pygidium, $\times 5$, U.S.N.M. No. 115891. 8, Hypotype, an associated free cheek, $\times 5$, U.S.N.M. No. 115892. All from 801-O.

Figs. 9, 10.—Alokistocare cf. A. modestum Lochman, new species. ............. 117
Dorsal views of two small cranidia, $\times 5$, $\times 3$, U.S.N.M. Nos. 115894, 115895, loc. 800a.

Figs. 11-16.—Alokistocare modestum Lochman, new species. .................... 116
11, Paratype, dorsal view of small cranidium showing outer surface, $\times 4$, U.S.N.M. No. 115899. 12, 15, 16, Holotype, side, front, and dorsal views of medium-sized cranidium; 12 and 15, $\times 3$, 16, $\times 4$, U.S.N.M. No. 115897. 13, Paratype, dorsal view of small cranidium showing outer surface, $\times 4$, U.S.N.M. No. 115899. 14, Paratype, an associated free cheek, $\times 4$, U.S.N.M. No. 115900. All from 801n.

Figs. 17-25.—Hyolithes sonora Lochman, new species. ............................. 113
17, Drawing of transverse section, $\times 1$. 18, Paratype, dorsal surface with ornamentation, $\times 4$, U.S.N.M. No. 115904, loc. 801-O. 19, Paratype, outer surface of dorsal side of large shell, $\times 4$, U.S.N.M. No. 115907, loc. 800a. 20, 21, 24, Holotype, dorsal, ventral, and side views of internal mold, $\times 3$. 22, 23, side and ventral views, $\times 1$, U.S.N.M. No. 115902, loc. 800c. 25, Paratype, large fragment of dorsal side showing longitudinal ridges, $\times 3$, U.S.N.M. No. 115905, loc. 801-O.

PLATE 28

Figs. 1-7.—Chancelloria eros Walcott. .................................................... 110
1, Hypotype, specimen with six side rays, several nearly full length, $\times 6$, U.S.N.M. No. 115912. 2, Hypotype, a worn specimen, $\times 8$, U.S.N.M. No. 115913. 3, Hypotype, specimen showing tubercles on end of rays, $\times 8$, U.S.N.M. No. 115914. 4, Hypotype, specimen showing several long curved rays, $\times 6$, U.S.N.M. No. 115915. 5, Hypotype, a very much worn spicule, $\times 10$, U.S.N.M. No. 115916, loc. 800c. 6, 7, Hypotype, side and top views of a silicified spicule with side rays broken, $\times 10$, U.S.N.M. No. 115919a, loc. 800a.

Figs. 8-11.—Problematicum III ............................................................... 109
8, 9, Side and top views of most complete specimen, $\times 5$, U.S.N.M. No. 115920. 10, 11, Two views of a smaller more acutely pointed specimen, $\times 6$, $\times 5$, U.S.N.M. No. 115921. All from loc. 800d.

Figs. 12-22.—Kistocare corbini Lochman. ............................................... 119
12, 13, Paratypes, two fragmentary free cheeks, $\times 5$, U.S.N.M. Nos. 115924, 115925. 14, 16, Holotype, side and dorsal views of cranidium with good outer surface, $\times 5$, U.S.N.M. No. 115923. 15, 18, Paratype, front and dorsal views of medium-sized cranidium, $\times 5$, U.S.N.M. No. 115926. 17, Paratype, small cranidium with posterior
SMITHSONIAN MISCELLANEOUS COLLECTIONS  VOL. 119

Page

limb, $\times 5$, U.S.N.M. No. 115927. 19, Paratype, cranidium showing surface granules, $\times 4$, U.S.N.M. No. 115931, loc. 801n. 20, Paratype, large broken cranidium, $\times 3$, U.S.N.M. No. 115928. 21, Paratype, a small pygidium, $\times 5$, U.S.N.M. No. 115929. All from 800c. 22, Paratype, a small cranidium, $\times 5$, U.S.N.M. No. 115932, loc. 801n.

Figs. 23-25.—Hedciconella, species undetermined. .......... 114
Lateral, top, and anterior views of the single internal mold, $\times 5$, U.S.N.M. No. 115936, loc. 800c.

Figs. 26-31.—Kistocare toutoensis (Resser) ................. 121
26, Holotype, dorsal view of micaceous sandstone internal mold, $\times 4$, U.S.N.M. No. 108614, U.S.N.M. loc. 74. 27, 30, 31, Hypotype, side, front, and dorsal views of best-preserved cranidium, $\times 4$, U.S.N.M. No. 115937. 28, Hypotype, a small, broken cranidium, $\times 5$, U.S.N.M. No. 115938. 29, Hypotype, a broken peeled cranidium, $\times 4$, U.S.N.M. No. 115939. All from loc. 800a.

PLATE 29

Figs. 1-10.—Athabaskia bela (Walcott) ...................... 128
1, Holotype, medium-sized cranidium showing border, $\times 3$, U.S.N.M. No. 115941. 2, 3, 4, Hypotype, dorsal, side, and front views of most complete cranidium, $\times 1$, U.S.N.M. No. 115942. All loc. 800c. 5, Hypotype, a large fragmentary cranidium, $\times 3$, U.S.N.M. No. 115945, loc. 801n. 6, Hypotype, dorsal view of pygidium, $\times 2$, U.S.N.M. No. 115943, loc. 800c. 7, 10, Hypotype, dorsal and rear views of broken pygidium, $\times 2$, U.S.N.M. No. 115946. 8, Hypotype, fragmentary pygidium showing pleural furrows, $\times 2$, U.S.N.M. No. 115947. 9, Hypotype, fragmentary pygidium with well-preserved surface, $\times 3$, U.S.N.M. No. 115948. 7-10 from loc. 801n.

Figs. 11-14.—Caboccella arrojosensis Lochman .......... 147
11, 12, 13, Holotype, front, side, and dorsal views of nearly complete cranidium. $\times 3$, U.S.N.M. No. 115950. 14, Paratype, dorsal view of smaller cranidium, $\times 3$, U.S.N.M. No. 115952. All from loc. 800c.

Figs. 15-19.—Arellanella sonora Lochman, new species .... 146
15, Holotype, dorsal view of small cranidium, $\times 5$, U.S.N.M. No. 115953. 16, Paratype, a small broken cranidium, $\times 5$, U.S.N.M. No. 115954. 17, 18, Paratype, dorsal and side views of larger cranidium, $\times 5$, U.S.N.M. No. 115955. 19, Paratype, another small cranidium, $\times 5$, U.S.N.M. No. 115956. All from 800a.

Figs. 20-22.—Arellanella aff. A. sonora Lochman, new species .......... 146
20, 21, Dorsal and front views of artificial cast of an impression of a cranidium, $\times 4$, $\times 5$, U.S.N.M. No. 115958. 22, Dorsal view of another poorly preserved shale cranidium, $\times 5$, U.S.N.M. No. 115959. All from loc. 800b.

Figs. 23-29.—Arellanella caborcana Lochman ............... 144
23, Paratype, a fragmentary free cheek, $\times 4$, U.S.N.M. No. 115962. 24, Paratype, a small pygidium, $\times 10$, U.S.N.M. No. 115963. 25, 26, 27, 28, Holotype, side views from left and right, front, and dorsal
views of medium-sized well-preserved cranidium; 25, 26, 27, × 3, 28, × 4, U.S.N.M. No. 115961. 29, Paratype, a larger pygidium, × 5, U.S.N.M. No. 115964. All from loc. 800a.

PLATE 30

Figs. 1-10.—Inglefieldia imperfecta Lochman, new species.................. 148
1, Paratype, a cranidium, anteroposterior compression, × 4, U.S.N.M. No. 115967. 2, Paratype, dorsal view of shale cranidium, slight lateral compression, × 4, U.S.N.M. No. 115968. 3, Paratype, cephalon and nearly complete thorax, × 3, U.S.N.M. No. 115969. All from 800e. 4, Paratype, distorted cranidium in limestone, × 4, U.S.N.M. No. 115975. 5, Paratype, cranidium in limestone, × 4, U.S.N.M. No. 115976. Both from loc. 800f. 6, Paratype, cephalon and part of thorax, slightly distorted, × 3, U.S.N.M. No. 115971. 7, Paratype, small poorly preserved pygidium, × 4, U.S.N.M. No. 115972. Both from loc. 800e'. 8, Holotype, dorsal view of large shale cranidium, × 5, U.S.N.M. No. 115966, loc. 800e. 9, Paratype, cranidium showing elongation due to lateral compression, × 3, U.S.N.M. No. 115973. 10, Paratype, cranidium showing distortion, × 4, U.S.N.M. No. 115974. Both from loc. 800e'.

Figs. 11-17.—Zacanthoides aff. Z. holopygus Resser......................... 143
11, Poorly preserved limestone pygidium showing single pair of marginal spines, × 4, U.S.N.M. No. 115978. 12, Dorsal view of small, imperfect limestone cranidium, × 5, U.S.N.M. No. 115979. Both from loc. 801c. 13, 14, Two free cheeks in shale, × 4, U.S.N.M. No. 115981, U.S.N.M. No. 115982. 15, Shale pygidium with last thoracic segment, × 4, U.S.N.M. No. 115983. 16, Distorted shale cranidium, × 4, U.S.N.M. No. 115984. 17, Thorax and pygidium, with hypostoma showing where cephalon removed, × 4, U.S.N.M. No. 115985. All from loc. 800e'.

PLATE 31

Figs. 1-3.—Athabaskia minor (Resser)........................................... 130
1, Hypotype, small, nearly complete pygidium, × 4, U.S.N.M. No. 115987. 2, Hypotype, fragmentary small cranidium, × 8, U.S.N.M. No. 115988. 3, Hypotype, fragment of a larger pygidium, × 3, U.S.N.M. No. 115989. All from loc. 800g.
Fig. 4.—Cf. Middle Cambrian trilobites...................................... 159
A distorted fragmentary cranidium, × 5, U.S.N.M. No. 115990, loc. 811a.

Figs. 5, 6.—Parenhmania, species undetermined.............................. 155
Dorsal views of two small imperfect cranidia, × 10, × 5, U.S.N.M. Nos. 115992, 115993, loc. 800h.

Fig. 7.—Genus and species undetermined 3................................. 159
Small fragmentary cranidium with upturned border, × 10, U.S.N.M. No. 115994, loc. 800h.
Fig. 8.—_Glossopleura_ species = _Sonoraspis torresi_ Stoyanow ........... 137
Carapace without cephalon, × 2, paratype, U.S.N.M. No. 116333, loc. 800e.

Fig. 9.—_Glossopleura_ species = _Sonoraspis gomezii_ Stoyanow ........... 137
Small carapace with well-preserved thorax and pygidium, × 1, paratype, U.S.N.M. No. 116335; plasticine replica of exterior from mold, plate 15, fig. 5.

Figs. 10, 11.—_Glossopleura_ species ........................................ 137
10, Dorsal view of complete but crushed cranidium, × 2, figured specimen U.S.N.M. No. 116336. 11, Incomplete cranidium showing some convexity, × 1, figured specimen, U.S.N.M. No. 115995, loc. 800e.

Figs. 12-14.—_Glossopleura_ species = _Sonoraspis gomezii_ Stoyanow ........... 137
12, Carapace of laterally compressed specimen, U.S.N.M. No. 116334; holotype, plasticine replica from mold, plate 14, fig. 6, × 1. 13, Pygidium and part of thorax, × 2, figured specimen U.S.N.M. No. 115996, loc. 800e. 14, Dorsal view of plasticine replica of specimen lacking only free cheeks, × 2. Same as pl. 14, fig. 5, U.S.N.M. No. 116335, loc. 800e.
INDEX

(Principal references are printed in italics.)

Acrothele, 14, 37, 44
colleni, 45
concava, 44, 45, pl. 12
sp., 18, 19
Agraulos, 152
stator, 76
Ajaicyathidae, 28
Ajaicythus nevadensis, 21, 27, 28, 20,
pl. 7, 9
rimouski, 21, 27, 28, pl. 9
Albertella, 8, 12, 60, 66, 73, 74, 75, 76,
137, 138, 158, 163
bowseri, 139
proveedora, 20, 21, 137, 139, 157,
pl. 23
aff. A. proveedora, 21, 139, pl. 23
Albertella beds, 20, 21
Albertella zone, 73, 74, 75, 77, 79, 81
Alokostocare, 50, 56, 57, 75, 77, 78, 117,
140
althea, 21, 57, 75, 114, pl. 27
idahoensis, 117
modestum, 20, 116, 118, pl. 27
cf. A. modestum, 18, 117, pl. 27
stator, 76
subcoronatum, 56
Alokostocarella, 77
brighemansis, 119
mexicana, 18, 20, 118, pl. 27
typicalis, 119
Alokostocaridae, 114
Amecephalus, 57, 58
piochensis, 56, 57, 58
Amecephalus? cf. A. piochensis, 55,
pl. 14
Anoria, 50, 52, 53, 54, 73, 75, 77, 80
baton, 52, 53
bessus, 52, 53
tothoisal, 52, 53, 136
Antagusmus, 7, 71, 73
buttsi, 22, 101, pl. 21
perola, 102
solitarius, 22, 102, 103, pl. 21
tenneasensis, 103
typicalis, 103
Antagusmus-Onchocephalus zone, 22, 60,
71, 73, 85
Aphelaspis, 66
Archaeocyathus atlanticus, 32
yavorskii, 21, 27, 31, pl. 10
Arellanella, 77, 144
caborca, 18, 144, 146, pl. 29
sonora, 18, 145, 146, pl. 29
aff. A. sonora, 18, 146, pl. 29
Arrojos formation, 6, 7, 9, 11, 14, 17,
18, 19, 20, 21, 60, 78, 79-80, pl. 1
Arrojos Hills, 2, 6, 8, 13, 17, 18, 81,
pl. 1-3
Atlantica, 75, 77, 128
anax, 128
atossa, 128
bela, 18, 20, 128, pl. 29
glacialis, 128
minor, 19, 130, pl. 31
ostheimeri, 128
Bathyuriscus belesis, 129
Bolaspis-Glyphaspis zone, 81
Bonnia, 7, 71
columbensis, 100
fieldensis, 100
sonora, 22, 99, pl. 21
tensa, 100
Bonnia zone, 71, 72
Brachiopoda, 36
references, 48
Bradoria, 109
rugulosa, 109
Bridge, J., 49
Bright Angel shale, 79, 80
Buelna formation, 4, 11, 12, 16, 19, 21,
22, 23, 60, 70, pls. 2, 4, 5
Buelna Hills, 2, 11, 12, 16, 21, pl. 5
Caborca, map of region about, 3
Caborcella, 147
arrojosensis, 18, 147, pl. 29
Caborcella beds, 18
Cambrocyathidae, 33
Cambrocyathus cf. C. occidentalis, 21,
27, 33, pl. 9
profundus, 30
Cañedo Hill, 2, 9, 16, 23
Cathedral dolomite, 79
Cerro Prieto formation, 7, 11, 12, 13,
17, 19, 23, 60, pls. 1-5
Chaetetes, 17
Chancelloria, 14
drusilla, 111
eros, 18, 20, 110, 112, pl. 28
Clathrocyathus, 30, 31
Clavaspidella, 75, 128, 130
Columnar sections, Arrojos Hills, 6, 8
Buelna Hills, 11
Prieto Hill, 11
Proveedora Hills, 6, 8
Coscinocyathidae, 31
Coscinocyathus sp., 21, 27, 31, pl. 9
181
Crepicephalidae, 122
Crepicephalus, 66

 Damnation limestone, 80
Dearborn limestone, 80

 Dictyonia, 37, 40
burgessensis, 40
minutipuncta, 19, 40, pl. 11
nyssa, 40
sp., 18, 19, 41, pl. 12

Difuntos Hills, 2, 12, 16, 18, 21, pl. 3

Diraphora, 14, 47
arrojosensis, 18, 21, 36, 47, pl. 13
belicostata, 48

Dolichometopsis, 131, 132
lepid, 132
poulsenii, 133
resseri, 132

Dolichometopus boccar, 50, 51
productus, 50, 51

tontoensis, 51

East Buelna, 12
Ehmania, 76
Ehmaniella, 76
Elliptocephala, 72
Erathia, 76, 155, 156
Erathia-Erathina zone, 78
Erathia, 76, 156
Erathia-Clappasis zone, 76, 78, 81
Elvinia, 66
Ethmophyllidae, 28
Ethmophyllum americanum, 21, 27, 30, pl. 7
copperi, 21, 27, 29, pls. 7, 9
whitneyi, 21, 27, 28, 29, pl. 8

Faunal lists, 18
Faunas, discussion of, 70

Girvanella, 4, 7, 9, 10, 11, 12, 13, 14, 17, 24, 60, 71, pl. 5
mexicana, 22, 24, pl. 6
references, 25
cf. G. sinensis, 20, 25, pl. 6
sp., 23

Glossopleura, 8, 12, 14, 17, 20, 50, 51, 52, 53, 54, 60, 66, 74, 75, 77, 135, 137, pl. 1
belesis, 136
boccar, 51, 53
leona, 20, 21, 135, 155, pl. 25
mckeei, 136, 137
producta, 53

Glossopleura sp., 20, 137, pl. 31
stephenensis, 53

Glossopleura-Kootenia zone, 60, 66, 74, 75, 77, 78, 80, 81, 113
Glossopleura-Sonoraspis, 18, 19
Gómez, I. G., 1, 49
Gordon shale, 79, 80

Helcionella sp. undet., 114, pl. 28

Hyolithes, 4, 15, 61, 84
cercops, 114
comptus, 113
idahoensis, 114
aff. H. princeps, 19, 21, 82, pl. 15
prolixus, 113
sonora, 18, 21, 113, pl. 27
cf. H. sonora, 20
sp., 20, 23
whitei, 22, 83, pl. 16

Inglefieldia, 58, 77, 148
discreta, 149
idahoensis, 78, 117
imperfecta, 18, 19, 148, 149, 150, pl. 30

Kinsobia varigata, 109
Kistocare, 77
corbinii, 18, 20, 119, pl. 28
tontoensis, 77, 117, 120, 121, pl. 28

Kochaspis, 74, 76, 79, 122, 124, 157
celer, 124, 125
aff. K. celer, 21, 123, pl. 24
copperi, 20, 122, 125, pl. 25
dispar, 123
liliana zone, 73, 74, 79
maladensis, 123
sp. undet., 20, 125, pl. 25

Kootenia, 9, 14, 17, 66, 75, 77, 78, 125, 127, pl. 1
erromena, 126, 127
exilaxata, 18, 20, 125, pl. 26
scapegoatensis, 125
tetonensis, 78

Kootenia beds, 21
Kootenidae, 125

Lingulella, 4, 37
granvillensis, 38
proveedorensis, 19, 37, pl. 13
sp., 19

Lista Blanca, 2, 13, 23, pl. 5
Localities, 18
Localities 800, 18, 19
Localities 801, 19, 20, 21
Localities 801q, 15, 27
Localities 801x, 15
Locality 801y, 15, 27
Locality 801z, 16
Locality 802, 21
Locality 807, 21, 22
Locality 807j, 16
Locality 809, 22, 23
Locality 811, 23
Locality 812, 23
Lower Cambrian faunas, 70, 81

Mexicaspis, 8, 14, 17, 74, 76, 139, pl. 1
difuntosensis, 21, 139, 143, 155, pl. 22
distospyge, 18, 20, 141, pl. 23

Mexicaspis bed, 18

Mexicella, 8, 12, 17, 74, 76, 159
Mexicana, 18, 20, 21, 138, 150, 152, 155, pl. 24
stator, 152

Micromitra, 39, 40
sp., 18, 39, pl. 13

Middle Cambrian faunas, 73, 81
Muav limestone, 80

Nevada, 72

Nisusia, 45
deissi, 46
montanensis, 46
sp., 20, 45, pl. 13

Obolella, 4, 10, 41, 60, 71, 72
atlantica, 42
chromatica, 42
crassa, 42
mexicana, 23, 41, pl. 12

Obolella beds, 19, 23, 36, 94

Obolella zone, 71, 72

Olenellus, 4, 71, 72, 73, 94
(Freemontia) fremonti, 22, 71, 91, 94, pl. 18
gilberti, 89, 91, 92
lapworthi, 89, 92
logani, 92
reticulatus, 89
thompsoni, 89, 91
(Olenellus) truemanii, 22, 71, 89, 90, 94, 97, pl. 18
sp. undet., 19, 22, 94

Olenellus zone, 21, 22, 71, 72, 81, 82, 85
Olenoides, 78

Onchocephalus thia, 105
virginicus, 105

Orthotheca huena, 22, 84, pl. 15

Pachyaspis, 12, 74, 75, 77, 152, 153
deborra, 21, 152, 155, pl. 25
isabella, 20, 154, 155, pl. 26
sp. undet., 21, 155, pl. 24
typicalis, 153

Paecuemias, 12, 72, 95
puertoblancoensis, 19, 21, 22, 94, pl. 19
transitans, 89, 92, 95

Parehmania, 75, 78, 81, 122, 155, 156, 159
sp., 19
sp. undet., 155, pl. 31
tontoensis, 122

Paterina, 38, 40
sp., 19, 22, 38, pl. 11

Pegmatreta, 15, 37, 42
arellanoi, 19, 43, 44, pl. 13
perplexa, 44
rara, 18, 42, pl. 12
rotunda, 44

Pleosponge reefs, 15, 16, 27, pl. 5

Pleospinges, 17

Pleospongia, 27

references, 34

Poulsen, 51, 52

Prieto Hill, 2, 10, 16, pls. 4, 5

Problematicum I, 19, 81, pl. 15

Problematicum II, 19, 81, pl. 15

Problematicum III, 18, 109, pl. 28

Protopharetra sp., 21, 27, 33, pl. 9

Proveedora formation, 4, 12, 13, 16, 19,
60, 70, pl. 1

Proveedora Hills, 2, 6, 8, 9, 10, 12, 13,
16, 17, 18, 19, pls. 1, 2, 4
map, 4
profile, 5

Proveedoria, 74, 76, 156
starquistae, 20, 156, pl. 21

Ptarmigiana, 8, 74, 76, 77, 131, 132
bispinosa, 20, 133, pl. 22
rossensis, 132, 133

Ptarmiganiidae, 128

Ptychoparia piochoensis, 56

Puerto Blanco formation, 4, 16, 19, 23,
60, 70, pl. 4

Puerto Blanco section, 78

Resser, C. E., 49, 51, 56, 58, 116
Salterella, 7, 9, 10, 12, 13, 15, 61, 71, 88
conulata, 86
expansa, 86
mexicana, 10, 22, 23, 85, 87, 88, pls. 15, 16, 17
cf. S. pulchella, 87, pl. 16
rugosa, 86, 87
sp., 19, 22, 23
sp. undet., 23, 88, pl. 17
Salterella beds, 22, 23
Scenella, 61
cf. S. reticulata, 22, 85, pl. 15
Scolithus, 12, 21, pl. 11
Sombrerella, 71
mexicana, 22, 107, pl. 20
Sonaraspis, 14, 17, 50, 52, 137
gonezi, 52, 54, pls. 14, 31
torresi, 52, 53, 54, 55, pls. 14, 31
Strotocephalus, 74, 76, 79, 157
arrojosensis, 20, 157, pl. 21
gordonensis, 158
Syringocnema favus, 34
? sp., 21, 27, 33, pls. 8, 9
Syringocnemidae, 33
Syspacephalus zone, 71

Torres, L., 1, 49
Tren formation, 4, 9, 12, 14, 15, 16, 18, 19, 66, 78, 81, pls. 1-3

Trilobites, 49, 60, 62, 65, 66, 70
references, 59, 159

Walcott, C. D., 51, 52, 56, 57, 58, 61
Wanneria, 71, 72, 73, 96, 97
halli, 89
mexicana, 97
mexicana prima, 19, 68, 96, 99, pl. 18
occidens, 97
rowei, 97
sp. undet., 22, 99, pl. 19
walcottana, 71
walcottana buelnaensis, 21, 98, pl. 19

West Buelna, 12, 164
Wimanella, 46
rossensis, 47
sp., 20, 47, pl. 13
takayamai, 47

Zacanthoidae, 137
Zacanthoides, 14, 66, 73, 75, 77, 80, 143
aff. Z. holopygus, 19, 20, 143, pl. 30
idahoensis, 144
cf. Z. waalpi, 80
Aerial View of the Proveedora Hills
Difuntos Hills, North End of the Arrojos Hills, and Pleosponge Reef
Puerto Blanco Formation: Prieto Hill; Cañedo Hill; Proveedora Hills
(Buelna and Cerro Prieto Formations)
Lista Blanca: West Buelna Hill: Surface of Cerro Prieto Limestone on Top of Prieto Hill. Showing Girvanella
(See explanation of plates at end of text.)
Pleospongia

(See explanation of plates at end of text.)
PLEOSPONGIA
(See explanation of plates at end of text.)
PLEOSPONGIA

(See explanation of plates at end of text.)
Pleospongia

(See explanation of plates at end of text.)
Brachiopoda

(See explanation of plates at end of text.)
Brachiopoda
(See explanation of plates at end of text.)
Brachiopoda
(See explanation of plates at end of text.)
Original Collection of Cambrian Trilobites from Sonora

(See explanation of plates at end of text.)
Trilobites
(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
Trilobites

(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
Trilobites

(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
TRILOBITES

(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
Trilobites
(See explanation of plates at end of text.)
TRILOBITES

(See explanation of plates at end of text.)
Trilobites
(See explanation of plates at end of text.)
Trilobites

(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)
TRILOBITES
(See explanation of plates at end of text.)