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TREMADOCIAN TRILOBITES FROM THE NOCHIXTLÁN REGION, OAXACA, MEXICO

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ABSTRACT Early Paleozoic fossils are described for the first time from southern Mexico. A Tremadocian fauna with 21 genera and 28 species of trilobites is described from the lower 60 meters of the Tiñu Formation of the Nochixtlán region of Oaxaca. New taxa include the subfamily, Plicatolininae, and the genera *Bifodina*, *Gymnagnostus*, *Leurostega*, *Plicatolinella*, and *Tinaspis*. Also new are 22 species that include *Angelina spinosa*, *Asaphellus artus*, *A. aspinus*, *A. communis*, *Bienvillia grandis*, *Bifodina longifrons*, *Geragnostus curvata*, *Gymnagnostus gongros*, *G.? mexicanus*, *Koldinioidia sulcatus*, *Leurostega aphelix*, *Onychopyge sculptura*, *Parabolinella prolata*, *P. tumifrons*, *P. variabilis*, *Pharostomina mexicana*, *Plicatolinella ocula*, *Richardsonella variagranula*, *Saukia globosa*, *Shumardia alata*, *S. ctenata*, and *Tinaspis totoyaca*.

Correlation of faunas from most of North America with those of the Tremadocian of Europe has been difficult because of the existence of largely mutually exclusive faunal provinces. A mixture in the Tiñu Formation of taxa that commonly occur in Europe, South America, and elsewhere in North America provides new data for correlation. Faunas in the calcareous lower member of the Tiñu approximately correlate with the *Saukia* Zone of the Late Cambrian as used in much of North America, and with the lower Tremadocian of Europe and South America. Faunas in the lower part of the shaly upper member of the Tiñu approximately correlate with Lower Ordovician trilobite zones A to D or E as used in the western United States, and probably with most of the upper Tremadocian of Europe and South America.

INTRODUCTION

UNTIL recently, rocks of unquestioned Early Paleozoic age have not been reported from southern Mexico. In 1965, as a result of geologic investigation in the Nochixtlán region of Oaxaca, Pantoja-Alor discovered two outcrops with fossiliferous sedimentary rocks of Paleozoic age (text-fig. 1). Fossils from those outcrops were sent to G. A. Cooper of the U. S. National Museum and A. R. Palmer of the U. S. Geological Survey for identification. In unpublished reports, Cooper (1966) and Palmer (1966) identified brachiopods and trilobites of Ordovician, Mississippian, and Pennsylvanian age.

The importance of further study of the Early Paleozoic fossils was evident from some interesting faunal relationships, good preservation of fossils, and lack of prior reports of Early Paleozoic fossils in southern Mexico. Other activities, however, prevented further study of the faunas by Cooper and Palmer, and therefore Robison was invited to continue the study. In late 1966, Pantoja-Alor and Robison made detailed collections of fossils from three measured stratigraphic sections in the Nochixtlán region. Subsequently, the discovery of Paleozoic rocks in Oaxaca was announced in a brief note by Pantoja-Alor & Robison (1967), and was followed by a formal description of stratigraphic units by Pantoja-Alor (1968).

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The major purpose of this paper is to describe the trilobites and to give a preliminary evaluation of the faunas collected in 1966. Accompanying papers by R. H. Flower and by E. L. Yochelson in this number of the *Journal of Paleontology* are concerned with associated cephalopods and gastropods, respectively. Associated conodonts have been identified by D. L. Clark, and a summary of Clark's conclusions is presented in this paper in the section on "Age and Correlation of Faunas." Other associated fossils, which include brachiopods, echinoderms, sponges, ostracodes, and problematica, have not been studied in detail at this time.

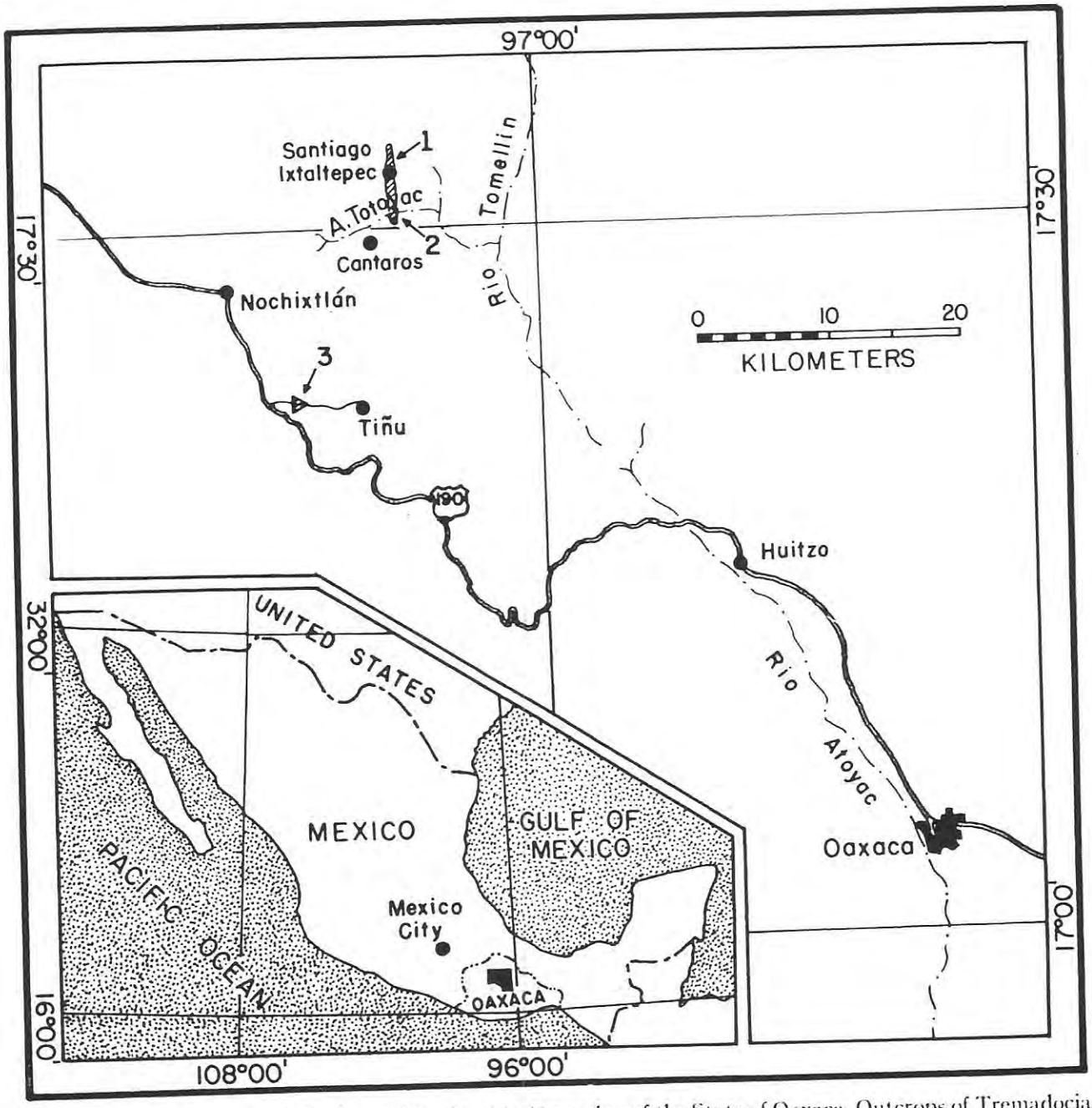
ACKNOWLEDGMENTS

Field work in southern Mexico was supported by the Walcott Fund of the Smithsonian Institution and by funds from the Instituto de Geología, Ciudad Universitaria. We thank, A. R. Palmer for critical review of the manuscript and helpful suggestions. The photographs of fossils were made by Mr. Jack Scott and the illustrations were drafted by Mr. L. B. Isham, both of the U. S. National Museum.

STRATIGRAPHY

Tiñu Formation

The Tiñu Formation was defined by Pantoja-Alor (1968) to include rocks of Early Paleozoic age in the Nochixtlán region. It is known to crop out in two areas (text-fig. 1).



TEXT-FIG. 1—Index maps of Mexico and the Nochixtlán region of the State of Oaxaca. Outcrops of Tremadocian rocks are cross-hatched. Measured stratigraphic sections (numbers and arrows) are: *1*, Santiago Ixtaltepec (see text-fig. 4), *2*, Arroyo Totoyac (see text-fig. 3), and *3*, Tiñu (see text-figs. 2A,B).

The type locality of the Tiñu Formation is a small area, about 200 by 500 meters, situated approximately 9 kilometers south-southeast of Nochixtlán. It is crossed by an unimproved road that connects the village of Tiñu with Federal Highway 190 (International Highway). At that locality, rocks of the formation occur in a graben-type fault block in Precambrian gneiss. Within the fault block, the Tiñu Formation lies nonconformably on Precambrian gneiss and is overlain disconformably by lower and middle Tertiary sandstone and conglomerate. Characteristics of the lower part of the stratigraphic section are shown by text-figure 2.

At the other area, the Tiñu Formation crops out for about 7 kilometers in a north-south band along the west wall of the Barranca de Santiago Ixtaltepec. The southern tip of the outcrop is about 14 kilometers east-northeast of Nochixtlán. In that area, the Tiñu Formation lies nonconformably on Precambrian gneiss and is overlain with angular unconformity by conglomeratic limestone of Mississippian age. Stratigraphic sections have been measured in Arroyo Totoyac near the south end of the outcrop (text-fig. 3) and just north of Santiago Ixtaltepec near the north end of the outcrop (text-fig. 4).

Mostly as a result of post-depositional erosion, thickness of the Tiñu Formation ranges from 23 meters in Arroyo Totoyac to a little more than 200 meters at the type locality. An unnamed lower member averages about 15 meters in thickness and characteristically is composed of interbedded thin- to medium-bedded dark fossiliferous limestone and thin to medium beds of light, generally unfossiliferous shale. An unnamed upper member is 7 to 24 meters thick in the Barranca de Santiago Ixtaltepec and mostly consists of noncalcareous fissile shale. Near Tiñu, the upper member is about 180 meters thick and mostly consists of shale, siltstone, and fine-grained sandstone, but also contains a few thin limestone beds, a 15-meter shale unit with scattered limestone concretions, and a few conglomeratic sandstone beds.

Observed stratigraphic occurrences and ranges of trilobites, conodonts, gastropods, and cephalopods in the Tiñu Formation are indicated on text-figures 2–4. The age and correlation of the faunas is discussed in the following section.

For further details concerning physical aspects of the Tiñu Formation, see Pantoja-Alor (1968).

PALEONTOLOGY

General Information

Depository.—Most of the specimens upon which this study is based, including all illustrated specimens, are in the collections of the U. S. National Museum, Washington, D. C. The remainder are in a reference collection at the Instituto de Geologia, Ciudad Universitaria, Mexico, D. F.

Terminology.—Morphological terms used here for the description of trilobites are the same as those defined either in Part O of the *Treatise on Invertebrate Paleontology* (Harrington and others, 1959, p. 117–126) or by Henningsmoen (1957, p. 12–14).

Locality and collection numbers.—Fossils described in this paper were collected at three localities identified below by U. S. National Museum locality numbers. One locality has been given two numbers. Stratigraphic collections from a measured section at each locality have been identified with the USNM locality number followed by successive letters. Location of each section is shown on text-figure 1, and the stratigraphic position of each collection is shown on text-figures 2–4.

USNM 16000 is the type section of the Tiñu Formation, which crops out in a small area crossed by the road that connects the village of Tiñu with Federal Highway 190. It is situated about 10 km south-southeast of Nochixtlán and can be reached by traveling 12.5 km southward from Nochixtlán on Federal Highway 190, and then 2.2 km eastward on the road to Tiñu.

USNM 16001 is an outcrop of the Tiñu Formation exposed along the stream in Arroyo Totoyac, and situated approximately 15 km east-northeast of Nochixtlán. The locality can be reached by descending a long steep trail from the village of San Pedro Cantaros.

USNM 16002 is an outcrop of the Tiñu Formation exposed on a steep south-facing slope about 600 m below the top of a prominent escarpment, and is situated approximately 18 km northeast of Nochixtlán. The locality can be reached by descending a steep trail from the end of an unimproved road that leads toward Santiago Ixtaltepec.

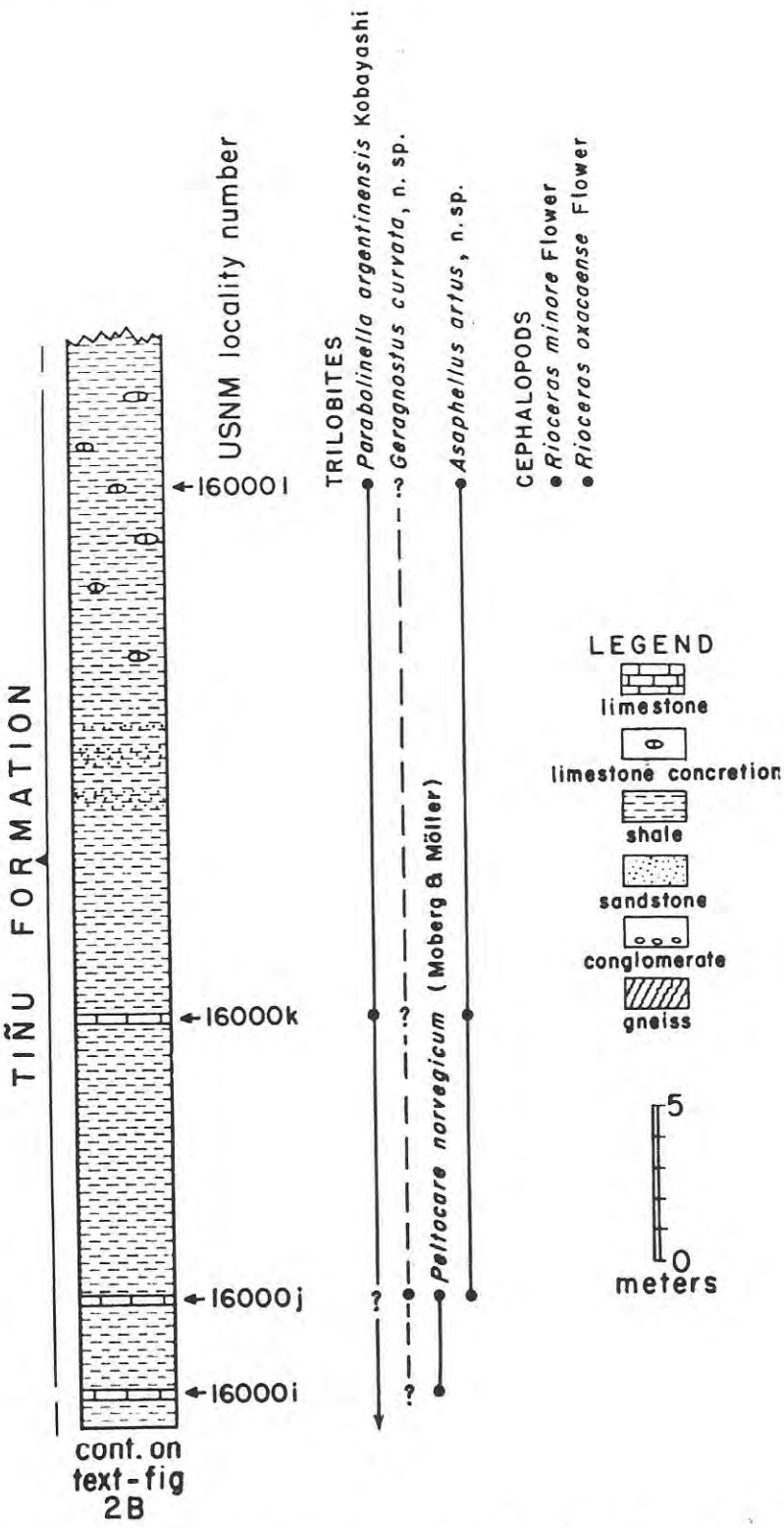
USNM 16004 is the same locality as 16001. The number has been used to identify stratigraphically undifferentiated collections of fossils made by Pantoja-Alor from the lower member of the Tiñu Formation.

Distribution of Faunas

Geographic.—Because of limited areal extent of known outcrops of the Tiñu Formation, little information has been obtained concerning the geographic ranges and facies relationships of its faunas. A comparison of observed faunal occurrences (text-figs. 2–4) indicates that most species from the calcareous lower member occur in more than one section, and the member exhibits a gross faunal uniformity. Much of the shaly upper member appears to have been removed by pre-Mississippian erosion in the Barranca de Santiago Ixtaltepec. Therefore, its sparse fauna mostly is known from collections made at USNM locality 16000 near Tiñu.

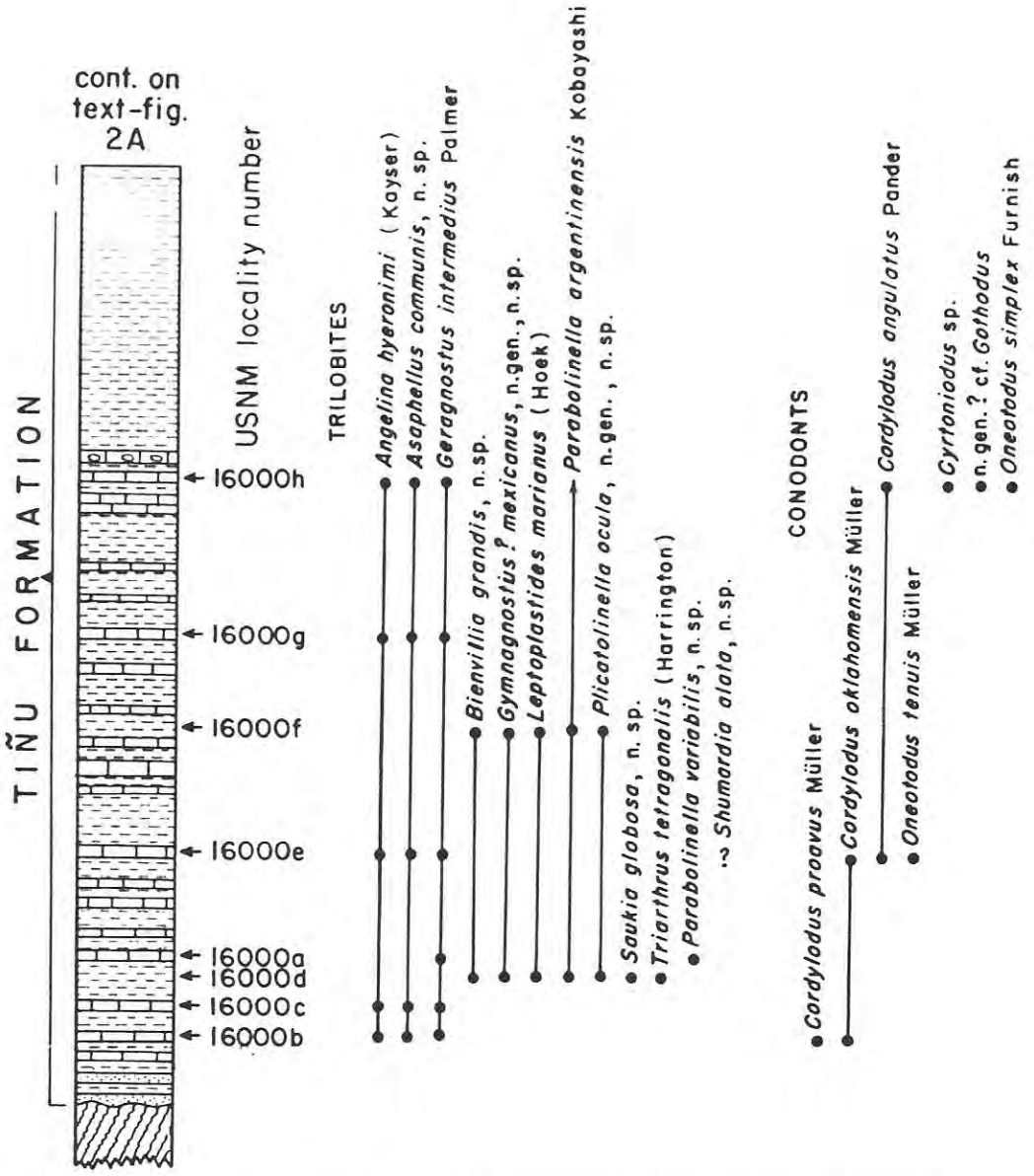
Stratigraphic.—A near discontinuity of trilobite range zones appears to coincide with the lithologic boundary between the lower and upper members of the Tiñu Formation. It is possible that the faunal change may be related to evolution in place, but the coincidence with a lithologic change also may indicate faunal displacement related to shifting environments. If the latter event occurred, the faunal discontinuity may be of little value for biostratigraphic zonation. Therefore, the establishment of formal biostratigraphic units is postponed pending the possible discovery of fossiliferous rocks of comparable age in nearby regions. For convenience in the meantime, the lower group of species will be referred to as the *Parabolina* assemblage, and the upper group will be referred to as the *Peltocare* assemblage.

Mode of occurrence suggests that trilobites of the *Parabolina* assemblage were adapted to a variety of shifting environments, and that many



TEXT-FIG. 2A—Section of the upper trilobite-bearing part of the Tiñu Formation near the village of Tiñu with occurrences (dots) and ranges (lines) of identified species of trilobites and cephalopods. Doubtful taxonomic identification is indicated by question mark. See text-figure 1 for location of section.

species were ecologically restricted to particular lithotopes. This is indicated by the somewhat cyclic repetition of limestone and shale beds in the lower member, and the fact that at least 25 species of trilobites occur in the *Parabolina* assemblage, but rarely do more than 4 or 5 species occur together in a single bed. Furthermore, the associations of species in contiguous beds commonly are mutually exclusive, but may be repeated in other beds of similar lithology. For example limestone beds in the section near Tiñu (text-fig. 2B) usually contain only *Angelina hyeronimi*, *Asaphellus communis*, and *Geragnostus intermedius*. Interbedded shale usually is



TEXT-FIG. 2B—Section of the lower part of the Tiñu Formation near the village of Tiñu with occurrences (dots) and ranges (lines) of identified species of trilobites and conodonts. Doubtful taxonomic identification is indicated by question mark. See text-figure 1 for location of section and text-figure 2A for legend.

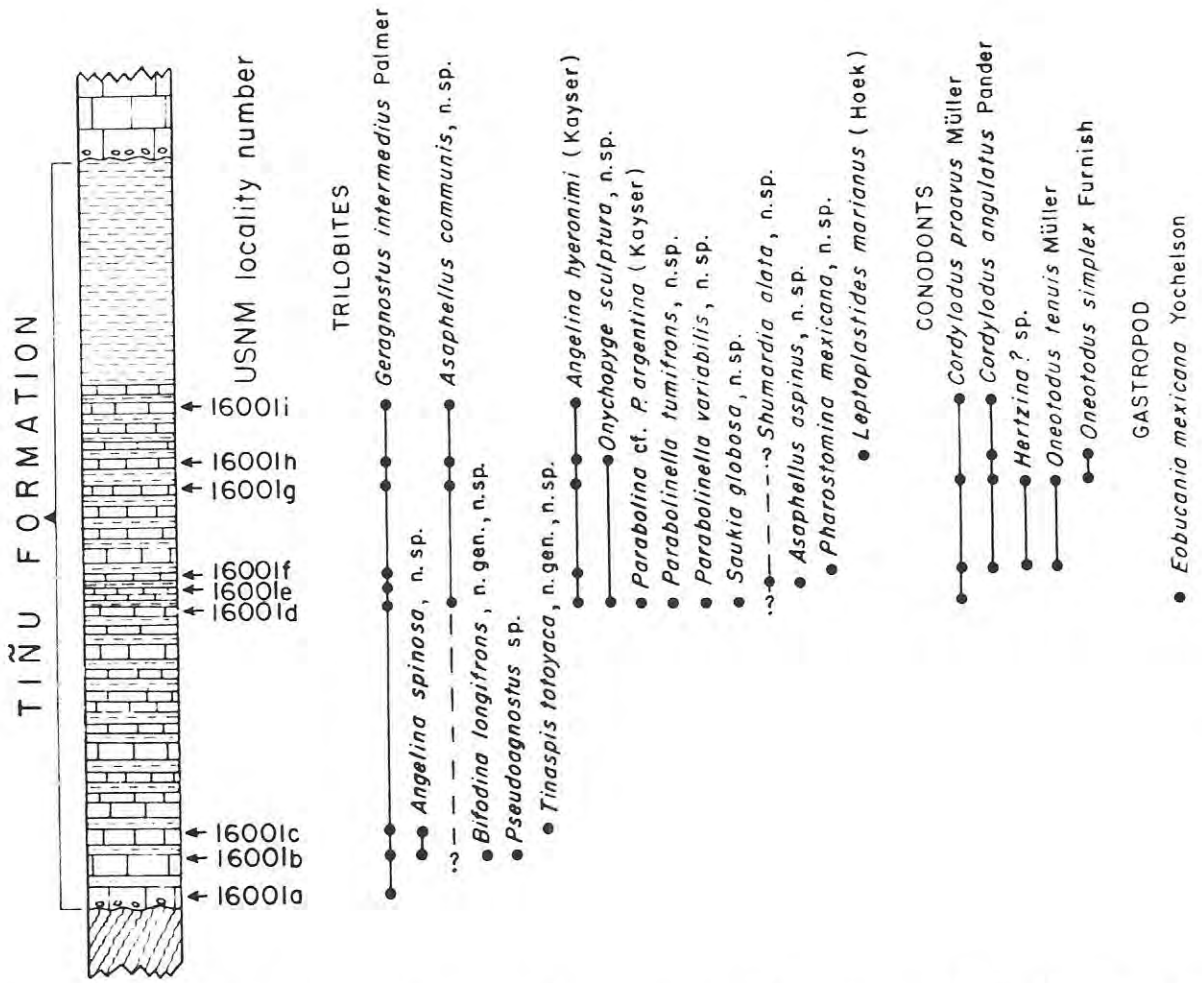
unfossiliferous, but at least two beds were observed to contain distinctive associations of *Bienvillia grandis*, *Gymnagnostus? mexicanus*, *Leptoplastides marianus*, *Parabolinella argentinensis*, and *Plicatolinella ocula*. In all sections, *Angelina* and *Asaphellus* may occur as coquinas, and if other species are present, they generally are represented by a minor number of specimens. In other instances, some species are represented by abundant specimens, but both the individual species and the entire association of species have been observed in only one bed (e.g., text-fig. 4, collection 16002b).

Comparison of the *Parabolina* assemblage from different sections indicates that a few species and even some genera occur in a homotaxial sequence. For example, *Angelina spinosa* and *Bifodina longifrons* only occur in the basal part of the lower member. *Parabolinella variabilis* and *Saukia globosa* occur in the middle part, and *Asaphellus aspinus* and *Onychopyge sculptura* occur in the middle and upper parts. Some of these taxa could prove to be useful biostratigraphic indices if similar sequences are discovered elsewhere.

Trilobites of the *Peltocare* assemblage are known only from the lower 40 meters of the shaly upper member of the Tiñu Formation. Occurrences are not sufficient to warrant further subdivision. The observed stratigraphic distribution of species is shown by text-figures 2A and 4.

Age and Correlation of Faunas

All of the trilobites known from the Tiñu Formation in the Nochixtlán region are Tremadocian in age. Evidence for that conclusion is the



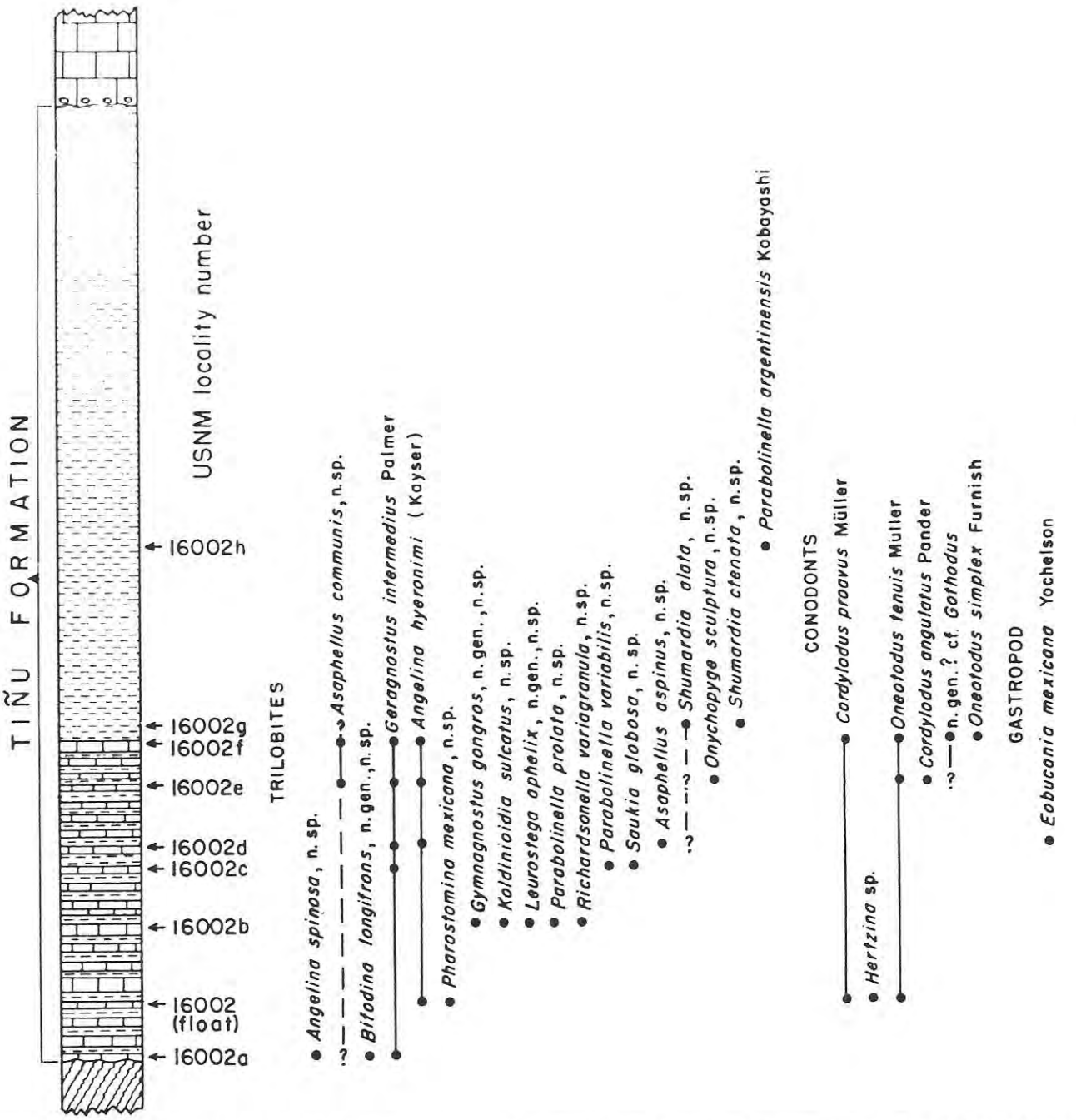
TEXT-FIG. 3—Section of the Tiñu Formation at Arroyo Totoyac with occurrences (dots) and ranges (lines) of identified species of trilobites, conodonts, and one gastropod. Doubtful taxonomic identification is indicated by question mark. See text-figure 1 for location of section and text-figure 2A for legend.

strong taxonomic similarity with faunas of Tremadocian age previously described from Europe and South America (table 1). The greatest similarity is with faunas from Argentina, followed successively by faunas from Great Britain, eastern Canada, and Scandinavia. If new genera from Mexico are ignored, 75 percent of the trilobite genera from the Tiñu Formation have been reported from Argentina, 63 percent from Great Britain, 56 percent from eastern Canada, and 44 percent from Scandinavia. Probably less than 20 percent of the trilobite genera from the Tiñu Formation have been reported from rocks either younger or older than the Tremadocian.

The occurrences of distinctive condonts and echinoderms also indicate a Tremadocian age for the Tiñu faunas. *Cordylodus angulatus* occurs in collections from all three sections of the lower member of the Tiñu, and according to Lindström (1960, p. 89), it is one of the characteristic condont species in the Tremadocian of Sweden. Echinoderm columnals and thecal plates that belong to *Macrocystella* occur with trilobites in several collections from the Tiñu Formation, and according to Christopher Paul (1967, oral report), *Macrocystella* previously has been reported only from Tremadocian rocks in Europe.

Further comparison of faunas indicates that the composition of the *Parabolina* assemblage from the lower member of the Tiñu Formation is closest to faunas of early Tremadocian age in South America and Europe. Of particular significance is the occurrence of *Onychopyge*, which has been reported only from the early Tremadocian, and *Parabolina*, a cosmopolitan genus that has not been reported from rocks younger than early Tremadocian. The sparse fauna of the *Peltocare* assemblage in the lower 40 meters of the upper member of the Tiñu is correlated with less confidence. Nevertheless, a late Tremadocian age is suggested by the occurrence of *Peltocare norvegicum*, which is a distinctive olenid trilobite previously reported only from the late Tremadocian of Norway, Sweden, and Argentina.

Systemic age assignment of the Tiñu faunas is complicated because of a dichotomy of opinion concerning placement of the Tremadocian



TEXT-FIG. 4—Section of the Tiñu Formation near Santiago Ixtaltepec with occurrences (dots) and ranges (lines) of identified species of trilobites, conodonts, and one gastropod. Doubtful taxonomic identification is indicated by question mark. See text-figure 1 for location of section and text-figure 2A for legend.

Stage. Some geologists, mostly British, assign the Tremadocian to the Cambrian, whereas others assign it to the Ordovician. Persuasive arguments have been presented by advocates of each opinion (e.g., Whittington & Williams, 1964; Skevington, 1966), but the problem is unresolved.

Correlation of faunas from most of North America with those of the Tremadocian of Europe has been difficult because of the existence of largely exclusive faunal provinces. As a result, the Cambrian-Ordovician boundary in North America, by common agreement, has been placed at the boundary between the *Saukia* and *Symphysurina* trilobite assemblage zones. In recent years the position of the upper Tremadocian boundary in relation to the North American section has been fairly well established, but little evidence has been discovered concerning the lower boundary. Data from graptolite and trilobite occurrences have been summarized by Whittington (1966, p. 700–705), who concluded that trilobite zones A–F of Ross (1951) and Hintze (1952) from the Lower Ordovician of the western United States are approximately late Tremadocian in age. A similar conclusion also

TABLE 1—Part of known geographic distribution of trilobite genera that occur in the Tiñu Formation. Sources of data are: (1) Harrington & Leanza, 1957; (2) Wilson, 1954, 1956; Winston & Nicholls, 1967; (3) miscellaneous; (4) Rasetti, 1944, 1954; Hutchinson, 1952; (5) Raw, 1908; Stubblefield & Bulman, 1927; Lake, 1906–1946; (6) Henningsmoen, 1959; Tjernvik, 1956; and (7) Sdzuy, 1955.

Trilobite genera from Tremadocian of Mexico	Argentina (1)	Texas (2)	Nevada (3)	Eastern Canada (4)	Great Britain (5)	Norway & Sweden (6)	Germany (7)
Angelina	X			?*	X		
Asaphellus	X			X	X		
Bienvillia	X*		X	X	X*	X	
Bifodina, n. gen.							
Geragnostus	X	X	X	?*	X*	X	X
Gymnagnostus, n. gen.							
Koldinioidia							
Leptoplastides	X*				X		
Leurostega, n. gen.							
Onychopyge	X						
Parabolina	X			X	X	X	X
Parabolinella	X	X	X	X	X	X	X
Peltocare	X*			X*	X*	X	
Pharostomina	X*						X
Plicatolinella, n. gen.							
Pseudagnostus	?*	X	X	X			
Richardsonella		X	X	X			
Saukia		X	X				
Shumardia	X	X		X	X	X	X
Tinaspis, n. gen.							
Triarthrus	X			X	X	X	X

* Different generic name used by author(s) cited, but here considered to be a synonym.

was reached by Lochman-Balk & Wilson (1967, p. 900), who correlated zones A thru lower G with the Tremadocian. In regard to the lower Tremadocian boundary, however, Whittington (1966, p. 700) concluded that

> no correlation is as yet possible between beds regarded as highest Cambrian in North America and the latest Cambrian of Britain and Balto-Scandia . . . Thus the limits of the Tremadoc, and especially the position of the base, in North America, cannot yet be placed precisely with reference to faunal zones.

The association of faunal elements in the Tiñu Formation provides new data that have a bearing on the correlation of North American faunas with those of the Tremadocian of Europe, and of particular significance are data concerning the lower Tremadocian. As mentioned previously, the *Parabolina* trilobite assemblage is early Tremadocian in age, has considerable similarity to European and South American faunas, and contains most of the trilobite species known from the Tiñu Formation. The assemblage has remarkably little similarity to North American faunas, but a few genera that are in common with North American faunas appear to be important for correlation. For example, *Saukia* is the index genus for the *Saukia* Zone, which has been considered to be the highest Cambrian zone in North America. *Saukia* is common throughout much of North America and eastern Asia, but has not been reported to range stratigraphically beyond the zone that bears its name. Also present are *Richardsonella*, another widespread genus previously known only from the *Saukia* Zone of North America, and *Pseudagnostus*, which is a cosmopolitan genus that appears in the early Late Cambrian and is not known to range higher than the *Saukia* Zone in North America or the lower Tremadocian elsewhere. Whittington (1966, p. 701) has pointed out that a number of writers have suggested the correlation of the *Saukia* Zone with the lower Tremadocian of Europe, but such a correlation has been based mainly on stratigraphic position rather than faunal similarity. The Tiñu fauna now provides faunal support for that correlation.

Conodonts from the Tiñu Formation have been identified by D. L. Clark (1967, unpublished report), and observed occurrences and ranges are shown on text-figures 2-4. According to Clark, *Hertzina* and *Oneotodus tenuis* previously have been reported only from Cambrian rocks, and *Oneotodus simplex* is a common species with worldwide distribution in the Lower Ordovician (Tremadocian). Based on unpublished study of conodonts from Utah, he also notes that *Cordylodus oklahomensis* and *C. proavus* range from the upper *Saukia* Zone in the upper Notch Peak Formation to the lower part of the *Symphysurina* Zone in the base of the House Limestone. Comparison of these occur-

rences with the associated trilobites and conodonts in the Tiñu Formation suggests that the *Parabolina–Peltocare* boundary in southern Mexico approximately correlates with the *Saukia–Symphysurina* boundary in the United States. It also suggests that the Cambrian–Ordovician boundary as traditionally defined in most of North America approximately correlates with the lower-upper boundary of the Tremadocian in Europe. An important implication of these conclusions is that the Cambrian–Ordovician boundary as traditionally defined in North America will not correlate with the Cambrian–Ordovician boundary in the type region of Wales regardless of ultimate stability at either the bottom or top of the Tremadocian as has been proposed.

Two new species of the cephalopod *Rioceras* occur in a limestone concretion that was collected 60 meters above the base of the Tiñu Formation (text-fig. 2A) and are described by R. H. Flower in an accompanying paper in this number of the *Journal of Paleontology*. According to Flower, *Rioceras* is known from the upper D and E Zones of Ross (1951) and Hintze (1952) in the Lower Ordovician of the United States. These cephalopods are associated with the highest known trilobites in the Tiñu Formation. Therefore, if the top of Zone F or the middle of Zone G correlates with the top of the Tremadocian, at least some of the Tiñu strata above 60 meters probably is latest Tremadocian in age.

SYSTEMATIC DESCRIPTIONS

Phylum ARTHROPODA Siebold & Stannius, 1845
Class TRILOBITA Walch, 1771
Order AGNOSTIDA Kobayashi, 1935
Family GERAGNOSTIDAE Howell, 1935
Genus GERAGNOSTUS Howell, 1935

Remarks.—*Homagnostus* and *Geragnostus* are segments of a phyletic complex that underwent gradual morphologic change during the Late Cambrian and Early Ordovician. Representatives of both genera usually have well developed axial and border furrows, a bilobed glabella, a tumid and sagittally tripartite pygidial axis with the anterior segment transversely tripartite and confluent pleural fields. Commonly, representatives of *Homagnostus* have an incomplete preglabellar median furrow, a pygidial axis that extends nearly to the posterior border furrow, and a posterior axial lobe that equals or exceeds the anterior pygidial axis in width. On the other hand, representatives of *Geragnostus* generally lack a vestige of a preglabellar median furrow and the axial lobe is shorter and tapers posteriorly. Loss of the preglabellar median furrow appears to have occurred gradually through time, and the presence or absence of a faint vestige of the furrow may be variable within temporally intermediate populations. Also, the posterior expansion or taper of the pygidial axis is variable within temporally intermediate populations. Such variation, as within *Geragnostus intermedius* Palmer, causes generic assignment to be arbitrary.

GERAGNOSTUS CURVATA, n. sp.
Pl. 97, figs. 11–14

Diagnosis.—Cephalon semicircular to sagittally elongate. Glabella approximately two-thirds length of cephalon; outlined by moderately deep axial furrow. Transglabellar furrow faint externally, but moderately well developed on internal mold; curved forward at distal ends. Basal lobes short and moderately to well defined. Genae appear smooth, but may have fine granules on internal mold. Border furrow wide and moderately deep. Border narrow.

Anterior thoracic segment unknown.

Posterior thoracic segment has tripartite axis about two-thirds width of segment. Median axial lobe-trapezoidal; lateral axial lobes narrower and tear-shaped. Anterior pleural bands about one-fourth width of posterior pleural bands.

Pygidium strongly convex. Axis elongate, tumid, well defined, and slightly constricted at second segment. Anterior lateral furrows isolate lateral lobes. Second axial segment has large median tubercle that does not displace posterior transverse axial furrow. Posterior axial lobe about 1.4 times combined length of anterior two segments. Pleural fields narrow in postaxial region. Border moderately wide, well defined, and has pair of short posterolateral spines.

Discussion.—*G. curvata*, n. sp., is characterized by a faint transglabellar furrow that curves forward at its distal ends. On exfoliated molds the transglabellar furrow is moderately deep. The pygidium is characterized by a tumid axis that extends almost to the posterior border furrow and posterolateral border spines that originate at points on a line with the posterior end of the axis.

G. curvata resembles a number of species of *Geragnostus*, but differs from all in important details. It differs from *G. intermedius* Palmer from lower in the Tiñu Formation by having a faint and distally forward directed transglabellar furrow. It has a more tumid pygidial axis than *G. callaveiformis* Harrington and Leanza, and the posterolateral border spines are opposite rather than forward from the end of the axis. The pygidium of *G. curvata* resembles that of *G. crassus* Tjernvik, but lacks the wide cephalic border furrow of that species.

Occurrence.—About 10 cephala and pygidia

and one posterior thoracic segment are in collection 16000j. A few poorly preserved specimens in collections 16000i, k, and l are questionably assigned to the species.

Holotype.—Cephalon illustrated on pl. 97, fig. 12, USNM 158875.

GERAGNOSTUS INTERMEDIUS Palmer
Pl. 97, figs. 1–10

Geragnostus intermedius PALMER, 1968, p. 24, pl. 12, figs. 1,2.

Diagnosis.—Cephalon ranges in outline from subquadrate to subcircular. Glabella bilobed, approximately two-thirds length of cephalon, slightly to moderately tapered toward anterior, evenly rounded anteriorly and posteriorly. Posterior glabellar lobe has faint node situated at approximate midpoint and very faint median keel on posterior slope. Basal lobes short and well defined. Faint vestige of preglabellar median furrow may be visible in oblique light. Genae smooth. Posterior borders expanded into pair of stubby broad-based spinules.

Thorax unknown.

Pygidium strongly convex. Axis tumid, well defined, and broadly rounded posteriorly. Anterior lateral furrows isolate lateral lobes of anterior axial segment and do not connect across middle of axis. Second axial segment may be slightly constricted, has large median tubercle that extends to, and may slightly displace posterior transverse axial furrow. Posterior axial lobe exceeds total of anterior two segments in sagittal length, may or may not exceed posterior segment in transverse width, and has faint terminal node just in front of posterior axial furrow. Pleural fields confluent and not much wider than border in plan view. Border relatively wide and has pair of stubby posterolateral spines.

Discussion.—Specimens from Mexico exhibit morphologic features that are transitional between those of typical representatives of *Homagnostus* and *Geragnostus*. They agree in all respects and are considered to be conspecific with *Geragnostus intermedius* Palmer from Alaska.

Abundant specimens are present in collections from Mexico and provide information concerning population variation. Most cephala lack a vestige of a preglabellar median furrow and most pygidia have a slight posterior taper to the axis, which are features typical of *Geragnostus*. Within the same collection, however, a transitional sequence of specimens may have end members that show a faint vestige of a preglabellar median furrow on the cphalon or a posteriorly expanded axis on the pygidium, which is typical of *Homagnostus*. Also, minor variation in cephalic outline, taper of the glabella, and width/length ratio of the pygidium can be observed, but consistent trends could not be distinguished in either growth series or stratigraphic series. The species is retained in *Geragnostus* because the overall morphologic aspect is more typical of that genus.

The stratigraphic sequence in Mexico is limited, but in Alaska (Palmer, 1968) the species occurs in a stratigraphically intermediate position between species of *Homagnostus* and more typical species of *Geragnostus*.

Geragnostus intermedius may be conspecific with agnostids from Montana that Lochman (1964, p. 464) assigned to *Geragnostus mundus* (Raymond). The original description of *Agnostus mundus* Raymond (1925, p. 14) is based on one poorly illustrated cephalon from British Columbia that obviously was misidentified by Raymond as a pygidium. With information available, even the generic identification of Raymond's specimen is questionable, and without knowledge from topotype material the further assignment of specimens to Raymond's taxon here is considered to be untenable.

G. intermedius also resembles *G. bisectus* (Matthew), *G. hoeki* Kobayashi, *G. tilcuyensis* (Kayser), and *G. vilonii* Harrington & Leanza, but differs consistently in details. It differs from *G. bisectus* by having a tapered glabella, narrower pleural fields, and a wider pygidial border. It differs from *G. hoeki* and *G. tilcuyensis* by the presence of pygidial spines, and from *G. vilonii* by having a tapered glabella, a more tumid pygidial axis, and a pygidial tubercle that does not extend across the posterior transverse axial furrow.

Occurrence.—*G. intermedius* occurs in more collections than any other species of trilobite dealt with during the present study. It is rare to abundant in collections 16000a–c, e, g, h; 16001a–i; and 16002a, c–f.

Genus GYMNAGNOSTUS, nov.

Type species.—*Gymnagnostus gongros* Robison & Pantoja-Alor, n. sp.

Diagnosis.—Cephalon of holaspides nearly featureless except for faint median glabellar node, partial outline of basal lobes, shallow border furrow, and narrow border. Meraspid cephala may possess shallow subparallel axial furrows that may extend forward as far as front of posterior glabellar lobe.

Thorax unknown.

Pygidium of intermediate and old holaspides nearly featureless except for median axial node, medium to shallow border furrow, and border of moderate width. Meraspides and young holaspides may exhibit faint to moderately well developed axial furrow and slightly tapered axis

with length about two-thirds that of pygidium.

Discussion. The disappearance of axial features is a common evolutionary trend in many lineages of agnostid trilobites. Convergent end members have smooth, relatively featureless exoskeletons, and may be difficult to differentiate. Species of smooth agnostid trilobites previously known from strata of Tremadocian or slightly older age usually have been assigned to one of the following genera: *Ciceragnostus*, *Gallagnostus*, *Leiagnostus*, *Litagnostus*, or *Phalacroma*. Smooth agnostid trilobites of Tremadocian age now are known from Mexico, but for reasons that follow, they are assigned to a new genus.

Authors such as Howell (1935, 1959), Kobayashi (1937), and Harrington & Leanza (1943, 1957) have assigned species of smooth agnostid trilobites of Tremadocian age to one or more of the genera *Ciceragnostus*, *Gallagnostus*, and *Phalacroma*. The generic assignment of all such agnostids is questioned after consideration of the following points: 1) the type species of these three genera all are of Middle Cambrian age; 2) neither an agnostid genus that displays well developed axial furrows, nor any non-agnostid trilobite genus is known to range from the Middle Cambrian to the Tremadocian. In fact, few trilobite genera range across the Middle–Late Cambrian boundary. 3) Taxonomists generally have considered characteristics of the axial region to be of major taxonomic significance in the generic classification of trilobites. 4) Little or nothing is known of the axial characteristics of the described species. 5) Morphologic features used to distinguish the various groups of smooth agnostids (e.g., marginal outline, general convexity, width of borders, presence or absence of spines, etc.) are of a nature more commonly used for differentiation of species rather than genera. Therefore, based on rates of evolutionary change indicated by other agnostid trilobites, and in the absence of criteria other than a smooth exoskeleton, it seems unlikely that *Ciceragnostus*, *Gallagnostus*, and *Phalacroma* ranged into the Tremadocian, and the previous assignment of species of smooth agnostid trilobites of Tremadocian age to these genera here is considered to be unjustified. Furthermore, without more information than has been published, most of these Tremadocian species are considered to be generically indeterminate.

Leiagnostus was proposed by Jaekel (1909, p. 401) and was defined by the following brief definition (translation): "Head and tail unmarked, head oval arched, tail with flat border." A new species, *L. erraticus*, was designated as the type and was based on one specimen from a glacial erratic that Jaekel interpreted as an apparent derivative from the "Echinospharitenkalk" of Ordovician age. A separate description of the species was not given by Jaekel and the lone specimen was illustrated (*idem*, fig. 22) only by a generalized line drawing. To our knowledge, *L. erraticus* has not been described subsequently or illustrated by photos.

Since 1909, *Leiagnostus* has become an all too convenient generic designation for several species of smooth agnostid trilobites of Ordovician age from Europe and South America. Little attention has been given to possible phyletic relationships, and a generic concept has not been formulated that is significantly different from those of some other smooth genera of agnostid trilobites (compare for example, Howell, 1959, p. 172–186). In view of these circumstances, continued assignment of species to *Leiagnostus* is considered to be meaningless until more is known of the type species.

Litagnostus was established by Rasetti (1944, p. 234, 235) for smooth agnostids of Late Cambrian age in Quebec. Based on the study of additional material from Nevada, Palmer (1955, p. 92) concluded that *Litagnostus* has close affinities to *Pseudagnostus*. Paratypes of *L. levisensis*, type species of *Litagnostus*, in collections of the U. S. National Museum have no apparent axial furrows. Nevertheless, the consistent occurrence of a small terminal node adjacent to the posterior border furrow indicates that internal axial structures extended to the posterior border furrow. This evidence further supports Palmer's conclusion, and *Litagnostus* here is considered to include a branch of smooth agnostids that probably descended from *Pseudagnostus*. To date, *Litagnostus* has been recognized only in the late Late Cambrian of North America.

Smooth agnostid trilobites occur in the Tiñu Formation of southern Mexico, but fortunately juvenile specimens of at least one species indicate a relationship to the *Homagnostus-Geragnostus-Trinodus* lineage. With the possible exception of the presently unrecognizable genus, *Leiagnostus*, a genus has not been proposed that includes a geragnostid branch with smooth holaspides. Therefore, a new genus, *Gymnagnostus*, is proposed to include such forms. Assignment of *Gymnagnostus* to the Geragnostidae is supported by the striking similarity of morphologic detail shown by late meraspid pygidia of *Gymnagnostus gongros*, n. sp. (pl. 97, fig. 28), *Homagnostus tumidosus* (Palmer, 1955, pl. 20, fig. 1), and *Trinodus elspethi* (Hunt, 1967, pl. 22, figs. 11,12). Comparative morphology and stratigraphic occurrence appear to limit the possible direct ancestry of *Gymnagnostus* to either *Homagnostus* or *Geragnostus*.

Present knowledge indicates that only two

groups of agnostid trilobites, geragnostids and pseudagnostids, range into the Tremadocian, and the pseudagnostids are relatively rare. Representatives of these groups can easily be distinguished by obvious differences in configuration of the pygidial axis in all known stages of growth (cf. Palmer, 1955, pl. 20). Pseudagnostids are characterized by an inflated pseudolobe that extends to the posterior border furrow, whereas geragnostids have a parallel-sided to slightly tapered axis that terminates well in front of the posterior border furrow. Therefore, if the axial configuration can be distinguished on any growth stage of a smooth holaspid agnostid of Tremadocian age, it is possible to assign specimens with a geragnostid axis to *Gymnagnostus* and those with a pseudagnostid axis to *Litagnostus*.

The possibility is recognized that *Gymnagnostus* and *Litagnostus*, as here conceived, may be polyphyletic if multiple branches evolved from each major geragnostid and pseudagnostid stock. Because of inherent inadequacy of the paleontological record, however, and because of the masking of differences due to convergent evolution, differentiation of such phyletic branches probably will not be possible even if they exist.

Because of the rareness of pseudagnostids of Tremadocian age, most agnostid species of Tremadocian age that have been assigned to *Ciceragnostus*, *Gallagnostus*, *Leiagnostus*, and *Phalacroma* probably are congeneric with *Gymnagnostus*, but without additional information *G. gongros* is the only species that definitely can be assigned to the genus at this time.

GYMNAGNOSTUS GONGROS, n. sp.
Pl. 97, figs. 24–33

Description.—Cephalon nearly featureless; length and width remains approximately equa

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EXPLANATION OF PLATE 97

FIGS. *1–10—Geragnostus intermedius* Palmer. *1,2*, Side and dorsal views of cephalon, USNM 158866; *3,4*, cephala that show morphologic variation, USNM 158867 and 158868; *5*, nearly exfoliated internal mold of cephalon, USNM 158869; *6,7*, side and dorsal views of pygidium, USNM 158870; *8,9*, pygidia that show variation in axial shape, USNM 158871 and 158872; *10*, young holaspid pygidium, USNM 158873. All ×10; *3* and *5* from 16001b, *10* from 16001d, and all others from 16002f.

11–14—Geragnostus curvata, n. sp. *11*, Posterior thoracic segment, USNM 158874; *12*, holotype cephalon, USNM 158875; *13*, cephalon, USNM 158876; *14*, partly exfoliated and broken pygidium, USNM 158877. All ×6 and all from 16000j.

15,16,19–22—Gymnagnostus? mexicanus, n. gen., n. sp. *15,16*, Cephala, ×10, USNM 158878 and 158879 from 16000f; *19,20*, meraspid cephala with faint axial furrows, ×15, USNM 158880 and 158881 from 16000d; *21*, partly crushed pygidium, ×7, USNM 158882 from 16000f; *22*, holotype pygidium, ×5½, USNM 158883 from 16000d.

17,18—Pseudagnostus sp. Partly exfoliated cephalon and pygidium, ×9, USNM 158884 and 158885 from 16001b.

23—Undetermined pseudagnostid. Nearly exfoliated cephalon, ×6, USNM 158886 from 16004.

24–33—Gymnagnostus gongros, n. gen., n. sp. *24–27*, Cephalic growth series from holaspid of moderate size to meraspid with partial axial furrows, ×10, 10, 15, and 20, USNM 158887–158890; *28*, meraspid 1 pygidium, ×20, USNM 158891; *29*, holotype pygidium, ×10, USNM 158892; *30–32*, intermediate-sized pygidia, ×10, 12, and 12, USNM 158893–158895; *33*, small holaspid pygidium with axial furrow and terminal axial node, ×20, USNM 158896. All from 16002b.

EXPLANATION OF PLATE 98

FIGS. *1–11—Asaphellus aspinus*, n. sp. *1,2*, Cranidia, ×2½ and 4, USNM 158897 and 158898; *3,5*, ventral views of fragmentary pygidia with postaxial boss on doublure, ×2½ and 3, USNM 158899 and 158900; *4,8,11*, pygidia, ×5, 4, and 2, USNM 158901–158903; *6,7*, hypostomata, ×3½ and 4, USNM 158904 and 158905; *9*, holotype librigena, ×2, USNM 158906; *10*, librigena, ×2½, USNM 158907. *2,4,7,10* from 16002d; others from 16001e.

12–22—Asaphellus communis, n. sp. *12*, Cranidium, ×1¼, USNM 158908 from 16004; *13*, librigena, ×2, USNM 158909; *14*, holotype cranidium, ×2, USNM 158910; *15*, ventral view of fragmentary librigena, ×1¼, USNM 158911; *16*, pygidium, ×1¼, USNM 158912 from 16000b; *17*, latex mold of interior cranidial surface showing muscle scars on glabella and caeca on preglabellar field, ×3, USNM 158913 from 16004; *18,19*, hypostoma, ×2½, USNM 158914; *20*, pygidium, ×2, USNM 158915 from 16002e; *21*, exfoliated pygidium showing segmentation of axis and caeca on pleurae, ×1½, USNM 158916; *22*, ventral view of pygidium with Y-shaped ridge pattern on median part of doublure, ×2, USNM 158917. All from 16001h unless otherwise indicated.

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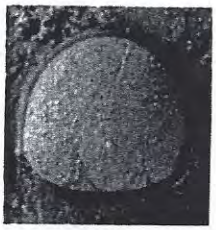
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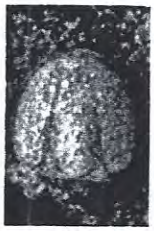
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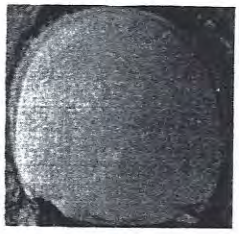
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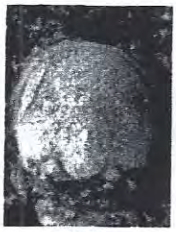
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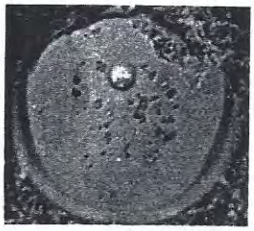
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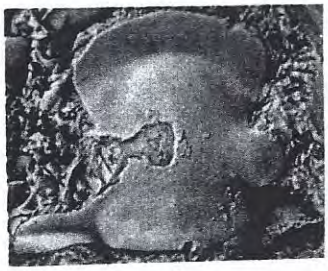
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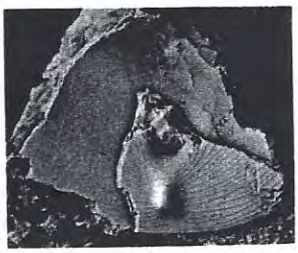
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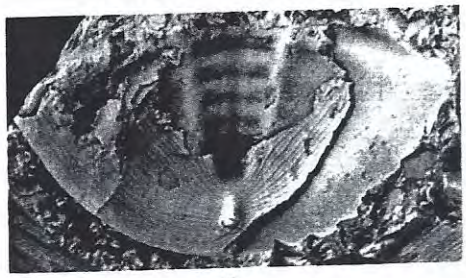
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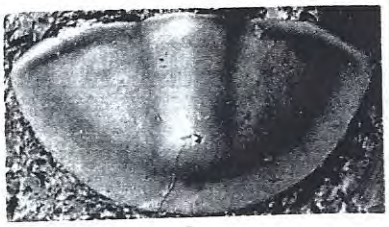
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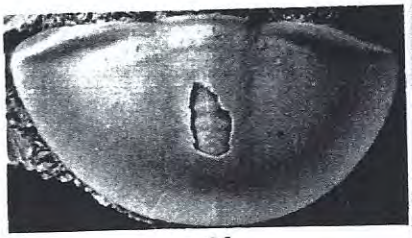
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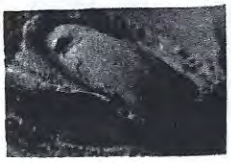
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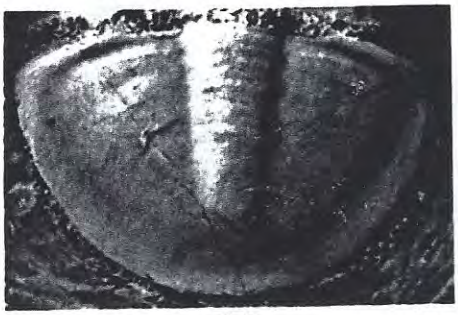
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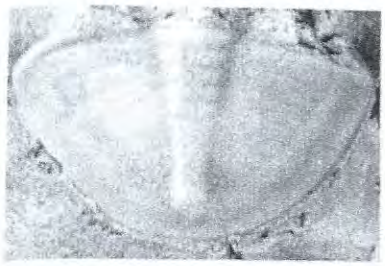
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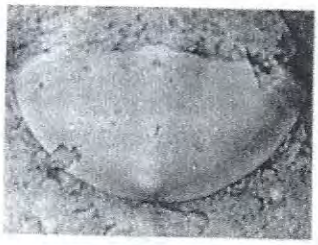
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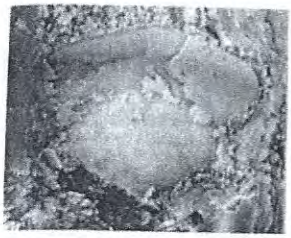
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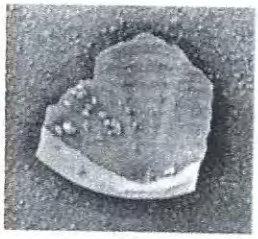
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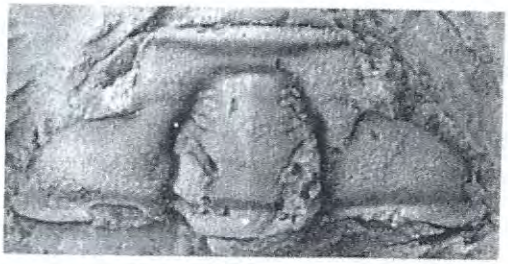
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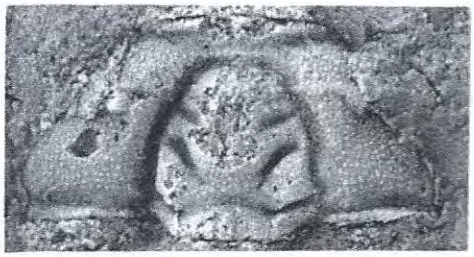
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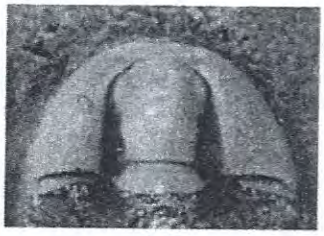
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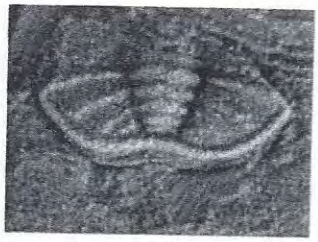
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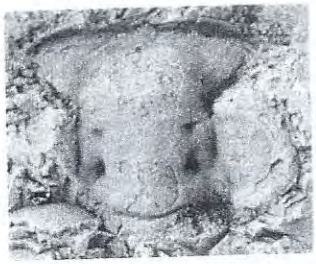
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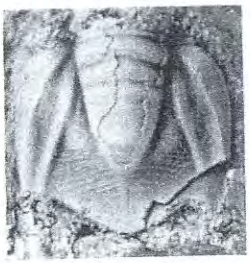
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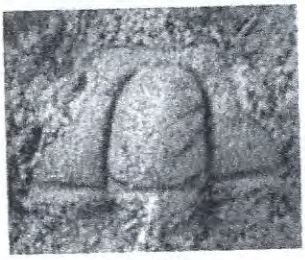
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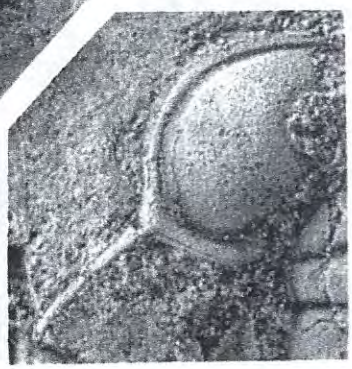
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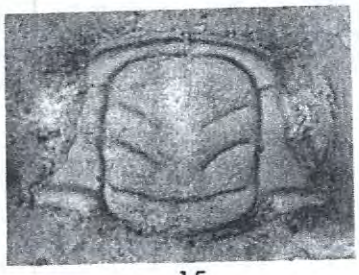
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during meraspid and holaspid stages. Glabellar node very faint, but usually visible in oblique light; situated approximately one-third cephalic length from posterior margin. Border furrow shallow, and border narrow. Posterior parts of axial furrow extend forward from posterior margin for about one-fourth length of cephalon on some meraspids, and is restricted to lateral sides of basal lobes on holaspides. Furrows between basal lobes and glabella disappear between early and late holaspid stages.

Thorax unknown.

Pygidium characterized by large median tubercle, strongly geniculate anterior margin, and border with pair of minute posterolateral spines. Length and width of pygidium approximately equal through early holaspid stage and then width becomes slightly greater than length in middle and late holaspid stages. Meraspides and early holaspides have shallow axial furrow, tapered axial lobe without transverse furrows, and terminal node at end of axis. Terminal node and all but very short anterior sections of axial furrow disappear between early and middle holaspid stages. Border about twice as wide as cephalic border; section between spines becomes relatively narrow on late holaspides.

Exoskeleton perforated with abundant minute punctae.

Discussion.—Of the smooth agnostids described to date, holaspides of *G. gongros*, n. sp., most closely resemble holaspides of *Litagnostus levisensis* Rasetti (1944, p. 235, pl. 36, figs. 5,6). Differences in detail however, indicate that the

Explanation of Plate 99

Figs. *1–6*—*Asaphellus artus*, n. sp. *1*, Holotype exfoliated pygidium, ×3½, USNM 158918 from 16000k; *2*, fragmentary pygidium showing postaxial doublure that is unmarked except for terrace lines, ×4½, USNM 158919; *3*, pygidium, probably large meraspid, ×6, USNM 158920; *4*, librigena, ×3½, USNM 158921; *5*, anterior part of partly exfoliated cranidium, ×2, USNM 158922; *6*, ventral view of fragmentary silicified pygidium showing narrow doublure, ×8, USNM 158923 from 16000j. From 16000l unless otherwise indicated.

7–12—*Pharostomina mexicana*, n. sp. *7*, Internal mold of cranidium with four pairs of lateral glabellar furrows, ×4, USNM 158924; *8*, silicified rostral plate, ×10, USNM 158925; *9*, holotype cranidium, ×5½, USNM 158926; *10*, cranidium, ×8, USNM 158927; *11*, silicified librigena, ×8, USNM 158928 from 16001f; *12*, pygidium, ×8, USNM 158929. All except *11* are from float 2 m above base of Tiñu Formation at 16002.

13–18—*Shumardia alata*, n. sp. *13–16*, Cranidia tentatively assigned to species (15 shows mold of confluent librigenal "band" at right of cranidium), USNM 158930–158933; *17*, holotype pygidium, USNM 158934; *18*, pygidium, USNM 158935. *13* is ×15 and from 16001h; others ×12 and from 16002g.

19,20—*Shumardia ctenata*, n. sp. *19*, Holotype pygidium, USNM 158936; *20*, pygidium, USNM 158937. Both ×15 and from 16002g.

21–24—*Bifodina longifrons*, n. gen., n. sp. *21,22,24*, Fragmentary cranidia, ×4, 3, and 2½, USNM 158938–158940; *23*, holotype cranidium associated with *Angelina spinosa*, n. sp., ×3½ USNM 158941. All from 16001b.

Explanation of Plate 100

Figs. *1–7,10*—*Onychopyge sculptura*, n. sp. *1*, Cranidium, ×4, USNM 158942 from 16002e; *2*, holotype cranidium ×2, USNM 158943; *3*, fragmentary librigena to show genal field, ×2, USNM 158944; *4–6*, fragmentary pygidia, ×2½, 3, and 2½, USNM 158945–158947; *7*, anterior part of cranidium, ×2¼, USNM 158948; *10*, fragmentary librigena to show genal spine, ×1½, USNM 158949. From 16001h unless otherwise indicated.

8,9,11–14—*Leptoplastides marianus* (Hoek). *8,9,11,12*, Cranidia, ×5, 6, 10, and 12, USNM 158950–158953; *13,14*, large and small librigenae tentatively assigned to species, ×3½ and 7, USNM 158954 and 158955. *12* and *13* from 16000f; others from 16000d.

15,17,18—*Triarthrus tetragonalis* (Harrington). *15*, Cranidium, ×2½ USNM 158956; *17*, cranidium (upper left corner), ×1½, USNM 158957; *18*, cranidia, including specimen in fig. *15*, associated with other trilobites, ×1. All from 16000d.

16–18—*Bienvillia grandis*, n. sp. *16*, Holotype cranidium with convexity little affected by compaction of matrix, ×5, USNM 158958 from 16000f; *17*, two cranidia on right side of photo, ×1½, USNM 158959 and 158960 from 16000d; *18*, cranidia associated with other trilobites, ×1 from 16000d.

18—Rock slab with (a) *Bienvillia grandis*, n. sp., (b) *Gymnagnostus? mexicanus*, n. gen., n. sp., (c) *Leptoplastides marianus* (Hoek), (d) *Parabolinella argentinensis* Kobayashi, (e) *Plicatolinella ocula*, n. gen., n. sp., and (f) *Triarthrus tetragonalis* (Harrington), ×1, USNM 158956 from 16000d.

two species are homeomorphs. Type specimens of *L. levisensis* lack axial furrows, but the presence of a terminal node adjacent to the border furrow indicates that internal axial structures extended to the border furrow, whereas the axis of *G. gongros* terminates well in front of the posterior border furrow.

In a redescription of *Geragnostus occitanus*, Dean (1966, p. 276) discussed a large amount of variation in depth and width of the axial furrow on representatives of that species, and concluded that "variation does not appear to be dependent on the stage of development attained, and supposedly immature individuals may show obsolete furrows like those of adults." Similar variation has not been observed among numerous specimens of *G. gongros*. Instead, development of the axial furrow is prominent only on juvenile specimens.

Occurrence.—More than 100 cephala and pygidia occur in collection 16002b.

Holotype.—Pygidium illustrated on pl. 97, fig. 29, USNM 158892.

Gymnagnostus? mexicanus, n. sp.
pl. 97, figs. 15,16,19–22

Description.—Cephalon subcircular, nearly featureless on holaspides; length and width subequal. Basal lobes short (exsag.) and faintly outlined. Glabellar node faint; situated approximately one-third cephalic length from posterior margin. Border furrow shallow, and border narrow. Axial furrow of meraspides moderately well defined at sides of posterior glabellar lobe and faint around anterior lobe.

Thorax unknown.

Pygidium of holaspides nearly featureless; meraspid pygidia unknown. Axial node faint; situated approximately one-fourth pygidial length from anterior margin. Border furrow shallow. Border about twice as wide as cephalic border; lacks spines.

Discussion.—Because the axial structure of the pygidium of this species is unknown, it can only questionably be assigned to *Gymnagnostus*.

G.? mexicanus differs from *G. gongros*, n. sp., by its smaller axial node on the pygidium, lack of border spines, and more constant width of the pygidial border. It also resembles specimens of *Gallagnostus bolivianus* illustrated by Harington and Leanza (1957, figs. 21.2a,b), but differs by having the basal lobes, glabellar node, and axial node of the pygidium better developed.

Occurrence.—More than 25 cephala and pygidia occur in collections 16000d and 16000f.

Holotype.—Pygidium illustrated on pl. 97, fig. 22, USNM 158883.

Family Pseudagnostidae Whitehouse, 1936
Genus Pseudagnostus Jaekel, 1909
Pseudagnostus sp.
Pl. 97, figs. 17,18

Two associated specimens, a cephalon and a pygidium, belong to *Pseudognostus*. Both specimens are nearly exfoliated and are characterized by shallow dorsal furrows on the internal molds. They resemble specimens from the Upper Cambrian of China and North Korea that Kobayshi (1933, p. 97; 135, p. 111) assigned to *Pseudagnostus cyclopygeformis* (Sun). Nevertheless, caution seems to be warranted in the specific identification of the specimens at hand. An interpretation by Bell & Ellinwood (1962, p. 389) suggests that considerable variation in depth of dorsal furrows may occur within a single species group of *Pseudagnostus*. If that interpretation is correct, the number of known specimens from Mexico may not be adequate for meaningful species identification.

Occurrence.—One cephalon and one pygidium in collection 16001b.

Undetermined Pseudagnostid
Pl. 97, fig. 23

A single exfoliated cephalon is characterized by anteriorly expanding sides, relatively angular anterolateral corners, blunt anterior margin, a trisegmented glabella in which the middle segment is bipartite, and a preglabellar median furrow. Based on the morphological characters shown, the specimen appears to be a pseudagnostid, but generic and specific identification is not considered to be warranted at this time.

Occurrence.—Collection 16004 in association with *Angelina hyeronimi* (Kayser), *Geragnostus intermedius* Palmer, *Saukia globosa*, n. sp., and *Shumardia alata?*, n. sp.

Family Asaphidae Burmeister, 1843
Genus Asaphellus Callaway

Asaphellus Callaway, 1877, p. 663, 664; Raymond, 1910, p. 37–39; Reed, 1930, p. 313, 314; Kobayashi, 1934, p. 547–549; 1937, p. 497; Lake, 1942, p. 319–321; Hupé, 1955, p. 218; Jaanusson, 1959, p. 0346; Balashova, 1960, p. 143.

Hemigyraspis Raymond, 1910, p. 41; Hupé, 1955, p. 216.

Type species.—*Asaphis homfrayi* Salter, 1866, p. 165, pl. 24, figs. 6–12.

Diagnosis.—Exoskeleton commonly large; some specimens exceed 10 cm. in length. Cephalon has broad concave border. Glabella broad, elongate, and flattened; sides nearly parallel, anterior bluntly rounded to modernately pointed Median node occurs on posterior part of glabella. Lateral glabellar furrows and occipital furrow not visible. Axial furrow faint to undefined.

Frontal area ranges in sagittal width from about 0.12 to 0.25 that of cranidium. Eyes situated next to axial furrow. Facial suture isoteliform. Librigenae with or without genal spines. Hypostoma has nonforked posterior margin.

Thorax composed of eight segments.

Pygidium semicircular. Axis distinctly narrower than in thorax; long and slightly tapered toward posterior; moderate to poorly defined; segmentation usually not visible externally, but internal mold may show as many as 10 rings. Articulating half ring very narrow (sag.). Pleural regions unfurrowed except for pair of strong anterior pleural furrows. Articulating facets well developed. Border broadly concave and undefined by border furrow.

Discussion.—The generic concept of *Asaphellus* here is modified to include three new species: *A. artus*, *A. aspinus*, and *A. communis*. Because of generalized morphology and the subdued nature of most furrows on species that have been assigned to *Asaphellus*, it is possible that future study may distinguish more than one genus. Based on available knowledge, however, the species now assigned to the genus appear to represent a geographically widespread, but genetically closely related group that commonly is found in rocks of Tremadocian age. To date, species that agree with the present concept of *Asaphellus* have been reported from Great Britian, Bohemia, Russian, Korea, Nova Scotia, Mexico, Bolivia, and Argentina.

Lake (1942, p. 325) has presented evidence to suggest that *Asaphus affinus* McCoy is a synonym of *Asaphellus homfrayi* (Salter). Therefore, because *A. affinus* is the type species of *Hemigyraspis* Raymond (1910, p. 41), *Hemigyraspis* is a junior synonym of *Asaphellus*.

It is noted that Ross (1957, p. 490) assigned a few specimens from the Lower Ordovician "C" Zone of the Deadwood Formation in Montana to *Megalaspis planilimbata* var. *cyclopyge* Harrington. At about the same time, Harrington & Leanza (1957, p. 145) concluded that of the specimens upon which the original description of *M. p. cyclopyge* was based, the fragmentary cranidia probably belonged to *Asaphellus* and the pygidia belonged to *Basiliella carinata* Harrington. They further concluded that *M. p. cyclopyge* is an invalid junior synonym of *B. carinata*. Ross' specimens from Montana lack the characteristic cranidial features of *Basiliella*, but do show great similarity to specimens that have been assigned to *Asaphellus* and here are considered to belong to that genus.

ASAPHELLUS ARTUS, n. sp.
Pl. 99, figs. 1–6

Description.—Cephalon known only from fragmentary cranidia and librigenae. Anterior part of glabella poorly defined. Frontal area concave and intermediate in length between that of *A. aspinus*, n. sp., and *A. communis*, n. sp. Librigenae have broadly concave lateral border furrows that are not confluent with posterior cephalic border furrow. Genal spines broad-based, stout, and of moderate length. Surface of genal spines and outer part of lateral fixigenal borders may have terrace lines.

Hypostoma and thorax unknown.

Pygidium semicircular; length about 0.6 width. Axis slender; tapered at anterior end and nearly parallel-sided at posterior end; anterior end about 0.25 width of pygidium; poorly defined externally, but moderately well defined on exfoliated mold; and has at least 10 rings and long terminal piece. Border vaguely defined by broad shallow border furrow. Doublure narrow for genus; marked with terrace lines; and lacks structures on postaxial surface.

Discussion.—Pygidia described above resemble some of those assigned to *Asaphellus catamarcensis* Kobayashi by Harrington & Leanza (1957, figs. 64.1, 65.4). The anterior margin of associated cranidia, however, is more obtuse than on cranidia of *A. catamarcensis* illustrated by Harrington & Leanza. Unfortunately, the type specimens of *A. catamarcensis*, which are in the collections of the U. S. National Museum, are poorly preserved in a sandstone matrix and preclude adequate evaluation of morphological characteristics. Because of that fact, a new species, *A. artus*, is proposed rather than use a species name that is applied to specifically indeterminate type specimens.

Of the known asaphids from Mexico, *A. artus* most closely resembles *A. communis*, n. sp., but differs from that species by having a shorter frontal area, a less well defined axial furrow, an uneven taper of the pygidial axis, and a much narrower pygidial doublure.

Occurrence.—More than 25 pygidia and a few fragmentary cranidia and librigenae are in collections 16000j–l.

Holotype.—Pygidium illustrated on pl. 99, fig. 1, USNM 158918.

ASAPHELLUS ASPINUS, n. sp.
Pl. 98, figs. 1–11

Description.—Exoskeleton relatively small; based on size of largest observed sclerites, total exoskeletal length probably seldom exceeded 4.0 cm. Cephalon semicircular in outline. Axial furrow undefined. Palpebral lobes almost 0.25 length of cranidium; situated behind cephalic midpoint. Frontal area concave with no distinct border furrow; length about 0.17 that of cranidium. Anterior courses of facial suture diverge

moderately in front of eyes and extend close to anterior margin before turning rather sharply inward across border to meet at cephalic midline. Posterior courses of facial suture sigmoidal before intersection with posterior margin approximately midway across pleural regions of cephalon. Librigenae lack genal spines. Hypostoma characterized by strap-like anterior wings; oval median body with pair of deep lateral furrows that are not connected; broad lateral borders marked with terrace lines; and narrow, adventrally upturned, nonforked posterior border.

Thorax unknown.

Pygidium semicircular; width nearly twice length. Axis faintly differentiated as low convexity between pleural fields; exfoliated specimens exhibit six rings and a long terminal piece on internal molds. Doublure wide, marked with terrace lines, and has large median boss midway between axial terminus and posterior margin.

Except for terrace lines where noted, surface of exoskeleton is smooth.

Discussion.—*A. aspinus* differs from all described species of *Asaphellus* by the lack of genal spines and the presence of a prominent median boss on the pygidial doublure. These differences approach the level at which some taxonomists would establish a new genus. In this instance, however, a close genetic relationship between this and other species assigned to *Asaphellus* appears to be indicated by great similarity in other morphologic features. Therefore, the differences noted are not considered to be sufficient to warrant the exclusion of the species from *Asaphellus*.

Occurrence.—The species is represented only in two collections, 16001e and 16002d, but specimens are so abundant in each that the rock is a coquina with more than 99 percent of the specimens being *A. aspinus*.

Holotype.—Librigenae illustrated on pl. 98, fig. 9, USNM 158906.

Asaphellus communis, n. sp.
Pl. 98, figs. 12–22

Description.—Exoskeleton relatively large; based on size of largest observed sclerites, maximum total length probably exceeded 10.0 cm. Cranidium gently convex. Axial furrow faint. Glabella parallel-sided except for slight constriction between eyes, and strongly rounded to moderately pointed anteriorly. Frontal area abnormally long, about 0.25 length of cranidium, and broadly concave. Anterior border and preglabellar field subequal in length; differentiated by change in slope rather than by furrows. Faint median preglabellar ridge crosses preglabellar field and disappears on posterior part of border. Palpebral areas of fixigenae bulbous in outline. Eyes about 0.20 length of cranidium; situated behind cranidial midpoint. Posterior areas of fixigenae strap-like; transverse width about 0.67 that of glabella. Anterior courses of facial suture arc slightly outward from in front of eyes, round inward at border, meet at midline in broad ogive, and cross doublure as median suture between librigenae. Posterior courses of facial suture sigmoidal. Librigenae have broadly concave lateral border furrows; broad-based, stout genal spines of moderate length; and wide doublures marked with terrace lines. Hypostoma subequal in length and width; has strap-like anterior wings, oval median body with deep lateral furrows and shallow anterior median sulcus, broad lateral borders marked with terrace lines, and a narrow nonforked posterior border.

Thorax unknown.

Pygidium semicircular; length about 0.6 width. Axis long, slender, and slightly tapered; anterior end about 0.25 width of pygidium; moderately well defined; external segmentation usually not visible, but internal molds exhibit as many as 10 rings and a terminal piece. Doublure wide, marked with terrace lines, and has posterior medial Y-shaped pattern of low ridges.

Except for terrace lines where noted, surface of exoskeleton is smooth.

Discussion.—*A. communis* is characterized by its abnormally wide frontal area. It further differs from *A. aspinus*, n. sp., by its larger maximum size, more broadly rounded anterolateral cranidial corners, more acuminate anterior cranidial margin, possession of genal spines, narrower pygidial axis with more segments, and a median ridge rather than a boss on the pygidial doublure. Specimens of comparable size from collections that contain *A. communis* and *A. aspinus* maintain the differences mentioned, which indicates that the two forms are not end members of an ontogenetic series.

Besides a sagittally more elongate frontal area, *A. communis* further differs from *A. homfrayi* (Salter) by its more posterior and larger eyes, and from *A. catamarcensis* Kobayashi by its wider (trans.) frontal area and more evenly tapered pygidial axis. It differs from *A. riojanus* Harrington and Leanza by having wider (exsag.) posterior fixigenal areas and more axial rings on the pygidium.

The median sulcus of the hypostoma probably accommodated the median ridge of the pygidial doublure when the animal was enrolled. Also, the faint median ridge on the preglabellar field and the pointed anterior end of the glabella may be functionally related morphologic features.

Occurrence. Generally common to abundant in collections 16000b, c, e, g, h; 16001d, g–i;

and 16002e, f. Abundant fragments that probably belong to *A. communis* occur in collections 16001b and 16002a and g, but positive identification is not possible.

Holotype. Cranidium illustrated on pl. 98, fig. 14, USNM 158910.

Family CALYMENIDAE Milne-Edwards, 1840

Remarks.—Representatives of the Calymenidae have not been recognized in rocks older than the Tremadocian. Based on comparisons of these forms with trilobites described from older rocks, it here is suggested that *Andrarina pusilla* (Westergard, 1922, p. 121, pl. 2, figs. 8–19) from the Olenid Series of Late Cambrian age in Sweden may be a member of the ancestral calymenid stock. *A. pusilla* differs in several characters from those of other species currently assigned to *Andrarina*. For example, it has a more tapered glabella, nearly parallel preocular facial sutures, differently-shaped occipital ring, and a markedly different pygidium. In comparison, it agrees well in most respects with characteristics of species of *Pharostomina* except for slightly larger eyes and a narrower exsagittal width of the posterior limbs. The species perhaps deserves assignment to a new genus, but that action is beyond the scope of the present study.

Genus PHAROSTOMINA Sdzuy, 1955

Knowledge of representatives of *Pharostomina* from Mexico does not appreciably alter the generic concept of Sdzuy (1955, p. 31), which is followed here. As indicated by Whittington (1959, p. 0453), *Colpocoryphoides* Harrington & Leanza (1957, p. 222) is a junior subjective synonym of *Pharostomina*.

PHAROSTOMINA MEXICANA, n. sp.
Pl. 99, figs. 7–12

Description.—Cranidium marked with abundant granules of moderate size. Glabella well defined by deep axial furrow, moderately convex, semiparabolic in outline, width slightly greater than length, and usually has three pairs of lateral glabellar furrows. S1 deep, convex, strongly oblique backward, almost isolating preoccipital glabellar lobe; S2 shorter, straight, and moderately oblique backward; S3 short, transverse to slightly oblique backward. One internal mold (pl. 99, fig. 7) displays what may be a fourth pair of short lateral glabellar furrows that are oblique forward. Occipital furrow deep, curved forward medially and obliquely forward at lateral ends. Occipital ring wide medially and narrow laterally, and has faint medial node. Preglabellar field very narrow (sag.), but consistently present. Anterior border furrow wide and deep. Anterior border nearly straight, about twice as wide (sag.) as preglabellar field, abruptly upturned, and moderately convex in transverse direction. Anterior and palpebral areas of fixigenae moderately wide; posterior areas transversely and sagittally very wide. Palpebral lobes small; opposite S3. Eye ridges poorly defined. Anterior sections of facial suture straight or slightly convergent from eyes to border furrow and then diagonal across border; posterior sections extend almost straight outward from eyes and then broadly curved backward. Librigenae narrow; borders of moderate width; genal spines short. Rostral plate narrow (trans.); margin adjacent to rostral suture approximately three times as wide as the posterior margin.

Hypostoma and thorax unknown.

Pygidium small, subelliptical, width slightly more than twice length, surface granulate. Axis about two-fifths width of pygidium, tapered posteriorly; has three, or possibly four rings and a terminal piece. Pleural fields triangular in outline; definition of pleural and interpleural furrows not determinate. Margin nonspinose.

Discussion.—*P. mexicana*, n. sp., is characterized by a consistently present, though narrow, preglabellar field, straight anterior border, usually three pairs of well developed lateral glabellar furrows, and surface granules. It differs from *P. trapezoidalis* (Harrington) by its nearly straight rather than concave-inward anterior margin, consistently present preglabellar field, and more anterior eyes. It differs from *P. ferentaria* Sdzuy by having surface granules and a more tapered glabella; and from *P. öpiki* Sdzuy by having at least three rather than two pairs of lateral glabellar furrows.

Occurrence.—More than 15 cranidia, several pygidia and librigenae, and one rostral plate occur in a piece of silty limestone that was collected from float material about 2 m above the base of the Tiñu Formation at locality 16002. One cranidium and one librigenae are present in collection 16001f.

Holotype.—Cranidium illustrated on pl. 99, fig. 9, USNM 158926.

Family CERATOPYGIDAE Linnarsson, 1869
Genus ONYCHOPYGE Harrington

Onychopyge HARRINGTON, 1938, p. 179; HARRINGTON & LEANZA, 1957, p. 187; POULSEN, 1959, p. 0364.
Prionopyge HARRINGTON & LEANZA, 1942, p. 140.

Type species.—*Onychopyge riojana* Harrington, 1938, p. 179, pl. 5, fig. 20.

Diagnosis.—Ceratopygidae characterized by abnormally large palpebral lobes with inner ends adjacent to irregular axial furrow. Glabella subrectangular with small medial node on preoccipital segment; may be slightly expanded or slightly

tapered anteriorly. Lateral glabellar furrows faint to moderately well defined; S1 doubly bifurcate with greatest depth at point of adaxial bifurcation, S2 pit-like and shallower than S1, S3 faint oblique forward. Frontal area concave. Preglabellar field narrow to moderately wide. Anterior border very narrow and abruptly upturned. Occipital furrow moderately deep and curved backward at midline. Occipital ring sagittally broad and of uniform width. Facial sutures opisthoparian; arcuately divergent from eyes to anterior border and marginal anteriorly; strongly divergent posteriorly. Librigenae have spines continuous with well defined lateral borders.

Number of thoracic segments unknown. Tips of segments strongly falcate.

Pygidium semicircular to subparabolic in outline. Axis parallel-sided to strongly tapered, extends into postaxial ridge, and has 5 to 7 rings. Anterior segment has broad pleural furrows and extends posteriorly into prominent pair of spines. Segmentation of remaining pleural fields poorly developed or absent.

Discussion.—Until now the concept of the genus, *Onychopyge*, has been based on poorly preserved specimens from Argentina that included only slightly more than a dozen sclerites (Harrington & Leanza, 1957, p. 187–189). Of that material, only two fragmentary cranidia are present and the remainder are mostly fragmentary pygidia. Similar forms also are rare in collections from Mexico, but the preservation is excellent. Therefore, based on new and better preserved material, the concept of the genus is modified somewhat in the diagnosis given here.

A few differences exhibited by Mexican specimens, such as a slightly tapered instead of slightly expanded glabella and better developed preglabellar field and lateral glabellar furrows, might be used to justify assignment to a new genus. However, because of close similarity of abnormally large palpebral lobes, facial sutures, genal spines, and most features of the pygidium, the Mexican forms here are considered to be congeneric with Argentine forms assigned to *Onychopyge*.

The abnormally large palpebral lobes and distinctive development of the anterior pygidial segment distinguishes *Onychopyge* from all other genera of the Ceratopygidae.

Onychopyge sculptura, n. sp.
Pl. 100, figs. 1–7,10

Description. A prominent Bertillon pattern of raised terrace lines covers much of exoskeleton. Terrace lines on spines and along borders are symmetrical in transverse section and more or less straight, but over much of remaining exoskeleton are irregular and asymmetrical with steepest slope on posterior or abaxial sides, which produces an imbricate aspect. Cranidium has slightly tapered subrectangular glabella. Axial furrow irregular; deep between ends of S1 and S3, shallow anteriorly and posteriorly. Lateral glabellar furrows moderately well developed. Abaxial ends of preoccipital segment isolated by posterolateral branches of S1 to form small elongate (exsag.) secondary lobes. Preglabellar field moderately wide (sag.). Palpebral lobes semicircular; approximately one-half length of glabella. Palpebral furrows shallow, but distinct. Posterior limbs narrow (exsag.) and strap-like. Librigenae have lateral border and doublure that both increase in width toward posterior, but doublure increases at greater rate. Genal spine stout and of moderate length.

Thoracic segments strongly falcate and have pleural furrows that become deep and wide in area of maximum curvature.

Pygidium subparabolic in outline; posterior margin forms slightly obtuse rounded angle at midline. Axis strongly tapered and has 5 or 6 rings and a terminal piece. Anterior segment extends posterolaterally into pair of long spines. Remainder of pleural field lacks both a border and indication of segmentation. Doublure extends inward to axial furrow.

Discussion.—*O. sculptura*, n. sp., is characterized by the peculiar Bertillon pattern of terrace lines that occurs on most parts of the exoskeletal surface. It differs from *O. argentina* Harrington & Leanza and *O. riojana* Harrington, the only other species for which cranidia are known, by having a well developed preglabellar field, a slightly tapered rather than slightly expanded glabella, and perhaps better developed lateral glabellar furrows. The pygidium of *O. sculptura* is similar to that of *O. longispina* Harrington & Leanza, but has a longer and more regularly tapered axis and more angular posterior margin.

Occurrence.—One thoracic segment in 16001d; three cranidia, two librigenae, two thoracic segments, and six pygidia in 16001h; and one cranidium in 16002e. All are fragmentary.

Holotype.—Cranidium illustrated on pl. 100, fig. 2, USNM 158943.

Family Leiostegiidae Bradley, 1925
Genus Tinaspis, nov.

Type species.—*Tinaspis totoyaca* Robison & Pantoja-Alor, n. sp.

Diagnosis.—Exoskeleton gonatoparian and probably subisopygous.

Cephalon has low profile. Glabella subrectangular, tapered slightly toward front or may be slightly constricted in area between anterior ends of palpebral lobes; transverse furrows absent. Axial and occipital furrows broad and very shal-

low. Preglabellar field absent. Anterior cranidial border narrow, sharply upturned, and marked with transverse terrace lines on front slope. Palpebral areas of fixigenae about 0.5 maximum width of glabella. Palpebral lobes poorly defined; situated opposite cranidial midpoint; length about 0.3 that of cranidium. Posterior areas of fixigenae slender (exsag.), approximately same width (trans.) as occipital ring, and reflexed forward at distal ends. Preocular facial suture convergent convex forward to margin at points midway across anterior fixigenae, marginal in between; postocular sutures strongly divergent and sinuous, intersect posterior margins near genal angles. Librigenae lack genal spines. Lateral border widens markedly toward posterior; is differentiated by very shallow, broad border furrow.

Hypostoma and thorax unknown.

Pygidium semicircular with geniculate anterior pleural margins. Axis at anterior end slightly narrower than pleural fields; moderately tapered; segmentation faintly visible only on anterior part of young holaspides and absent on old holaspides. Axial furrow moderately well developed anteriorly and disappears posteriorly. Pleural fields strongly convex near outer margins; smooth in old holaspides except for pair of faint anterior pleural furrows. Border absent. Margin nonspinose.

Discussion.—The elongate conico-truncate glabella, lack of preglabellar field, moderately wide fixigenae, and general pygidial proportions of *Tinaspis*, n. gen., suggest affinities with asiatic member of the Leiostegiidae such as *Chuangia*. Nevertheless, *Tinaspis* differs from typical representatives of *Chuangia* by its shallower axial furrow, narrower anterior cranidial border furrow, lack of genal spines, longer pygidial axis, and strongly convex rather than moderately concave postaxial area.

Tinaspis also resembles *Illaenurus* of the Illaenuridae by possession of an unfurrowed glabella that extends to the anterior cranidial border furrow, narrow rim-like anterior border with transverse terrace lines on front slope, slender posterior fixigenal areas that curve forward at distal ends, lack of genal spines, and semicircular pygidium. Major differences are the better development of axial and cephalic border furrows, slightly tapered glabella, much wider fixigenae, and relatively longer pygidium on *Tinaspis*.

The total morphological aspect of *Tinaspis* suggests a closer affinity to the leiostegiids than to the illaenurids, and for that reason the genus is assigned to the family Leiostegiidae. The combination of characters shown by *Tinaspis*, however, may indicate a closer phyletic relationship between the Leiostegiidae and Illaenuridae than previously has been considered.

Tinaspis totoyaca, n. sp.
Pl. 101, figs. 16–24

Description. Because *Tinaspis* presently is monotypic, characteristics of this species are the same as those given in the generic diagnosis.

Occurrence. Five cranidia, four pygidia, and one librigena occur in collection 16001c.

Holotype. Cranidium illustrated on pl. 101, figs. 20,24, USNM 158980.

Family Olenidae Burmeister, 1843
Subfamily Oleninae Burmeister, 1843
Genus Angelina Salter, 1859

Remarks.—With one minor exception, Henningsmoen's (1957, p. 155, 156) diagnosis of *Angelina* is followed here. His diagnosis is modified to include species without pygidial border spines, as well as those with spines. The diagnostic restriction apparently was an oversight because his list of included species contains *A. steinmanni* (=*A. hyeronimi*) that has a nonspinose pygidial border.

Many trilobite genera consistently either possess or lack pygidial border spines. In the olenidae, however, the occurrence of pygidial spines is greatly variable, and several olenid genera in addition to *Angelina* include species both with and without pygidial spines.

Henningsmoen (1957, p. 156) considered the phyletic relationships of *Angelina* to be uncertain, but suggested that the genus possibly was closest to *Parabolina* or perhaps *Parabolinites*. Based on morphologic comparisons and stratigraphic occurrences of Mexican trilobites, it is suggested here that *Angelina* may be most closely related to *Parabolinella*. A similar suggestion was made long ago by Brögger (1898, p. 198).

Angelina hyeronimi (Kayser)
Pl. 101, figs. 1–7

Arionellus hyeronimi Kayser, 1876, p. 7, pl. 1, fig. 5.
Angelina hyeronimi (Kayser) Harrington & Leanza, 1957, p. 99–101, fig. 35 (for synonomy to date).
Angelina steinmanni (Kayser) Henningsmoen, 1957, p. 157.

Diagnosis.—Cranidium subtrapezoidal in outline. Glabella proportionately large, subquadrate, and usually well defined by slightly convergent axial furrows. One or two pairs of oblique lateral glabellar furrows may be faintly visible. Occipital furrow straight in middle half and may be either bifurcate or curved obliquely forward at lateral ends. Frontal area moderately downsloping; anterior border set off from preglabellar field by line of irregularly spaced tiny pits that may be straight or bowed slightly to

anterior or posterior. Palpebral area of fixigenae narrow with eyes situated only slightly anterior from cranidial midpoint. Preocular sections of facial suture parallel or slightly divergent, curved inward at position of border pits, and diagonal across anterior border to midline of cephalon; postocular sections nearly straight. Librigenae have long broad-based genal spines in direct continuation with lateral border. Lateral border furrow faint posteriorly and absent anteriorly. Rostrum and median suture absent, and doublures of librigenae are confluent.

Thorax, where known from South American specimens, has 15 segments.

Pygidium transversely elongate; width approximately three times length. Axis has one or two rings and a terminal piece. Margin nonspinose.

Exoskeleton moderately thick and usually smooth, but may be marked with either abundant tiny granules or minute perforations.

Discussion.—Numerous specimens from Mexico agree in practically all details with the description of *A. hyeronimi* by Harrington & Leanza (1957, p. 99–101), which was based on numerous specimens from Argentina and Bolivia. Mexican specimens generally have slightly more divergent preocular facial sutures than do most South American specimens, but this minor difference is not considered to be of specific significance.

A. steinmanni, as well as other South American species of *Angelina*, were considered by Harrington & Leanza (1957, p. 100–101) to be synonyms of *A. hyeronimi*. At about the same time, Henningsmoen (1957, p. 57) considered *A. steinmanni* to be a valid species. The conclusion of Harrington & Leanza is followed here.

Comparison of lengthy descriptions by Harrington & Leanza (1957, p. 99, 100 and 109) of *Angelina hyeronimi* and *Parabolinella coelatifrons* shows the wording to be almost identical, and close similarity of specimens is indicated by accompanying illustrations, but the two species

EXPLANATION OF PLATE 101

FIGS. *1–7*—*Angelina hyeronimi* Kayser. *1*, Cranidium, ×2, USNM 158961 from 16004; *2*, cranidium, ×4, USNM 158962 from 16001d; *3*, pathologic librigena on which genal spine has been destroyed and wound has healed, ×3½, USNM 158963 from 16002f; *4*, cranidium, ×3½, USNM 158964 from 16002e; *5*, pygidium, ×6, USNM 158965 from 16002f; *6*, pygidium, ×5, USNM 158966 from 16001h; *7*, librigena, ×3, USNM 158967 from 16002f.

8–15—*Angelina spinosa*, n. sp. *8*, Holotype cranidium, ×3½, USNM 158968; *9,10*, cranidia, both ×4½, USNM 158969 and 158970; *11*, pygidium, ×6, USNM 158971; *12*, hypostoma, ×4, USNM 158972; *13,14*, small cranidia, ×6 and 7, USNM 158973 and 158974; *15*, librigena, ×3, USNM 158975. *9,10*, and *12* from 16001b; others from 16001c.

16–24—*Tinaspis totoyaca*, n. gen., n. sp. *16*, Librigena, ×6, USNM 158976; *17,21*, dorsal and side views of fragmentary cranidium, ×6, USNM 158977; *18*, pathologic cranidium (note healed gash on palpebral area of right fixigena), ×5, USNM 158978; *19,22*, dorsal and side views of pygidium, ×5, USNM 158979; *20,24*, front and dorsal views of holotype cranidium, ×6, USNM 158980; *23*, pygidium, ×10, USNM 158981. All from 16001c.

25,26—*Parabolina* cf. *P. argentina* (Kayser). Cranidia, ×5 and 8, USNM 158982 and 158983 from 16001d.

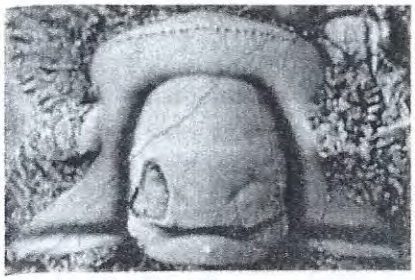
EXPLANATION OF PLATE 102

FIGS. *1,2,4,5,7,8*—*Parabolinella argentinensis* Kobayashi. *1*, Cranidium, ×2, USNM 158984 from 16002h; *2,4,5*, cranidia, ×2½, 5½, and 9, USNM 158985–158987 from 16000d; *7*, librigena, ×1½, USNM 158988 from 16000d; *8*, pygidium tentatively assigned to species, ×2½, USNM 158989 from 16000d.

3,6,9—*Parabolinella prolata*, n. sp. *3*, Two cranidia, one on right is holotype, ×9, USNM 158990; *6*, cranidium, ×9, USNM 158991; *9*, librigena, ×6, USNM 158992. All from 16002b.

10–16—*Parabolinella tumifrons*, n. sp. *10,13,16*, Exfoliated cranidia, ×6, 7, and 7, USNM 158993–158995 from 16001d; *11,15*, dorsal and oblique views of holotype cranidium, ×5, USNM 158996 from 16004; *12*, cranidium, ×6, USNM 158997 from 16001d; *14*, librigena, ×6, USNM 158998 from 16001d.

17–21—*Parabolinella variabilis*, n. sp. *17*, Pygidium, ×6, USNM 158999; *18*, partly exfoliated cranidium, ×7, USNM 159000; *19*, partly exfoliated holotype cranidium, ×3, USNM 159001; *20*, exfoliated cranidium, ×3½, USNM 159002; *21*, fragmentary librigena, ×4, USNM 159003; *18* from 16001d, others from 16002c.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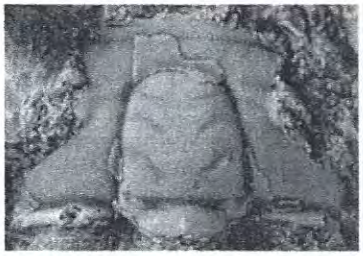
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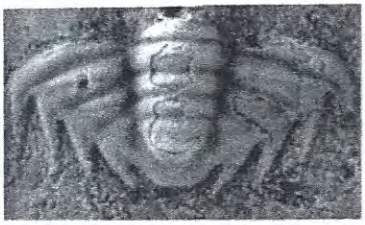
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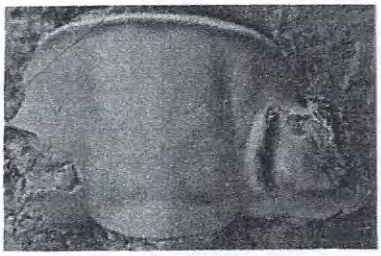
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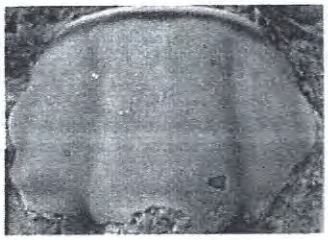
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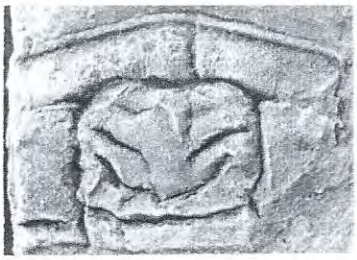
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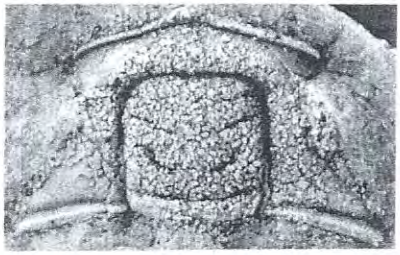
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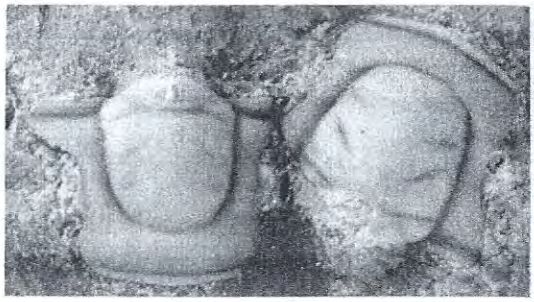
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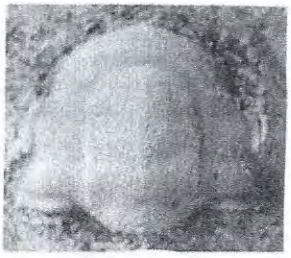

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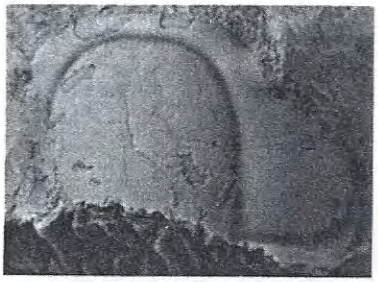

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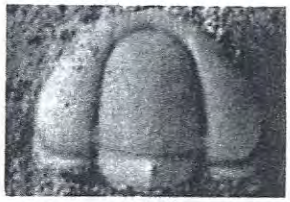

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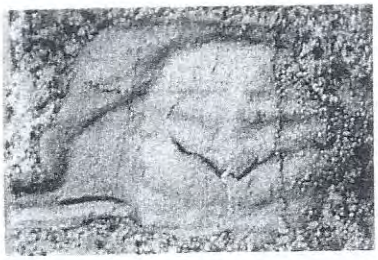
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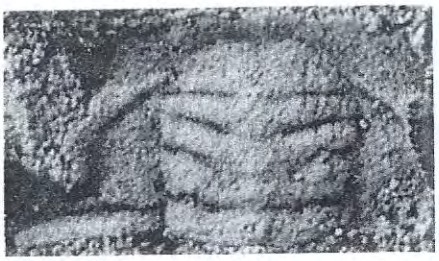
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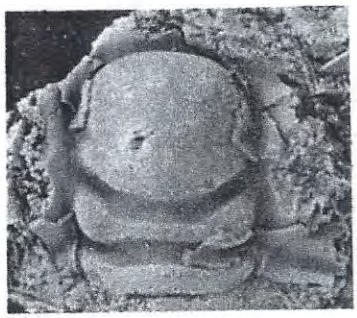
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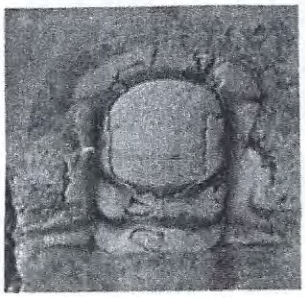
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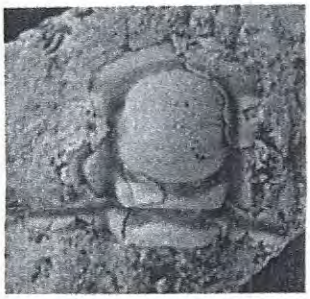
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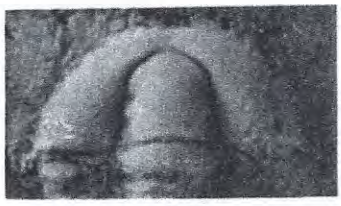
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were not compared. It is suggested here that *P. coelatifrons* should be reassigned to *Angelina*, and that it may even be conspecific with *A. hyeronimi*.

Occurrence. More than 100 specimens, represented only by disarticulated sclerites, are known from collections 16000b, c, e, g, h; 16001d, f–i; and 16002d–f. The species also has been reported from Argentina and Bolivia.

ANGELINA SPINOSA, n. sp.
Pl. 101, figs. 8–15

Description.—Cephalon known only from disarticulated sclerites. Glabella subconical with bluntly rounded anterior end. Three pairs of shallow lateral glabellar furrows usually are present; S1 convex or bifurcate oblique backwards with bifurcation usually visible only on internal mold; S2 convex to geniculate oblique backwards; and S3 straight oblique backwards, but usually visible only on internal mold. Occipital furrow straight in middle half and bifurcate distally. Occipital ring broad in middle half and has small medial node. Frontal area approximately 0.25 length of cranidium, moderately to gently downsloping; crescentic and convex anterior border is set off from preglabellar field by distinct but shallow border furrow. Line of tiny pits usually is present in border furrow. Palpebral area of fixigenae narrow. Palpebral lobes of medium size for olenid; situated opposite lateral ends of S2 and anterior from glabellar midpoint. Eye ridges faint or absent; extended, when present, from axial furrow opposite lateral ends of S3. Preocular sections of facial suture moderately divergent, curved sharply inward at border furrow, and diagonal across anterior border to midline of cephalon; postocular sections divergent sinuous. Librigenae have broad-based long genal spines in direct continuation with lateral border. Lateral and posterior border furrows well developed and confluent at slightly acute angle. Hypostoma elongate with narrow shallow furrow that separates convex oval median body from moderately wide (sag.) posterior border; lateral and posterior margins sharply upturned.

Thorax unknown.

Pygidium subtriangular in outline; width approximately twice length. Axis slightly tapered posteriorly; maximum width about 0.7 that of pleural fields; and has four rings and short blunt

EXPLANATION OF PLATE 103

FIGS. *1–13*—*Leurostega aphelix*, n. gen., n. sp. *1,10*, Dorsal and side views of holotype cranidium, ×3, USNM 159004; *7–9,4,3,2* cephalic growth series (note gradual disappearance of granules and furrows, and decrease in relative size of palpebral lobes), ×13, 11, 7½, 6, 6, and 4½, USNM 159005–159011; *5,6*, librigenae, ×6 and 4, USNM 159012 and 159013; *11–13*, pygidia (associated with *Koldinioidia sulcatus*, n. sp., on *13*), ×3, 5½, and 5½, USNM 159014–159016. All from 16002b.

14–23—*Peltocare norvegicum* (Moberg & Möller). *14,20*, Librigenae, ×3 and 9, USNM 159017 and 159018; *15–18*, holaspid cranidia of various sizes, ×6, 4½, 4, and 5, USNM 159019–159022; *19*, meraspid cranidium, ×14, USNM 159023; *21–23*, pygidia, ×4, 5, 7, USNM 159024–159026. All from 16000i.

24–26—*Plicatolinella ocula*, n. gen., n. sp. *24*, Two small, probably holaspid cranidia, ×8, USNM 159027 from 16000d; *25*, meraspid cranidium, ×10, USNM 159028 from 16000f; *26*, two holaspid cranidia of intermediate size, ×5, USNM 159029 from 16000f.

EXPLANATION OF PLATE 104

FIGS. *1–4*—*Plicatolinella ocula*, n. gen., n. sp. *1*, Holotype cranidium, ×4, USNM 159030 from 16000f; *2*, cranidium, ×8, USNM 159031 from 16000d; *3*, cranidium, ×7½, USNM 159032 from 16000f; *4*, fragmentary pygidium, ×4, USNM 159033 from 16000f.

5–11—*Richardsonella variagranula*, n. sp. *5*, Part of pygidium, ×4, USNM 159034; *6*, latex cast of pygidium, ×8, USNM 159035; *7*, holotype cranidium, ×2¼, USNM 159036; *8,9*, cranidia (note decrease in number of granules with increase in size), ×3 and 4, USNM 159037 and 159038; *10*, pathologic librigena (note tumor-like structure on genal field and incomplete genal spine with secondary spinule), ×1½, USNM 159039; *11*, librigena, ×3, USNM 159040. All from 16002b.

12–19—*Saukia globosa*, n. sp. *12,17*, Cranidia, both ×2½, USNM 159041 and 159042 from 16004; *13*, exfoliated holotype cranidium, ×2½, USNM 159043 from 16002c; *14*, librigena, ×2½, USNM 159044 from 16001d; *15,19*, pygidia, ×4 and 2, USNM 159045 and 159046 from 16004; *16,18*, cranidia, ×2½, and 7, USNM 159047 and 159048 from 16001d.

20–23—*Koldinioidia sulcatus*, n. sp. *20*, Holotype cranidium, ×12, USNM 159049; *21,22*, cranidia, ×12, USNM 159050 and 159051; *23*, cranidium, ×20, USNM 159052. All from 16002b.

terminal piece. Pleural fields triangular; marked with three to four broad shallow pleural furrows and two to three faint interpleural furrows. Posterior margin has four pairs of short inwardly directed spines.

Exoskeleton relatively thin; commonly has abundant tiny perforations, and the internal mold of old holaspid cranidia are marked with scattered coarse granules.

Discussion.—*A. spinosa* differs from all described species of *Angelina* by having better developed lateral glabellar furrows. It further differs from *A. sedgwicki* Salter, type species of the genus, by having a broadly curved anterior cranidial border furrow, four instead of three axial rings on the pygidium, and four instead of two pairs of pygidial spines. *A. spinosa* most notably differs from *A. hyeronimi* (Kayser) by having a less quadrate glabella, a convex rather than flat anterior cranidial border, more sinuous postocular facial sutures, and a spinose rather than nonspinose pygidium.

Occurrence.—16001b and 16001c each contain more than 25 cranidia along with other associated parts, and 16002a has one cranidium and one pygidium.

Holotype.—Cranidium illustrated on pl. 101, fig. 8, USNM 158968.

Genus Bienvillia Clark, 1924

The generic diagnosis of Henningsmoen (1957, p. 142) is followed here.

Bienvillia grandis, n. sp.
Pl. 100, figs. 16–18

Description.—Cranidium ranges up to 25 mm in length. Glabella usually parallel sided or slightly tapered anteriorly, but sides may bow slightly outward; anterolateral corners well rounded; anterior end moderately to bluntly rounded. S1 bigeniculate oblique backwards; S2 straight or convex oblique backwards and slightly shallower than S1; S3 faint or absent. Occipital ring of nearly uniform width and has small medial node. Frontal area approximately same length (sag.) as occipital ring. Pits not apparent in border furrow of most specimens, but become well developed in some large holaspides. Anterior margin slightly to moderately bowed forward. Palpebral lobes range from 0.16 to 0.25 length of cranidium; situated opposite or slightly anterior from cranidial midpoint. Posterior fixigenae about three-fourths width (trans.) of occipital ring. Facial sutures slightly to moderately divergent in front of eyes.

Discussion.—Only cranidia definitely are known for *B. grandis*, n. sp., and a few represent some of the largest known olenid trilobites. The species is characterized by the combination of well rounded anteriolateral glabellar corners, bigeniculate S1 furrows, medially situated eyes, narrow preglabellar field, rounded anterior margin, and wide posterior fixigenae. Small holaspid cranidia display morphological characteristics similar to those of large holaspid cranidia and thereby eliminate the possibility that definitive characters of the species are related to size.

B. grandis appears to be most similar to *B. shinetonensis* (Lake), but differs from that species by having a less quadrate glabella, more posteriorly situated eyes, and wider posterior fixigenae. It differs from the type species of *Bienvillia*, *B. corax* (Billings), by having a narrower preglabellar field, more posteriorly situated eyes, and wider posterior fixigenae. For further comparison of *B. grandis*, see the discussion of *Triarthrus tetragonalis* (Harrington) in this paper.

Occurrence.—Several cranidia are preserved in a siltstone matrix in collections 16000d and f.

Holotype.—Cranidium illustrated on pl. 100, fig. 16, USNM 158958.

Genus Parabolina Salter, 1849

Parabolina cf. P. argentina (Kayser)
Pl. 101, figs. 25,26

Olenus argentinus Kayser, 1876, p. 6, pl. 1, figs. 1–3.
Parabolina argentina (Kayser) Harrington & Leanza, 1957, p. 81–85, figs. 25,26; Henningsmoen, 1957, p. 116, 117 (for synonomies to date); Frederickson, 1958, p. 541–543, pl. 80.

Remarks.—Three cranidia have characteristics of *P. argentina* as redescribed by Harrington & Leanza (1957, p. 81–85). They have a tapered glabella with S1 and S2 each faintly connected across the glabella, an occipital furrow that terminates just before reaching the axial furrow, a short frontal area, and eyes situated opposite the cranidial midpoint.

Complete specimens described by Harrington & Leanza from Argentina have 12 thoracic segments with macropleural spines on the 8th segment and a long axial spine on the 12th segment. The pygidium, contrary to the diagnosis of Henningsmoen (1957, p. 117), has three pairs of border spines. Until the thorax and pygidium of the Mexican form are known, its identity with *P. argentina* is open to question.

Occurrence.—Three cranidia occur in collection 16001d. In addition to the occurrence of these questionable specimens, *P. argentina* has been reported from Argentina and Bolivia (Harrington & Leanza, 1957), Venezuela (Frederickson, 1958), and Newfoundland (Richardson, 1948).

Genus Parabolinella Brögger

Parabolinella Brögger, 1882, p. 102; Kobayashi, 1938, p. 185, 186 (synonony to date); Shaw, 1951,

p. 101, 102; HENNINGSMOEN, 1957, p. 132 134 POULSEN, 1959, p. 0267; BALASHOVA, 1960, p. 111.
Moxomia WALCOTT, 1924, p. 59; 1925, p. 107; HENNINGSMOEN, 1957, p. 160; POULSEN, 1959, p. 0267.

Type species. *Parabolinella limitis* Brögger (part), 1882, p. 102 104, pl. 3, figs. 2,2a,2b (not figs. 4,4a). Type designated by Bassler, 1915, p. 943.

Diagnosis. Exoskeleton opisthoparian and micropygous.

Cephalon semicircular. Glabella ranges in outline from subrectangular to quadrate and may be slightly tapered or expanded toward front. Lateral furrows not connected across glabella; S1 usually bifurcate oblique backwards and prominent; S2 convex or straight oblique backwards, almost as deep as S1; S3 faint or absent, transverse when present. Preglabellar field well developed. Border furrow commonly pitted. Anterior border narrow and convex. Palpebral lobes situated opposite or anterior from cephalic midpoint. Facial sutures slightly convergent to moderately divergent and generally straight in front of eyes, divergent and commonly straight behind eyes. Librigenae have long genal spines that usually continue course of lateral border.

Thorax has up to 21 segments.

Pygidium alate; width commonly about three times length. Axis has one to three rings and blunt terminal piece. Margin lacks spines.

Discussion.—Henningsmoen (1957, p. 132–142) discussed the morphology, occurrences, and inferred phylogeny of species of *Parabolinella* known at the time of his study. The discovery of three new species of *Parabolinella* in Mexico now requires slight modification of the generic concept.

The general features of *Parabolinella tumifrons*, n. sp., are similar to those of specimens from Nevada and British Columbia that Walcott (1924, p. 59; 1925, p. 107) assigned to *Moxomia*. Harrington & Leanza (1957, p. 105, 107) discussed the characteristics of *Moxomia* and concluded the differences between its type species and the type species of *Parabolinella* are no greater than differences observed between other accepted species of *Parabolinella*. Therefore, they considered *Moxomia* to be a synonym of *Parabolinella*. Variation between species of *Parabolinella* in Mexico also support the suppression of *Moxomia*.

PARABOLINELLA ARGENTINENSIS Kobayashi
Pl. 102, figs. 1,2,4,5,7,8

Parabolinella argentinensis KOBAYASHI, 1936a, p. 88, pl. 15, figs. 1–5; HENNINGSMOEN, 1957, p. 134 (for synonomy to date); HARRINGTON & LEANZA, 1957, p. 103–105, figs. 36,37.

Diagnosis.—Cephalon characterized by relatively large quadrate glabella with two or three pairs of transverse furrows. S1 deepest and bifurcate oblique backwards; S2 nearly as deep as S1, straight, and oblique backwards; S3 faint or absent, transverse when present. Frontal area from 0.25 to 0.33 length of cranidium; preglabellar field moderately convex to tumid; anterior border narrow, commonly angular at midline. Palpebral lobes anterior from cranidial midpoint. Facial sutures straight and moderately divergent in front of eyes; divergent straight behind eyes. Librigenae have long genal spines that continue curvature of lateral border.

Thorax has 19 segments.

Pygidium has axis with one or two rings and a terminal piece.

See Harrington & Leanza (1957, p. 103–105) for detailed description.

Discussion.—Only disarticulated cranidia, librigenae, and questionable pygidia are known from Mexico. They fit well within the range of illustrated variability shown by specimens from Argentina (Harrington & Leanza, 1957), including moderate variation in swelling and slope of the preglabellar field.

P. argentinensis has strong similarity to *P. triarthra* (Callaway), but differs by having a maximum of 19 instead of 21 thoracic segments where known and more divergent anterior facial sutures. It is a moot point whether these differences are of specific significance or whether they merely represent intraspecific variation within a single geographically widespread species. *P. argentinensis* here is retained as a separate species because the slight differences appear to be consistent within different geographic realms.

Occurrence.—Five cranidia, two librigenae, and two questionable pygidia in 16000d; one cranidium in 16000f; three cranidia in 16000k; one cranidium in 160001; and two cranidia in 16002h.

PARABOLINELLA PROLATA, n. sp.
Pl. 102, figs. 3,6,9

Description.—Size relatively small; largest observed cranidium four mm in length. Glabella slightly tapered and has rounded anterolateral corners; length approximately equal to maximum width. Transverse glabellar furrows usually poorly developed; S1 sinuous oblique backwards; S2 straight oblique backwards; S3 absent. Occipital furrow bifurcates laterally. Occipital ring has medial node. Frontal area about 0.25 times length of cranidium; preglabellar field relatively long, anterior border furrow not pitted, and anterior cranidial border relatively narrow. Palpebral lobes opposite cranidial midpoint. Facial sutures nearly parallel in front

of eyes and rounded inward just before reaching border; divergent and slightly sinuous behind eyes. Librigenae have narrow lateral and posterior borders that meet at slightly acute angle; genal spines long, slender, and slightly offset from course of lateral border. Surfaces of cranidium and librigenae marked with abundant minute pits.

Thorax and pygidium unknown.

Discussion.—*P. prolata* is characterized by its relatively small size, poorly developed glabellar furrows, relatively long preglabellar field, palpebral lobes situated opposite cranidial midpoint, and narrow cephalic border. The combination of these features distinguishes it from all other species of *Parabolinella*. Furthermore, differences in development of glabellar furrows, width of preglabellar field, and position of palpebral lobes also are apparent when compared with specimens of comparable size from growth series of other species such as *P. tumifrons* and *P. variabilis*.

Occurrence.—More than 25 cranidia and one librigena are known from collection 16002b.

Holotype.—Cranidium illustrated on pl. 102, fig. 3 (specimen on right), USNM 158990.

PARABOLINELLA TUMIFRONS, n. sp.
Pl. 102, figs. 10–16

Description.—Known only from cephalon. Glabella slightly tapered and has rounded anterolateral corners; length usually slightly greater than width, but may be subequal in length and width. S1 usually bigeniculate oblique backwards, but may be bifurcate on internal mold; S2 convex or straight oblique backwards; S3 absent except on internal mold. Occipital furrow bifurcates laterally. Occipital ring has medial node. Frontal area 0.20 to 0.25 length of cranidium. Preglabellar field tumid, steeply inclined, and crossed by irregular transverse terrace lines and faint radial caeca. Anterior border furrow pitted. Anterior border upturned. Palpebral lobes anterior from cranidial midpoint. Facial sutures parallel or slightly convergent in front of eyes, divergent and straight behind eyes. Librigenae have long genal spines and well developed lateral and posterior borders that meet at slightly acute angle.

Discussion.—*P. tumifrons* is characterized by its tumid and steep preglabellar field, tapered and slightly elongate glabella, and the common loss of the posterior branch of the S1 furrows. It most closely resembles specimens that Walcott (1924, p. 59) named *Moxomia hecuba*. Walcott (1925, p. 107) subsequently considered *M. hecuba* to be a synonym of *Crepicephalus* (*Bathyurus?*) *angulatus* Hall & Whitfield (1877, p. 220, pl. 2, fig. 28). The types of *C. angulatus* could not be located in the collections of the U.S. National Museum during the present study, and based on the illustration given by Hall & Whitfield it appears unlikely that *C. angulatus* and *M. hecuba* are cogeneric. Harrington & Leanza (1957, p. 105, 107) have given adequate reasons why *M. hecuba* should be assigned to *Parabolinella* (see also generic discussion of *Parabolinella* in this paper). *P. tumifrons* differs from *P. hecuba* by having a more tapered and more elongate glabella, more anteriorly situated eyes, and generally convergent rather than divergent anterior facial sutures.

A comparison of *P. tumifrons* with *P. variabilis*, n. sp., is given in the discussion of the latter species.

Occurrence.—Common in 16001d and 16004.

Holotype.—Cranidium illustrated on pl. 102, figs. 11 and 15, USNM 158996.

PARABOLINELLA VARIABILIS, n. sp.
Pl. 102, figs. 17–21

Description.—Cephalon characterized by slightly tapered glabella with rounded anterolateral corners. Width of glabella approximately equals length in stratigraphically oldest specimens, but becomes slightly greater than length in younger specimens. S1 bifurcate oblique backwards; S2 convex oblique backwards; S3 transverse and faint or may be absent. Occipital furrow bifurcates laterally. Occipital ring has medial node. Frontal area about 0.25 length of cranidium. Preglabellar field moderately convex, moderately inclined forward, and may have a few transverse terrace lines. Border furrow pitted. Palpebral lobes anterior from cranidial midpoint. Facial sutures parallel or slightly divergent in front of eyes, divergent and straight behind eyes. Librigenae have long genal spines.

Hypostoma and thorax unknown.

Pygidium has one ring and large terminal piece in axis.

Discussion.—*P. variabilis* has a more tapered glabella than *P. argentinensis*. It differs from *P. tumifrons* by having a glabella of either subequal maximum width and length or with maximum width slightly greater than length, a less tumid and less inclined preglabellar field, and generally divergent facial sutures in front of the eyes. A few transitional specimens, however, can not be assigned with confidence to either *P. variabilis* or *P. tumifrons*.

Compared to species reported from outside Mexico, *P. variabilis* perhaps most closely resembles *P.? punctolineata* Kobayashi (1936b, p. 166) from the Yukon Territory of Canada. That species, unfortunately, is known only from one fragmentary cranidium and one fragmentary librigena, which makes any comparison tenuous.

Nevertheless, the preglabellar field of *P. variabilis* lacks the caeca reported on *P.? punctolineata*, and instead may have scattered transverse terrace lines.

Occurrence. Common in 16000a, 16001d, and 16002c.

Holotype. Cranidium illustrated on pl. 102, fig. 19, USNM 159001.

Genus TRIARTHRUS Green, 1832

Remarks. The generic diagnosis of Henningsmoen (1957, p. 147) is followed here, except for a minor modification to include forms with posterior fixigenae that may be slightly wider (trans.) than half the transverse width of the occipital ring. Such modification is proposed in order to include *Parabolinella tetragonalis* Harrington, which Henningsmoen in 1957 (p. 144) reassigned to *Bienvillia*. At about the same time, Harrington & Leanza (1957, p. 113–115) reassigned the same species to *Triarthrus*. The species apparently is transitional morphologically and stratigraphically between typical representatives of *Bienvillia* and *Triarthrus*. Therefore, generic assignment is arbitrary. The overall aspect of *tetragonalis* here is considered to be closer to *Triarthrus* than to *Bienvillia*, and for that reason the generic assignment of Harrington & Leanza is followed.

TRIARTHRUS TETRAGONALIS (Harrington)
Pl. 100, figs. 15,17,18

Parabolinella tetragonalis HARRINGTON, 1938, p. 196, pl. 7, figs. 3,4.
Triarthrus tetragonalis (Harrington) HARRINGTON & LEANZA, 1952, p. 192; 1957, p. 113–115, fig. 42,1–8.
Bienvillia tetragonalis tetragonalis (Harrington) HENNINGSMOEN, 1957, p. 144.
Bienvillia tetragonalis broeggeri HENNINGSMOEN, 1957, p. 145, pl. 8; pl. 11, figs. 1–7.
Parabolinella limitis BRÖGGER (part), 1882, p. 102, pl. 3, fig. 4 (not fig. 2a,b); STØRMER, 1920, p. 9, pl. 1, figs. 7,8.

Diagnosis.—Cephalon characterized by quadrate glabella. S1 and S2 subequal in development; usually straight or convex oblique backwards; normally do not reach axial furrow. Preglabellar field narrow. Palpebral lobes small, close to glabella, and situated slightly forward from cranidial midpoint. Posterior fixigenae 0.5 to 0.6 transverse width of occipital ring. Librigenae narrow with long genal spines. Thorax has 14 segments. Pygidium small and transversely elongate; axis has two or three rings and a terminal piece; posterior margin lacks spines.

For a detailed description of *T. tetragonalis*, see Harrington & Leanza (1957, p. 113–115).

Discussion.—Only cranidia of *T. tetragonalis* have been identified in Mexico. They are associated with cranidia of *Bienvillia grandis*, n. sp., which they resemble in general aspect (pl. 100, fig. 18). In detail, however, *T. tetragonalis* differs from *B. grandis* by having a more quadrate glabella, usually convex rather than bigeniculate S1 furrows, less curved anterior cranidial margin, more anteriorly situated eyes, and narrower posterior fixigenae. Also, the largest observed cranidia of *T. tetragonalis* are only about half the size of the largest observed cranidia of *B. grandis*.

Henningsmoen (1957, p. 145) assigned some specimens from Norway to the subspecies *Bienvillia tetragonalis broeggeri*. Definitive characters of that taxon appear to fall within the range of morphologic variation exhibited by specimens of *Triarthrus tetragonalis* from Argentina (Harrington & Leanza, 1957, Fig. 42). Specimens from Mexico also fall within that range of variation, and subspecies of *T. tetragonalis* are not recognized here.

The assignment of *tetragonalis* to *Triarthrus* rather than *Bienvillia* is discussed in the generic remarks concerning *Triarthrus*.

Occurrence.—About 10 cranidia occur in collection 16000d.

Subfamily PELTURINAE Hawle & Corda, 1847
Genus LEPTOPLASTIDES Raw, 1908

The generic diagnosis of Henningsmoen (1957, p. 264, 265) is followed here.

LEPTOPLASTIDES MARIANUS (Hoek)
Pl. 100, figs. 8,9,11–14

Parabolinopsis mariana HOEK, *in* STEINMANN & HOEK, 1912, p. 226, pl. 7, figs. 1–3; HARRINGTON & LEANZA, 1957, p. 89–93, figs. 29,30,1–10.
Leptoplastides marianus (Hoek) HENNINGSMOEN, 1957, p. 266 (for synonomy to date).

Diagnosis.—Cephalon characterized by relatively large subquadrate glabella without lateral furrows on large holaspides, short frontal area with border furrow bowed backward, small palpebral lobes situated close to and opposite anterior part of glabella, and librigenae with spines that diverge outward from course of lateral border. Thorax has 14 segments. Pygidium transversely elongate; axis has two rings and terminal piece; anterolateral margin has two pairs of short spines.

Discussion.–Several cranidia and librigenae are known from Mexico that agree in all respects with the detailed description by Harrington & Leanza (1957, p. 89–93) of *Parabolinopsis mariana* Hoek from Bolivia and Argentina. In a monograph of the Olenidae, Henningsmoen (1957, p. 266) concluded that *Parabolinopsis* is a junior synonym of *Leptoplastides*, and he assigned *P. mariana* to *Leptoplastides*. That decision is followed here.

Late meraspid or early holaspid cranidia of *L. marianus* from Mexico have two pairs of

poorly defined lateral glabellar furrows, a moderately well defined anterior border furrow, a narrow upturned anterior border, and a prominent medial node on the occipital ring. On larger holaspides the lateral glabellar furrows and occipital node disappear, the anterior border furrow becomes faint, and the anterior border develops a downward slope.

A growth series of librigenae that probably belong to *L. marianus* show a progressive change in the outer spine angle of the genal spine (for definition, see Henningsmoen, 1957, p. 13). The outer spine angle is about 135° on small meraspides (pl. 100, fig. 14), and changes to about 160–170° on large holaspides (pl. 100, fig. 13).

Gross similarity of axial features (including two pairs of lateral glabellar furrows on at least juvenile specimens), similar facial sutures and librigenae, the same number of thoracic segments in some species, and somewhat similar pygidial features, suggest that *Leptoplastides* may have evolved from *Bienvillia*.

Occurrence.—More than 25 cranidia and several librigenae occur in collections 16000d and 16000f, and one cranidium is known from collection 16001h.

Genus LEUROSTEGA, nov.

Type species.—*Leurostega aphelix* Robison & Pantoja-Alor, n. sp.

Diagnosis.—Late holaspides have moderately convex cephalon characterized by almost complete disappearance of furrows on external surface. Late meraspides or early holaspides have well developed axial furrow, subrectangular glabella with three pairs of lateral furrows, short spine or prominent node on occipital ring, and frontal area about 0.2 length of cranidium. Specimens from intermediate ontogenetic stages have transitional morphologic characters. During observed ontogeny, palpebral lobes maintain a position approximately opposite cephalic midpoint. Facial sutures opisthoparian; anterior sections converge slightly in front of eyes, arc diagonally across border area, and intersect anterior margin at cephalic midline; posterior sections are diagonally backward from eyes and cut posterior margins about midway across genal regions. Librigenae have short genal spines that diverge from lateral margin.

Hypostoma and thorax unknown.

Pygidium transversely subelliptical; width about twice length. Axis elevated above pleural fields, tapered posteriorly, and has 3 or 4 rings and a terminal piece. Posterior margin broadly rounded and nonspinose.

Discussion. Representatives of late ontogenetic stages of *Leurostega* and some members of *Leiobienvillia* show great similarity in the almost complete disappearance of furrows on the cranidium. Rasetti (1954, p. 583) has demonstrated that *Leiobienvillia* is a member of the Olenidae closely related to *Bienvillia*. Overall morphologic characteristics indicate that *Leurostega* also is a member of the Olenidae, but differences in glabellar shape, relative obliqueness and depth of S2 furrows, and anterior courses of the facial suture make it unlikely that *Leurostega* was derived from *Bienvillia*. Instead, a combination of characters such as subrectangular glabella, broadly triangular anterior cranidial border, genal spines that diverge slightly from the lateral border, and general features of the pygidium suggest a possible phyletic relationship with some members of *Protopeltura* (compare pl. 103, figs. 1–13 with Henningsmoen, 1957, pl. 23). Other possible, but less likely ancestral sources for *Leurostega* are *Angelina* and *Parabolinella*.

Late Cambrian and Early Ordovician genera such as *Illaenurus*, *Kingstonia*, *Leiobienvillia*, *Leiocoryphe*, *Leurostega*, *Plethomethopus*, *Stenopilus*, and *Symphysurina* represent good examples of trilobite homeomorphy. Representatives of these genera superficially resemble one another because of disappearance of furrows, especially on the cranidium, but they differ in particular structural details. Of this group of homeomorphs, only *Leurostega* and *Leiobienvillia* are olenids.

Leurostega presently is known only from the early Tremadocian of southern Mexico.

LEUROSTEGA APHELIX, n. sp.
Pl. 103, figs. 1–13

Description.—Because *Leurostega* is monotypic, information presented here is supplementary to the generic diagnosis.

Smallest observed cranidium (1.25 mm long) has subrectangular glabella with 3 pairs of lateral furrows; S1 and S2 deep and connected across glabella, S3 faint and discontinuous. Axial furrow deep and wide. Occipital ring has short spine. Frontal area about 0.2 times length of cranidium and has faint anterior border furrow. Eye ridges narrow and slightly oblique backward. Palpebral furrows well developed. Palpebral area of fixigenae moderately wide. Most of external surface covered with coarse granules.

Successively larger cranidia show progressive decrease in distinctness of furrows and ridges until moderately convex featureless condition develops by time length of about 5 mm is reached. Occipital spine degenerates to node, and is absent in late holaspides. Surface granulation disappears by time cranidium is about 4 mm long, and occipital area becomes finely pitted.

During ontogeny the rate of increase in length

of palpebral lobes was less than rate of increase in length of cranidium. This caused the palpebral lobe/cranidial length ratio to change from about 0.40 on cranidia 1.25 mm in length to about 0.20 on cranidia 10.0 mm in length.

Pygidium shows little change in depth of furrows on observed growth stages. Axis has 3 or 4 rings and a terminal piece. Anterior ring furrow is wide and flat-bottomed in middle, but fades toward axial furrow. Pleural fields have 3 pairs of broad shallow pleural furrows and may show up to 3 pairs of interpleural furrows. Margin is slightly upturned to form narrow, thread-like border. Almost all external surface covered with closely spaced irregular terrace lines.

Discussion.— Taxonomic comparisons are made in the generic discussion.

L. aphelix is characterized by a remarkable amount of cranidial variation during ontogeny. Loss of granules on the external surface and disappearance of furrows are two of the most obvious characters that change. Similar, but less pronounced change occurs in an associated species, *Richardsonella variagranula*. Another associated species, *Gymnagnostus gongros*, also loses furrows during growth. These three species include at least 95 percent of the specimens in collection 16002b. It is suggested that these occurrences of similar ontogenetic trends in associated species may indicate a strong, but unknown environmental influence on the populations.

Occurrence.—More than 100 disarticulated specimens occur in collection 16002b.

Holotype.—Cranidium illustrated on pl. 103, figs. 1 and 10, USNM 159004.

Genus PELTOCARE Henningsmoen, 1957

The generic diagnosis of Henningsmoen (1957, p. 246) is followed here.

PELTOCARE NORVEGICUM (Moberg & Möller)
Pl. 103, figs. 14–23

Acerocare norvegicum MOBERG & MÖLLER, 1898, p. 243.

Peltocare norvegicum (Moberg & Möller) HENNINGSMOEN, 1957, p. 247, pl. 2, fig. 9; pl. 8; pl. 27, figs. 6,8,10–14 (see for synonomy to date).

Acerocarina glaber (Harrington) HARRINGTON & LEANZA, 1957, p. 93, fig. 3a–d.

Diagnosis.—Cephalon characterized by relatively large subquadrate glabella without lateral furrows, short frontal area without anterior cranidial border, small palpebral lobes close to glabella and almost on line with preglabellar axial furrow, and genae without spines. Thorax has 12 segments. Pygidium alate, has 3 axial rings and a terminal piece, and is covered with irregular terrace lines.

For further details see Henningsmoen, 1957, p. 247, and Harrington & Leanza, 1957, p. 93–95.

Discussion. Henningsmoen (1957, p. 248) considered *Cyclognathus glaber* (Harrington) to be a probable junior synonym of *Acerocare norvegicum* Moberg & Möller, which he designated as the type species of a new genus, *Peltocare*. At about the same time, Harrington & Leanza (1957, p. 93–95) redescribed *C. glaber* and assigned it to *Acerocarina*. The writers agree with Henningsmoen that significant differences are not apparent when representatives of *norvegicum* and *glaber* are compared, and we too consider them to be synonyms and representatives of *Peltocare*.

Disarticulated specimens from Mexico agree in practically all respects with Henningsmoen's (1957) concept of *P. norvegicum* and Harrington & Leanza's (1957) concept of *A. glaber*. Mexican specimens appear to have a more convex (trans.) cranidium which causes the posterior fixigenae to appear to be transversely shorter in plan view. Specimens illustrated by both Henningsmoen and Harrington & Leanza appear to have been somewhat flattened, perhaps by diagenetic compaction. On the other hand, most specimens from Mexico show little indication of flattening, and it is suggested that the slight differences in cranidial convexity are of secondary origin.

Most of the frontal and genal areas of the cranidium are finely pitted on the specimens from Mexico. Similar pitting has not been reported on specimens from Norway, Sweden, and Argentina, but may have been overlooked or may not be present because of different preservation.

Occurrence.—More than 50 cranidia and several pygidia and librigenae occur in collections 16000i and j.

Subfamily PLICATOLININAE, nov.

Diagnosis.—Micropygous to heteropygous olenids with low exoskeletal profile. Cephalon semicircular and characterized by four pairs transverse glabellar furrows, narrow anterior and lateral border, and slender genal spines that continue uninterrupted course from lateral border. Thorax has up to 21 segments. Pygidium ranges in width from about two to three times length and may or may not have posterior medial notch.

Discussion.—Recently accumulated knowledge concerning plicatolinid trilobites indicates that the group is geographically widespread. At least three generic groups can be distinguished, but one group yet is undescribed.

Plicatolina is characterized by short anteriorly situated palpebral lobes and a small pygidium with a width approximately three times its length. Described species of *Plicatolina* include *P.*

kindlei Shaw (1951) from Vermont, *P. scalpta* Harrington & Leanza (1957) from Argentina and Bolivia, and *P. quadrata* Pokrovskaya (1966) and *P. yakutica* Pokrovshaya (1966) from the Russian platform.

Plicatolinella, n. gen., is characterized by posteriorly situated palpebral lobes that are continuous with prominent eye ridges, narrow (exsag.) strap-like posterior fixigenal areas, and a bilobate pygidium with a width about twice its length and a prominent posterior median notch. The genus presently is known only from the Tremadocian of southern Mexico.

A third, but undescribed, group of plicatolinids is represented in several U.S. Geological Survey collections from the Late Cambrian of Nevada. Some of them have pygidia similar to that of *Plicatolinella*, but associated cranidia have a relatively long frontal area and palpebral lobes similar to those of *Plicatolina*.

Genus PLICATOLINELLA, nov.

Type species.—*Plicatolinella ocula* Robison & Pantoja-Alor, n. sp.

Diagnosis.—Cephalon low in profile. Glabella subquadrate, has four pairs lateral furrows, and may have faint anterior median sulcus. Occipital furrow nearly straight or bowed slightly backward; comparable in depth to S1 furrows. Frontal area shorter than occipital ring in sagittal length; has very narrow rim-like anterior border; and anterior margin may have backward medial bow. Anterior and palpebral areas of fixigenae range from 0.3 and 0.5 width of glabella. Eye ridges prominent; oblique backwards from intersection with axial furrow opposite S4; and continuous with palpebral lobes. Combined eye ridge-palpebral lobe forms crescentic structure that extends almost to posterior border of fixigena on large holaspides. Posterior area of fixigenae narrow (exsag.) and strap-like. Facial suture opisthoparian; anterior courses parallel to slightly convergent convex; posterior courses strongly divergent. Librigenae known only from fragments, but have long slender genal spines.

Hypostoma and thorax unknown.

Pygidium bilobate because of posterior medial notch; width approximately twice length. Axis poorly defined posteriorly; has at least three rings and terminal piece. Pleural fields nearly flat; have four pairs of oblique pleural furrows that become strongly curved at distal ends, and three pairs of faint interpleural furrows. Border furrow and marginal spines absent.

Discussion.—*Plicatolinella*, n. gen., strongly resembles *Plicatolina*, but differs by having more posteriorly situated palpebral lobes, much narrower (exsag.) posterior fixigenal areas, and a larger and longer pygidium with at least one more axial ring and a prominent posterior medial notch. *Plicatolinella* and *Plicatolina* appear to be closely related, but little meaningful evidence yet is available concerning phylogeny of the two genera.

PLICATOLINELLA OCULA, n. sp.
Pl. 103, figs. 24–26; pl. 104, figs. 1–4

Description.—Because *Plicatolinella* is monotypic, information presented here is supplementary to the generic diagnosis.

Meraspid cranidia characteristically have a glabella with lateral sides bowed outward and well-rounded anterolateral corners. During ontogeny, the lateral glabellar sides become straighter and anterolateral corners become more angular. All lateral glabellar furrows are nearly straight transverse and terminate medially against a longitudinal hemitubular structure on early meraspides. During ontogeny, the S1 and S2 furrows become slightly oblique backwards and all transverse furrows become shallow or disappear on late holaspides, and node disappears on old holaspides.

Discussion.—Taxonomic comparisons are made in the family discussion of Plicatolininae and the generic discussion of *Plicatolinella*.

Occurrence.—More than 25 cranidia, two pygidia, and a few fragments of librigenae occur in a soft siltstone matrix of collections 16000d and f.

Holotype.—Cranidium illustrated on pl. 104, fig. 1, USNM 159030.

Family REMOPLEURIDIDAE Hawle & Corda, 1847
Genus RICHARDSONELLA Raymond, 1924

Type species.—*Dikelocephalus megalops* Billings, 1860, p. 311, fig. 309.

Remarks.—From the study of partly undescribed faunas, Palmer (1968, 77, 78) concluded that possibly two or three groups of generic magnitude now are included in the broad concept of *Richardsonella* as presented by Rasetti (1944, p. 255) and as followed by Whittington (1959, p. 0329). Representatives of each group have nearly indistinguishable cranidia, but strikingly different pygidia and perhaps different librigenae. The broad concept of *Richardsonella* is followed here, however, pending the formal establishment of new genera.

RICHARDSONELLA VARIAGRANULA, n. sp.
Pl. 104, figs. 5–11

Description. Cephalon of young holaspides is marked with large granules on most of dorsal surface except in furrows, on palpebral lobes, and on borders. Progressively older holaspides show gradual loss of granules until present only on corners of glabella, occipital ring, and inner

part of genal fields. As granules disappear on preglabellar field, reticulate caeca progressively become more prominent. Anterior and lateral cephalic borders and genal spines marked with raised terrace lines.

Glabella bluntly rounded anteriorly; sides bow slightly outward and commonly have slight constrictions opposite anterior ends of palpebral lobes. Three pairs of lateral glabellar furrows are oblique backwards and become faint on some large holaspides. Occipital furrow constricted medially and distally. Occipital ring broad (sag.) and flat. Frontal area divided by deep punctate border furrow. Preglabellar field steeply inclined and anterior border sharply upturned; length of anterior border ranges from 0.33 to 0.40 that of preglabellar field. Palpebral lobes large, crescentic, and close to glabella. Posterior fixigenae unknown. Facial suture kainelliform with only moderate anterior flare. Librigenae have long genal spines, deep lateral border furrows, and broad shallow posterior border furrows.

Hypostoma and thorax unknown.

Pygidium approximately twice as wide as long. Axis strongly annulated with three rings and a terminal piece. Narrow postaxial ridge commonly extends from axis to posterior margin. Segments of pleural fields extend into either four or five pairs of short, broad-based spines. Surfaces of pleural ridges and axial rings carry large granules.

Discussion.—This species differs from all others in the genus by the nature and distribution of its ornamentation. In features other than ornamentation, cranidia of *R. variagranula* resemble the type species, *R. megalops*, but the glabellar sides commonly are more bowed, the area between the axial and palpebral furrows is narrower (trans.), and the anterior courses of the facial suture are not as divergent.

Matrix adheres tightly to the exoskeleton, perhaps because of the granulation, and preparation of good specimens is difficult.

Occurrence.—*R. variagranula* occurs only in collection 16002b. More than 25 cranidia plus numerous other disarticulated sclerites, however, indicate that the species was a common faunal element at the time of deposition.

Holotype.—Cranidium illustrated on pl. 104, fig. 7, USNM 159036.

Family SAUKIIDAE Ulrich & Resser, 1930
Genus SAUKIA Walcott, 1914

Remarks.—The saukids are greatly in need of a thorough taxonomic study. Pending such a study, a loose version of Ulrich & Resser's (1933, p. 168–171) concept of *Saukia* is followed here.

By definition (Ulrich & Resser, 1933) *Saukia* is characterized by the presence of coarse granules on the surface of the exoskeleton, whereas *Saukiella* lacks granules. It is noted that the opposite situation erroneously is indicated by illustrations of the two genera in the *Treatise on Invertebrate Paleontology* (Lochman, 1959, figs. 239.1 and 239.3a,b).

SAUKIA GLOBOSA, n. sp.
Pl. 104, figs. 12–19

Description. Exoskeleton unusually thick. Surface of glabella, occipital ring, and inner part of genal fields usually carry scattered large granules.

Cranidium elongate. Glabella tumid and subrectangular; sides may be parallel or slightly tapered toward front, S1 furrow wide and deep, bowed posteriorly, and connected across glabella; S2 and S3 furrows short, faint, and oblique backward. Occipital furrow wide, deep, and straight medially; slightly constricted and directed forward at distal ends. Occipital ring flat and has two small medial nodes one behind the other. Axial furrow wide, deep, and marked with pair of prominent fossulae near anterolateral corners of glabella. Preglabellar field absent. Anterior border furrow coincident with preglabellar furrow, slightly bowed around anterior end of glabella, and continues laterally to meet border furrows of librigenae. Anterior border flat and slopes moderately forward, anterior and palpebral areas of fixigenae narrow. Palpebral lobes approximately 0.25 length of cranidium; situated posterior from cranidial midpoint. Preocular facial sutures diverge slightly to border furrow and round inward across border; postocular sutures diverge abruptly, which causes posterior area of fixigenae to be strap-like. Librigenae have broad lateral borders that continue uninterrupted into long stout genal spines. Lateral and posterior border furrows continuous; intersection forms slightly acute angle. Genal field convex.

Hypostoma, rostrum if present, and thorax unknown.

Pygidium transversely subelliptical with rounded corners at intersection of anterior and posterior margins. Axis slightly tapered posteriorly; has four prominent rings and long terminal piece than may show faint development of fifth ring. Pleural and interpleural furrows well defined across most of pleural field, but fade near margins. Border furrow absent.

Discussion.—The argillaceous limestone matrix in all collections with *S. globosa*, n. sp., adheres much more tightly to the external than to the internal exoskeletal surface of that species. Therefore, all of the prepared specimens consist of wholly, or at least partly exfoliated internal molds. Nevertheless, this state of preservation is

similar to that of most saukiid material from the upper Mississippi Valley where the saukiids are abundantly represented as molds in sandstone and shale.

Most exfoliated cranidia and librigenae of *S. globosa* exhibit scattered coarse granules, but some apparently lack granules, and other transitional forms have only a few faint granules. By definition (Ulrich & Resser, 1933), the presence or absence of coarse granules on the exoskeleton has been used as a generic criterion to distinguish representatives of *Saukia* and *Saukiella*. Such a criterion, however, has seldom, if ever, been considered by taxonomists to have generic significance in other groups of trilobites. The variation in granulosity shown by *S. globosa* indicates that the status of *Saukiella* as a valid genus perhaps needs to be reevaluated.

S. globosa differs from all described species of *Saukia* by having fewer and variable numbers of granules on the surface and internal mold of the exoskeleton. It has a strong resemblance to specimens from southern Manchuria that Kobayashi (1931, p. 182, pl. 22, figs. 12–16) assigned to *Ptychaspis chinhsiensis* Sun. The development and course of the anterior border furrow on the fixigenae, development of glabellar furrows, position of the palpebral lobes, and segmentation of the pygidial axis particularly are similar, but *S. globosa* has a relatively wider and shorter glabella and *P. chinhsiensis* lacks granules.

It is noted that Kobayashi (1933, p. 130) later reassigned *P. chinhsiensis* to *Tellerina*. Because the species has a shorter and differently developed frontal area and a pygidial axis that extends almost to the posterior pygidial margin, it is not considered here to belong to *Tellerina*, but appears to be more closely akin to *Saukia* or *Saukiella* as defined by Ulrich & Resser.

Compared with North American saukiids, *S. globosa* probably most closely resembles *Saukia tumida* Ulrich & Resser, but differs from that species by having fewer granules, less well developed S2 furrows, a narrower (sag.) preoccipital glabellar segment, and a more swollen glabella.

Occurrence.—Approximately 25 cranidia plus associated parts occur in 16001d and 16002c and one pygidium occurs in 16000d.

Holotype.—Cranidium illustrated on pl. 104, fig. 13, USNM 159043.

Family SHUMARDIIDAE Lake, 1907
Genus KOLDINIOIDIA Kobayashi

Koldinioidia KOBAYASHI, 1931, p. 187; 1933, p. 99, 100; HUPÉ, 1955, p. 154; POULSEN, 1959, p. 0246.

Type species.—*Koldinioidia typicalis* Kobayashi, 1931, p. 187, pl. 22, figs. 8b,9.

Diagnosis.—Exoskeleton tiny; largest observed cephalon approximately two mm long. Cephalon semicircular in outline. Glabella ranges from cylindrical and broadly rounded anteriorly to moderately tapered and pointed anteriorly. Two pairs short pit-like lateral glabella furrows usually present. Axial furrow deep and wide posteriorly; shallow and narrow or absent at front of glabella. Occipital furrow straight and well developed. Occipital ring sagittally broad. Genae undifferentiated except for shallow preglabellar sulcus on some species; convex with steep outer margins; wide laterally and narrow anteriorly; unmarked except for posterior border furrows. Pygidium roughly triangular with six axial segments and no border.

Discussion.—*Koldinioidia* previously has been reported only from late Late Cambrian strata in Manchuria. Therefore, the occurrence of *K. sulcatus*, n. sp., in Mexico greatly extends the known geographic distribution of the genus. Other faunal relationships suggest that specimens of *Koldinioidia* from Manchuria and Mexico are of similar age.

The general morphologic similarity of *Koldinioidia* and *Shumardia* indicates close affinity, and relative stratigraphic occurrences suggest that *Shumardia* may have evolved from *Koldinioidia*. *Shumardia* is characterized by an anteriorly expanded glabella with commonly well developed anterolateral lobes, whereas *Koldinioidia* has a parallel-sided or tapered glabella with undeveloped or only faintly developed anterolateral lobes.

It is noted that a sketch of *K. yenchouensis* by Hupé (1955, p. 154, fig. 134.8) gives an erroneous character to *Koldinioidia* by showing a cephalic border. The type specimen of *K. yenchouensis* in the collections of the U. S. National Museum shows no such border, nor does any other known representative of the genus.

KOLDINIOIDIA SULCATUS, n. sp.
Pl. 104, figs. 20–23

Description.—Largest cephala characterized by slightly tapered glabella with two pairs well developed pit-like lateral furrows. Smallest known cephala (about 0.5 mm) have conical glabella with only faintly developed S1 furrows. Occipital ring has faint median node. Genae separated by shallow preglabellar sulcus; posterior width less than that of occipital ring. Posterior borders narrow (exsag.) and lower than adjacent genae.

Known only from cranidia.

Discussion.—The largest known specimens of *K. sulcatus*, n. sp., show the faint development of a pair of accessory furrows that extend forward and obliquely inward from near the proximal ends of the S2 furrows. These accessory

furrows partially isolate small anterolateral glabellar lobes similar to, but much smaller than those on specimens of *Shumardia*. A deeper anterior development of these furrows on some specimens gives the false appearance of a third pair of lateral furrows. Close examination, however, indicates that they are not primary furrows comparable to the S1 and S2 furrows. Similar accessory furrows are not apparent on other described species of *Koldinioidia* and thereby help to differentiate *K. sulcatus*.

K. sulcatus most closely resembles *K. paiensis* Endo, but differs from that species by having a wider frontal area, a preglabellar median sulcus, and a faint occipital node.

Occurrence.—More than 10 cranidia occur in collection 16002b.

Holotype.—Cranidium illustrated on pl. 104, fig. 20, USNM 159049.

Genus SHUMARDIA Billings, 1862

Remarks.—The generic diagnosis of Poulsen (1959, p. 0245) is followed here.

Walcott (1913, p. 241) once assigned a pygidium to *Shumardia* that came from the Middle Cambrian of China. That pygidium subsequently was assigned to *Solenoparia intermedia* (Walcott) by Resser (1942, p. 51). Nevertheless, apparently on the basis of the pygidium designated by Walcott, some authors have continued to extend the range of *Shumardia* back to the Middle Cambrian. An evaluation of available evidence suggests that *Shumardia* probably did not appear before the beginning of the Tremadocian.

SHUMARDIA ALATA, n. sp.
Pl. 99, figs. 13–18

Description.—Cephalon semicircular in outline; width approximately twice length. Glabella moderately inflated and broadly pointed at anterior end; S1 and S2 furrows poorly developed; anterolateral lobes usually either undefined or faintly defined, but rarely may be moderately well defined. Occipital ring wider (trans.) than posterior glabellar segment; may have faint median node. Axial furrow wide and deep laterally, becomes narrow and shallow at front of glabella. Genae convex; posterior width approximately equals that of occipital ring on small holaspides, but ranges up to 1.4 times wider than occipital ring on largest known holaspides. Facial suture marginal. Librigenae confluent and consist of a curved striated band that comprises the cephalic doublure.

Pygidium transversely elongate and alate in form; width 2.5 to 3.0 times length. Axis tapered and extends to posterior border; has 3 or 4 rings. Pleural regions crossed by 3 or 4 slightly oblique, granulated ridges. Border narrow and ridge-like with granules along crest; bowed forward at midline. Wide ventral doublure extends downward and outward from posterior border.

Discussion.—Cranidia of *Shumardia* occur in several collections from the Tiñu Formation of Mexico, but pygidia are known only from collections 16001e and 16002g. Two distinct kinds of pygidia are present in 16002g, but differences that can be used to separate associated cranidia into two groups are not apparent. One type of pygidium is fairly common and is characterized by an alate outline and a prominent border, whereas the other type is scarce, has a semicircular outline, and lacks a border. Whether or not the two kinds of pygidia represent sexual dimorphism in a single species is at this time a moot point, and unless cogent evidence can be presented to indicate such a condition, it seems appropriate to designate separate species. The alate type of pygidium here is assigned to *Shumardia alata*, n. sp., and on the basis of relative numbers, it is assumed that most or all of the cranidia in 16002g also belong to this species. The semicircular type of pygidium is assigned to *Shumardia ctenata*, n. sp. Cranidia in other collections are indistinguishable from those questionably assigned to *S. alata* in 16002g. Therefore, in the absence of associated pygidia, they too can only questionably be assigned to *S. alata*.

S. alata is similar to *S. pusilla* (Sars), but differs in detail from that species by having a relatively shorter and wider pygidium and usually less well developed anterolateral lobes on the glabella (see Stubblefield, 1926, pls. 14–16). *S. alata* also resembles *S. erquensis* Kobayashi, but differs from that species by having a shorter and wider pygidium with more axial segments.

Occurrence.—About 10 pygidia and more than 100 cranidia occur in collection 16002g. As discussed above, the cranidia are questionably assigned to *S. alata*. Eight fragmentary pygidia occur in collection 16001e. More than 50 cranidia that also questionably are assigned to this species occur in collections 16000e, 16001d, h, and 16002d and e.

Holotype.—Pygidium illustrated on pl. 99, fig. 17, USNM 158934.

SHUMARDIA CTENATA, n. sp.
Pl. 99, figs. 19,20

Description.—Cephalon probably similar to that of *S. alata*.

Pygidium oval to semicircular in outline; width about 1.5 times length. Axis tapered; maximum width about equal to that of pleural regions; has up to five rings, each with transverse row of granules. Pleural regions lack border and have up to five backward curved pleurae that terminate in blunt spines. Anterior pleural

bands have double row of granules and posterior pleural bands are smooth.

Discussion.—As mentioned in the discussion of *Shumardia alata*, two kinds of shumardiid pygidia are known from collection 16002g and only one kind of cranidium. The ovoid spinose type of pygidium without a border here is assigned to *S. ctenata*, n. sp.

Pygidia of *S. ctenata* are similar to those of *S. bottnica* Wiman (see Wiman, 1905, pl. 3, fig. 38, and Moberg & Segerberg, 1906, pl. 4, fig. 16), but appear to differ by having more axial rings and double rows of granules on the anterior pleural bands.

In 1907, Lake (p. 40) considered *S. bottnica* to be a synonym of *S. pusilla*. Later, Harrington & Leanza (1957, p. 79) considered *S. bottnica* and *S. pusilla* to be separate species. Their separation was based on supposed differences in cranidial features, but the nature of those differences was not stated. The present writers also consider the two forms to represent separate species, but see little if any meaningful cranidial differences shown by published illustrations. Instead, the most obvious differences are to be seen on the pygidia where *S. pusilla* has a border and only slightly oblique pleurae, whereas *S. bottnica* has no border and has strongly curved pleurae.

Occurrence.—Four pygidia occur in collection 16002g. Numerous associated cranidia are present, but without articulated specimens it is not possible to determine which, if any cranidia belong to *S. ctenata* and which belong to *S. alata*.

Holotype.—Pygidium illustrated on pl. 99, fig. 19, USNM 158936.

Family Unknown

Genus BIFODINA, nov.

Type species.—*Bifodina longifrons* Robison & Pantoja-Alor, n. sp.

Diagnosis.—Known only from cranidia. Axial furrow moderately wide and shallow laterally, narrow and shallow anteriorly. Glabella flattened, unfurrowed; tapers slightly forward, blunt anteriorly; posterior width approximately equals length. When viewed in oblique light, glabellar surface may show faint complex muscle-scar pattern. Occipital furrow deepest and widest just inside axial furrow. Occipital ring medially flattened and widened posteriorly; narrows and extends forward at distal ends. Frontal area relatively long and broad, length slightly less than that of glabella. Preglabellar field and anterior border each moderately convex and subequal in sagittal length. Anterior border furrow broad, shallow, and arcuate; marked with pair of large shallow pits that commonly are crossed transversely by narrow elongate grooves. Eye ridges and palpebral furrows faint. Palpebral area of fixigenae moderately wide. Palpebral lobes situated posterior from cephalic midpoint; length ranges from 0.18 to 0.21 times cephalic length. Posterior area of fixigenae approximately equal to posterior glabella in transverse width, and has prominent posterior border furrow. Facial suture probably opisthoparian; anterior courses diverge moderately from eyes to border furrow and arc inward across border; posterior courses are divergent sinuous. Exoskeleton relatively thick; surface usually smooth, but may have a few terrace lines along edge of anterior border, and preglabellar field may show very faint caeca.

Discussion.—Representatives of *Bifodina* are characterized by a large frontal area with a pair of prominent pits in the anterior border furrow. Otherwise, the over-all cranidial aspect is similar to that of many generalized ptychopariid trilobites such as those found among the conaspids and aphelaspids. With respect to the pair of pits in the border furrow, *Bifodina* resembles *Meteoraspis*, but differs by having a sagittally longer frontal area and a truncate instead of a strongly rounded glabella.

Bifodina presently is known only from the early Tremadocian of southern Mexico.

BIFODINA LONGIFRONS, n. sp.

Pl. 99, figs 21–24

Description.—Because *Bifodina* is monotypic, characteristics of this species are the same as those given in the generic diagnosis.

Occurrence.—Fourteen cranidia occur in collection 16001b and two cranidia occur in collection 16002a. Specimens in both collections occur in a biosparite limestone with abundant broken trilobite, echinoderm, and brachiopod fragments that indicates a high energy environment.

Holotype.—Cranidium illustrated on pl. 99, fig. 23, USNM 158941.

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