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Productidinid brachiopods (Strophomenata, Productida), including *Martinezchaconia luisae* new genus and new species of Linoproductidae, from the Carboniferous of Santiago Ixtaltepec region, Oaxaca, Southeast México

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ABSTRACT

We describe three brachiopod species of the Suborder Productidina from the Ixtaltepec Formation, Carboniferous of the north of Oaxaca State, southern Mexico, found in peri-reef deposits. *Stegacanthia bowsheri* and *Undaria* sp. are members of the families Sentosiidae and Monticuliferidae respectively and were found in strata of the Visean (Middle Mississippian). *Martinezchaconia luisae*, new genus and species of the Family Linoproductidae, was recollected in Bashkirian-Moscovian (Lower-Middle Pennsylvanian) strata. The respective ages are inferred from the index species of brachiopods associated with the productidines herein described.

Keywords: Brachiopods, Productidina, Carboniferous, Mexico.

RESUMEN

Se describen tres especies de braquiópodos del Suborden Productidina que se encontraron en rocas carboníferas, depositadas en ambientes peri-arrecifales de la Formación Ixtaltepec en el norte del Estado de Oaxaca, Sur de México. *Stegacanthia bowsheri* y *Undaria* sp., son representantes de las familias Sentosiidae y Monticuliferidae respectivamente, proceden de estratos del Viséense (Misisípico Medio). *Martinezchaconia luisae,* nuevo género y especie de la Familia Linoproductidae, se encontró en estratos del Bashkiriense-Moscoviense (Pensilvánico Inferior-Medio). Las respectivas edades se infieren a partir de especies índice de braquiópodos que se encuentran asociadas y que han sido referidas previamente para los estratos fosilíferos estudiados.

Palabras clave: Braquiópodos, Productidina, Carbonífero, México.

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1. INTRODUCTION

In 1970, the Mexican geologist J. Pantoja-Alor reported the presence of Cambrian-Ordovician and Carboniferous outcrops in the region of Asunción Nochixtlán, north of Oaxaca state, southern México. Since that year, several publications have been generated describing the Paleozoic marine fauna of the region, which is characterized by its great abundance and diversity of invertebrates. Examples of such publications are those related with the Carboniferous material, such as the description of bryozoans (González-Mora & Sour-Tovar, 2014), brachiopods (Navarro-Santillán *et al*., 2002; Sour-Tovar & Martínez-Chacón, 2004; Torres-Martínez *et al*., 2008; Torres-Martínez & Sour-Tovar, 2012, 2016a, 2016b), bivalves (Quiroz-Barroso & Perrilliat, 1997, 1998), trilobites (Morón-Ríos & Perrilliat, 1988) and crinoids (Villanueva-Olea *et al*., 2011; Villanueva-Olea & Sour-Tovar, 2015).

Brachiopods are the most abundant and diverse group at all stratigraphic levels of Carboniferous age from northern Oaxaca State. The works that have been published on them suggest strong paleobiogeographical affinities with North American coal faunas, over those found in the Mid-Continent region, but the presence of endemic genera and species is remarkable. In particular, brachiopods of the Order Productida are the most common taxa and many of their suborders are well represented. The present work reports the presence of three species of the Suborder Productidina, which had never been recorded in the Carboniferous outcrops of the State of Oaxaca.

2. GEOLOGICAL SETTING AND AGES

The Carboniferous outcrops are located in the Santiago Ixtaltepec region, which occurs to 19 km northwest of the city of Asunción Nochixtlán, Oaxaca State in southern Mexico. The specimens described in this work were collected in the type section Arroyo de las Pulgas of the Ixtaltepec Formation (Pantoja-Alor, 1970), located to 500 m north of Santiago Ixtaltepec town, between 17°32' and 17°33' latitude N and 97°06'and 97°07' longitude W (Fig. 1).

In the region of Santiago Ixtaltepec is possible to observe the Oaxacan Complex, a basement composed of Proterozoic pegmatites, schist, paragneiss and orthogneiss with ages of 900-1100 million years (Fries *et al*., 1962; Solari *et al*., 2003). Overlaying the Precambrian basement is the Tiñú Formation (Robison & Pantoja-Alor, 1968), a Cambrian-Ordovician succession of calcareous and argillaceous rocks with abundant trilobites and other invertebrate fossils (Robison & Pantoja-Alor, 1968; Landing *et al*., 2007, 2010). The Carboniferous succession begins on top of the Tiñú Formation and was originally divided into two formations (Pantoja-Alor, 1970; Navarro-Santillán *et al*., 2002). The lower formation is the Santiago Formation, an informal unit by homonymy that was considered as Mississippian. The upper one is the Ixtaltepec Formation, Late Mississippian and Pennsylvanian in age. Santiago Formation is 165 m thick and unconformably overlies the Tiñú Formation (Cambrian-Ordovician). It has been informally divided

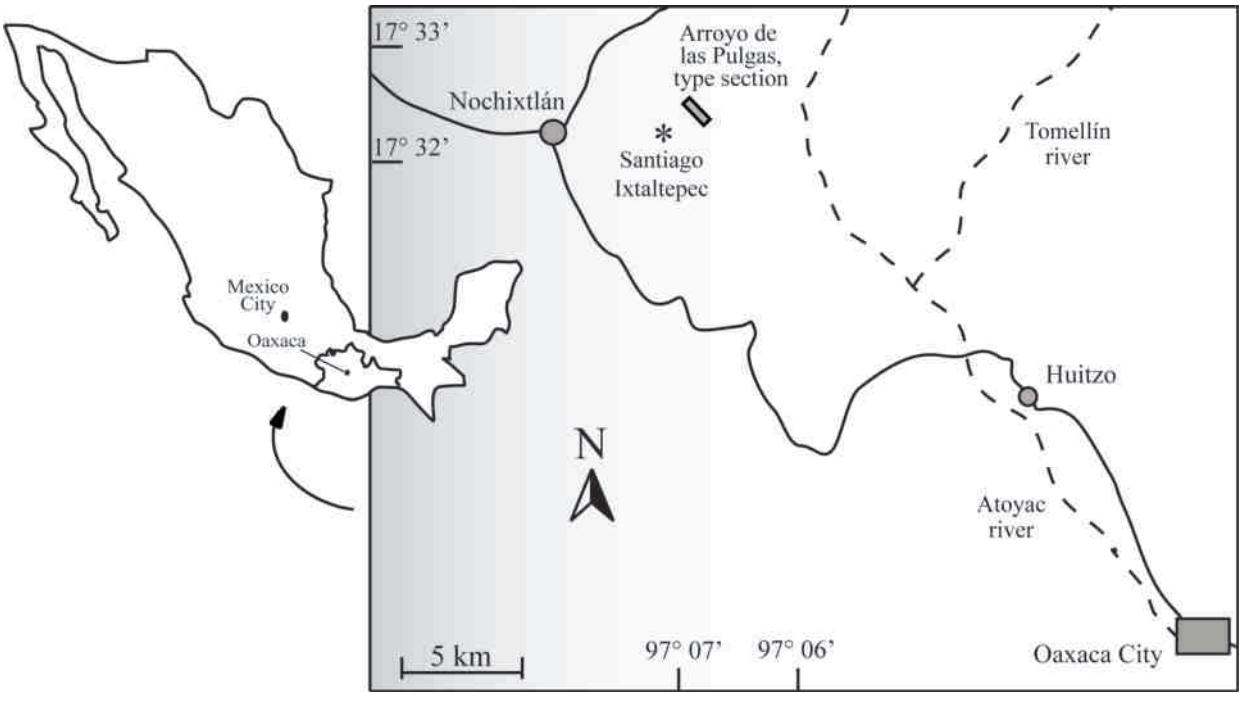

Figure 1. Geographic location of the Ixtaltepec Formation, Arroyo de las Pulgas type section.

into two members. The Lower Member consists of 65 m of sandstone, limestone and calcareous sandstone containing abundant fossils of invertebrates of the Early Mississippian (Tournaisian) (Quiroz-Barroso *et al*., 2000; Navarro-Santillán *et al*., 2002). The Upper Member is composed of approximately 100 m of shale and fine-grained sandstone, including Middle Mississippian cephalopods (Castillo-Espinoza, 2013).

The Ixtaltepec Formation is 430 m thick at the type section Arroyo de las Pulgas, where conformably overlies the Santiago Formation. The basal part includes 90 m of interbedded siltstone, sandstone, sandy limestone and shale. The rest of the Ixtaltepec Formation is mainly made up of shale and minor fine-grained sandstone. Eight fossiliferous intervals, from the base to the top (API-1 to API-8), have been recognized in this formation (Fig. 2), each one characterized by its own fossil association. The productidinid brachiopods described in the present work were collected in the units API-2 (*Stegacanthia bowsheri* and *Undaria* sp.) and API-7 (*Martinezchaconia luisae*). Unit API-2 is characterized by the presence of different brachiopods (Torres-Martínez & Sour-Tovar, 2012, 2016a, 2016b), bivalves (Quiroz-Barroso & Perrilliat, 1997, 1998), crinoids (Villanueva-Olea & Sour-Tovar, 2015) and other groups of invertebrates not formally described to date. Among the brachiopods that have been referred for this unit, the species *Ovatia muralis* (Torres-Martínez & Sour-Tovar, 2012), *Inflatia inflata* (Torres-Martínez & Sour-Tovar, 2016b) and *Orbiculoidea caneyana* (Torres-Martínez & Sour-Tovar, 2016a), allowed assigning the Unit API-2 to the Visean (Middle Mississippian).

In the Unit API-7, the brachiopods *Neochonetes* (*N*) *granulifer* (Sour-Tovar & Martínez-Chacón, 2004), *Echinaria knighti*, *Linoproductus platyumbonus*, *Linoproductus prattenianus* (Torres-Martínez & Sour-Tovar, 2012), *Orbiculoidea missouriensis, O. capuliformis* (Torres-Martínez & Sour-Tovar, 2016a) and *Reticulatia huecoensis*, (Torres-Martínez & Sour-Tovar, 2016b) suggest a Bashkirian-Moscovian (Early-Middle Pennsylvanian) age and allow to assign the new genus herein described to this interval of time. It has been inferred that the deposition of sediments of the Ixtaltepec Formation occurred in a shallow sea that, over time, underwent variations in depth, energy and input of types of sediments developing intertidal, reef or peri-reef sub-environments (González-Mora & Sour-Tovar, 2014; Torres-Martínez & Sour Tovar, 2016a). In particular, the Units API-2 and API-7 are characterized by the dominance of fine strata of shale and limonite with few lenses of carbonates. In both units, it has been inferred that they were deposited in a peri-reef environment.

Unconformably overlaying the Ixtaltepec Formation is the Yododeñe Formation, a conglomerate of Permian to Jurassic age. In the study region, Cretaceous calcareous rocks cover the Paleozoic outcrops. Figure 2 shows the stratigraphic column of the Santiago Ixtaltepec region, the relationship between the different units that have been recognized and the location of the stratigraphic units in which brachiopods described were collected.

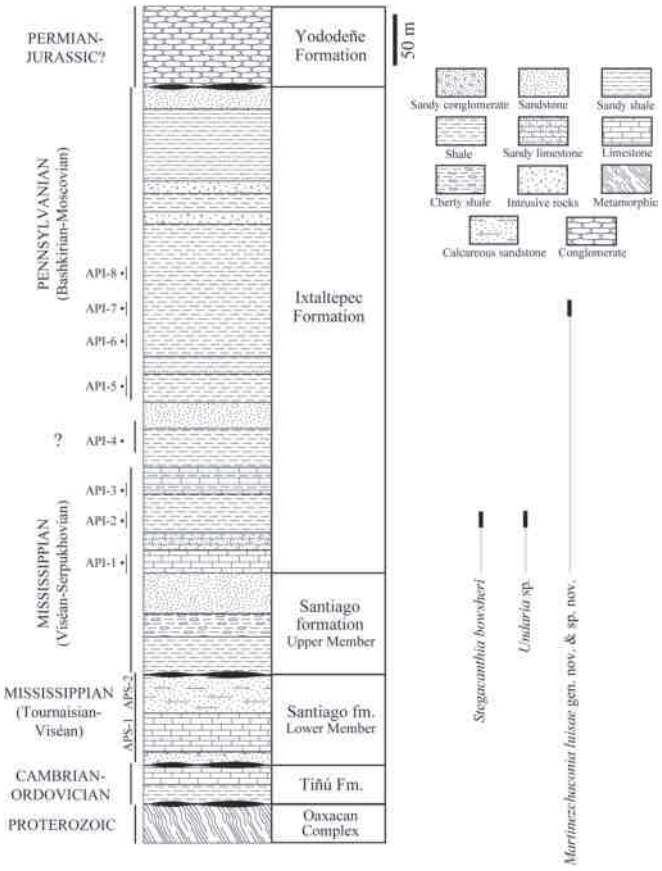

Figure 2. Stratigraphic column of the Santiago Ixtaltepec region. It shows the relationship between the different units that have been recognized and the location of the stratigraphic units in which brachiopods described were collected.

3. SYSTEMATIC PALAEONTOLOGY

All specimens studied are deposited at the Museo de Paleontología, Facultad de Ciencias, Universidad Nacional Autónoma de México. Type and figured specimens are designated in the descriptions by the prefix FCMP. The material is preserved as internal and external molds of both valves. In many cases, the internal molds of ventral valves are composite molds where it is just possible to see the external morphology. The description is based on the terminology of Brunton *et al*. (2000).

Phylum **BRACHIOPODA** Duméril, 1805

Subphylum **RHYNCHONELLIFORMEA** Williams, Carlson, Brunton, Holmer & Popov, 1996

Class **STROPHOMENATA** Williams, Carlson, Brunton, Holmer & Popov, 1996

Order **PRODUCTIDA** Sarytcheva & Sokolskaya, 1959

Suborder **PRODUCTIDINA** Waagen, 1883

Superfamily **Echinoconchoidea** Stehli, 1954

Family **Sentosiidae** McKellar, 1970

Subfamily **Sentosiinae** McKellar, 1970

Tribe **Sentosiini** McKellar, 1970

Genus *Stegacanthia* Muir-Wood & Cooper, 1960

Type species *Stegacanthia bowsheri* Muir-Wood & Cooper, 1960 (New Mexico, United States. Upper Visean).

Stegacanthia bowsheri, Muir-Wood & Cooper, 1960
(Figs 3a-b)

1960 *Stegacanthia bowsheri* Muir-Wood & Cooper, p. 199, 200, pl. 48, figs 1-12.

1968 *Stegacanthia* aff. *bowsheri*, Carter, p. 1141.

1987 *Stegacanthia* cf. *bowsheri*, Carter, p. 33, pl. 11, figs 7-12.

2005 *Stegacanthia bowsheri*, Shi *et al*., p. 47, pl. 3I-J, 7.

2014 *Stegacanthia bowsheri*, Carter *et al*., p. 273, figs 7N-P.

Occurrence. The specimen described is from Ixtaltepec Formation, Arroyo de las Pulgas type section, level API-2, Visean (Middle Mississippian).

Material. A composite mold; a ventral external mold with part of dorsal internal and external molds (FCMP 1200).

Description. Medium-sized concavo-convex shell, subpentagonal in outline with greatest width at midlength. The specimen described is incomplete with approximately 16 mm in length and 25 mm in width. Ventral valve slightly convex, not geniculate, most inflated in posterior region. Sulcus moderately deep. Flanks spread. Strongly curved acute umbo on the hingeline with beak small. Hinge smaller than the greatest width. Short ears. Surface ornamented by lamellose bands, which are more width at the posterior half of the valve, overlapping next anterior band. Spines in concentric rows above the bands, seven occurring in a space of 5 mm at midlength. Dorsal valve slightly concave with low fold, similar ornament to ventral valve but narrower bands and smaller spines. Interior with externally bilobate cardinal process. Median septum low, reaches a larger size than midlength. Subtrigonal and dendritic adductor scars.

Remarks. Ixtaltepec specimen resembles *Stegacanthia bowsheri* material from the Lake Valley Formation (Upper Mississippian) of New Mexico, described by Muir-Wood & Cooper (1960, p. 199, figs. 1-12). Traits as the nongeniculated ventral valve, umbo incurved on the hingeline, hinge smaller than the greatest width, short ears, lamellose bands of irregular width which overlapping next anterior band, lamellae ornamented of spines in concentric rows above bands, 14 occurring in a space of 10 mm and a dorsal valve slightly concave with narrower bands and smaller spines allowed relating the specimen herein described with those reported in New Mexico. This species has been recorded in the Mississippian of New Mexico (Muir-Wood & Cooper, 1960), Missouri (Carter, 1968) and Arizona (Carter *et al*., 2014) in the United States, as well as in Canada (Carter, 1987) and China (Shi *et al*., 2005). This is the first occurrence of *S. bowsheri* in Mexico.

Superfamily **Linoproductoidea** Stehli, 1954

Family **Linoproductidae** Stehli, 1954

Subfamily **Anidanthinae** Waterhouse, 1968

Genus *Martinezchaconia* Torres-Martínez & Sour-Tovar gen. nov.

Type species *Martinezchaconia luisae* Torres-Martínez & Sour-Tovar sp. nov.

Diagnosis. Ventral valve with greatest convexity at midlength, geniculated, short trail. Sulcus extending from the beak until the anterior margin. Ears well-differentiated subquadrate to subtriangular, separated from umbonal slopes by a shallow concave flexure. The ornamentation consists of low costae, begins on the beak and extends to end of trail, absent on ears. Narrow and irregular rugae on the entire valve. Spines on ears, occurring in single row parallel to hinge. Dorsal valve with weak median fold. Ornament is similar to the ventral valve, without spines. Interior with fine median septum, extended forward about two-thirds of the length of the valve. Small cardinal process, posteriorly bilobate and anteriorly tetralobate. Lateral ridges diverge slightly from the hinge, reaching the midlength of ears. Adductor scars dendritic, posterior and anterior no differenced. Small endospines anterior of the visceral disc.

Etymology. In recognition of Dr. María Luisa Martínez Chacón, by her academic work and contributions on the palaeontology of invertebrates, particularly of brachiopods.

Occurrence. The specimens described are from Ixtaltepec Formation, Arroyo de las Pulgas type section, level API-7, Bashkirian-Moscovian (Lower-Middle Pennsylvanian).

Remarks. The genus described is assigned to the subfamily Anidanthinae based on shape of ears, concentric lamellae on both valves and deep corpus cavity (Brunton *et al*., 2000). Although the description of the subfamily Anidanthinae by Brunton *et al.* (2000) includes well-developed ears as a distinctive character, not all the genera included in this group share this morphologic feature. Only *Akatchania*, *Kuvelousia* and *Zia* display well-differentiated ears, a trait also present in the new genus *Martinezchaconia*. Mexican specimens have certain structural similarities with other taxa within the subfamily. However, they do not belong to any of the previously described genera. *Martinezchaconia* resembles *Anidanthus* Hill, 1950 (upper early Permian-lower late Permian of Australia, northern and central Asia and central America), due to the presence of spines in row near hinge, absence of costae on ears and dorsal lamellae. However, *Anidanthus* shows different transverse shape in outline, large ears, spines widely scattered on corpus, and median septum about half disk length. *Akatchania* Klets *in* Abramov & Grigorjeva, 1988 (early Permian = Asselian of central Siberia) differs from *Martinezchaconia* by its shallow cavity, hinge width approximately equal to corpus width, widely separated lamellae, short median septum, and complete lateral ridges in both valves. *Fusiproductus* Waterhouse, 1975 (late Permian = Capitanian of China, ?Urals and ?Siberia) is different from *Martinezchaconia* by its smaller size, highly enrolled ventral valve, wide outline with large subtubular ventral ears, and single spines on ears. *Kuvelousia* Waterhouse, 1968 (late Permian = Kazanian of Arctic Canada, USA and eastern Australia) is distinguished from *Martinezchaconia* by its larger size, widely scattered spines on ventral valve, thicker dorsal valve, and larger median septum. *Megousia* Muir-Wood & Cooper, 1960 (lower late Permian of North America, eastern Australia and Tasmania) differs from the new genus by its transverse shape, spines scattered on ventral valve, costae on ears, and extended ears curving anterodorsally. *Protanidanthus* Liao, 1979 (early Permian of China) is different from *Martinezchaconia* by its transverse shape, widely scattered spines on ventral valve, large ears, more convex ventral valve, and lack of dorsal lamellae. *Zia* Sutherland & Harlow, 1973 (late Carboniferous = Bashkirian-early Permian = Asselian of southern USA) differs from *Martinezchaconia* in its subcircular shape, flattened ventral disk, scattered spines on ventral valve, divergent lateral ridges into ear baffles, and smaller median septum. *Mongousia* Manankov, 2008 (late Permian of Mongolia) can be distinguished from *Martinezchaconia* by its transverse shape, large trail, strongly pronounced and stretched ears with their ends crescent-like curved, thin spines scattered on ventral valve, and well-pronounced and divided adductor scars. *Nuanducosia* Torres-Martínez & Sour-Tovar, 2012 (late Carboniferous = Moscovian of Mexico) differs from the new genus in the larger size, transverse shape, large ears, spines on trail and ears, and trilobate cardinal process.

Martinezchaconia luisae Torres-Martínez & Sour-Tovar sp. nov.
(Figs 3c-j)

Etymology. Like for the genus.

Types. A ventral internal mold (FCMP 1201) (holotype), two ventral external molds (FCMP 1202, 1203), four dorsal external molds (FCMP 1204, 1205, 1206, 1207) and two dorsal internal molds (FCMP 1208, 1209).

Occurrence. The specimens described are from Ixtaltepec Formation, Arroyo de las Pulgas type section, level API-7, Bashkirian-Moscovian (Lower-Middle Pennsylvanian).

Diagnosis. Ventral valve with sulcus posteriorly narrow, extending from the beak until the anterior edge. The acute beak slightly overhanging hinge. Ears well-differentiated, slightly arched. Surface ornamented by subequal costae, 12 to 16 occur in a space of 10 mm at anterior margin, separated by slightly narrower intercostal furrows, bifurcation starting at visceral disc, interrupted and enlarged by rugae. Discontinuous rugae on the valve, more notorious on flanks and ears. Four spines occurring on each ear. Dorsal valve slightly concave, principally on visceral disc. Concentric lamellae are notorious on the entire valve. Interior with long median septum. Small cardinal process, posteriorly bilobate. Lateral ridges short, reach the midlength of ears. Adductor scars are elongated and subtrigonal. Six to eight concentric rows of small endospines in front of the visceral disc.

Description. Shell moderate-sized for the subfamily, concavo-convex, subquadrate in outline, greatest width at hingeline. Deep corpus cavity. Ventral valve slightly convex with greatest convexity at midlength, geniculated, short trail. Sulcus posteriorly narrow, extending from the beak until the anterior edge. Narrow umbo, the acute beak slightly overhanging hinge. Ears well differentiated, slightly arched, subquadrate to subtriangular, separated from umbonal slopes by a shallow concave flexure. Ornamented by subequal low costae, 12 to 16 per 10 mm at anterior margin which begin on the beak and extend to end of trail, separated by slightly narrower intercostal furrows, absent on ears, bifurcation starting at visceral disc, interrupted and enlarged by rugae. Narrow, discontinuous, and irregular rugae on the valve, more notorious on flanks and ears. Four spines occurring on each ear, in single row parallel to hinge. Ventral interior not observed. Dorsal valve slightly concave, principally on

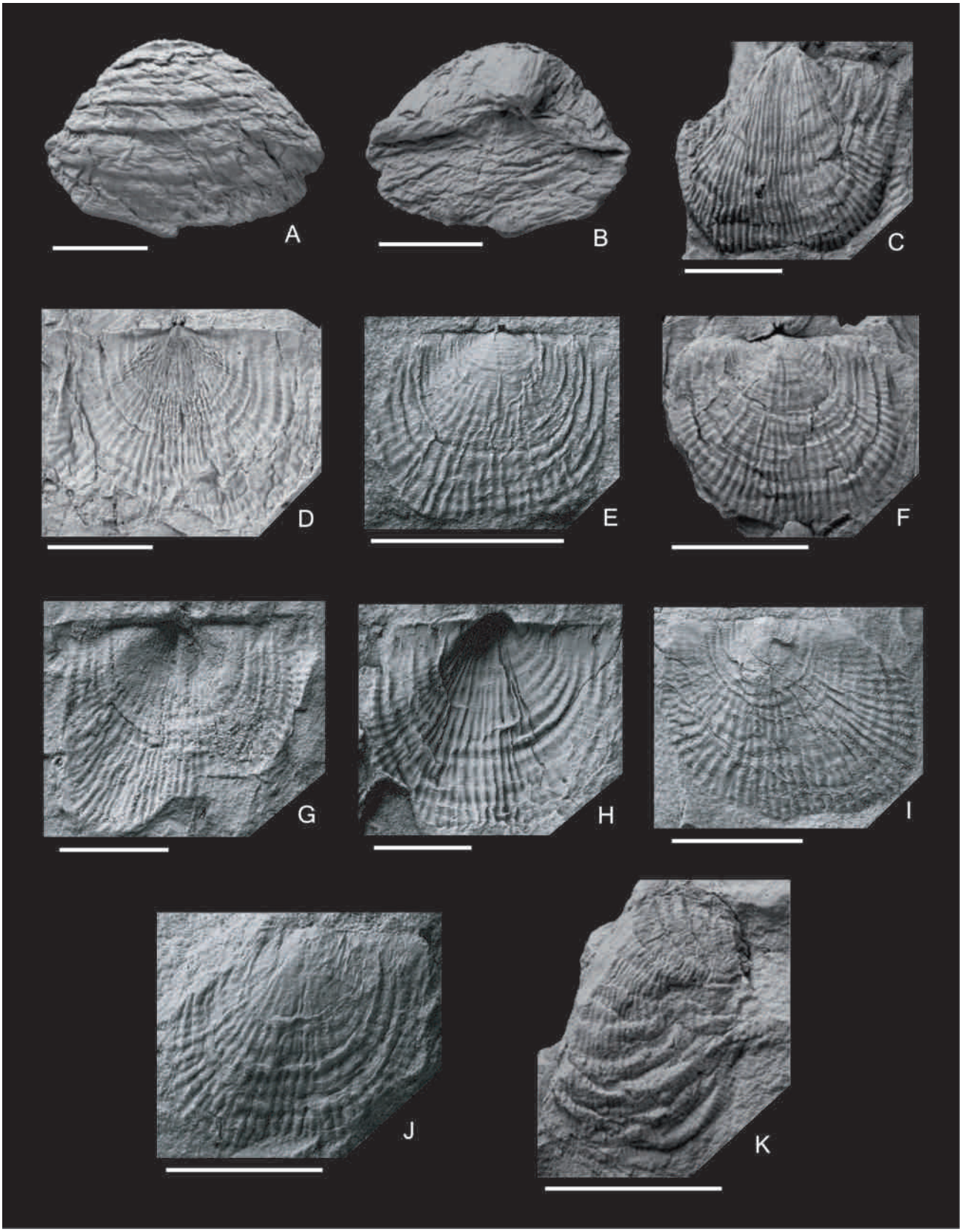

Figure 3. a, b) *Stegacanthia bowsheri* Muir-Wood & Cooper. FCMP 1200, composite mold in ventral **(a)** and dorsal view **(b)**. **c-j)** *Martinezchaconia luisae* Torres-Martínez & Sour-Tovar. **c)** FCMP 1201, holotype, ventral internal mold. **(d)** FCMP 1209, dorsal internal mold. **(e)** FCMP 1207, dorsal external mold. **(f)** FCMP 1205, dorsal external mold. **(g)** FCMP 1208, dorsal internal mold. **(h)** FCMP 1202, ventral external mold. **(i)** FCMP 1206, dorsal external mold. **(j)** FCMP 1204, dorsal external mold. **k)** *Undaria* sp. FCMP 1210, ventral valve. Scale bars = 1.0 cm.

visceral disc. Gentle median fold, corresponding to sulcus of ventral valve. Short ears, separated from umbonal slopes by a weak concave flexure. Ornament is similar to the ventral valve, but concentric lamellae are more notorious on the entire valve. Spines not observed and presumably absent. Interior with fine median septum, long, extended forward about two-thirds of the length of the valve. Small cardinal process, short, posteriorly bilobate and anteriorly tetralobate. Lateral ridges short and are slightly divergent from the hinge, reaching the midlength of ears. Adductor scars are dendritic, elongated, subtrigonal, posterior and anterior un-differenced. Six to eight concentric rows of small endospines in front of the visceral disc. Braquial ridges not observed. Measurements in millimeters and indices in Table 1.

Table 1. Shell dimensions (in millimeters) of *Martinezchaconia luisae* gen. nov. and sp. nov. with the number of costae per 10 mm in the anterior margin. Asterisks indicate estimated sizes (incomplete sample).

Specimen	Length	Greatest width	Height	No. of costae per 10 mm
Ventral valves				
FCMP 1201	21.2	24.4	5.5*	14
FCMP 1202	18.2	21.9	---	13
FCMP 1203	14.3	17.5	---	14
Dorsal valves				
FCMP 1204	13.2	16.6	---	16
FCMP 1205	16.7	18.0	---	14
FCMP 1206	18.6	22.6*	---	12
FCMP 1207	13.5	13.0	---	15
FCMP 1208	19.8*	23.8	---	13?
FCMP 1209	20.4	24.0	---	14?

Family **Monticuliferidae** Muir-Wood & Cooper, 1960

Subfamily **Auriculispininae** Waterhouse 1986 (*in* Waterhouse & Briggs, 1986)

Tribe **Auriculispinini** Waterhouse 1986 (*in* Waterhouse & Briggs, 1986)

Genus *Undaria* Muir-Wood & Cooper, 1960

Type species *Undaria manxensis* Muir-Wood & Cooper, 1960 (Balladoole, Isle of Man, Great Britain. Visean).

Undaria sp.

(Fig. 3k)

Occurrence. The specimen described is from Ixtaltepec Formation, Arroyo de las Pulgas type section, level API-2, Visean (Middle Mississippian).

Material. A ventral valve (FCMP 1210).

Description. Ventral valve convex, most inflated in posterior region, elongate-oval in outline, tubiform, the greatest width at midlength. Long trail. Narrow corpus cavity. Small and slightly convex ears at angle to visceral disc. Flanks steep and umbo short. The specimen is incomplete with approximately 16 mm in length and 13 mm in width. The ornamentation consists of very fine costae, extending from the umbo until the anterior margin, bifurcating at the edge, 18 occurring in a space of 5 mm over anterior area, absent on ears. Broad, concentric and flexuous rugae on entire valve, rarely bifurcated, occurring 8 in a space of 10 mm on the middle of the valve. Spines scattered on the trail, as well as clustered on ears.

Remarks. The material of *Undaria* sp. from Santiago Ixtaltepec displays distinctive traits of the genus such as a small size, large and tubiform trail, complete and prominent costae on concentric rugae, widely scattered spines on the ventral valve and other spines on and near of the hinge (Brunton *et al*., 2000, p. 545). The specimen is very similar to *Undaria manxensis* (early Carboniferous = Visean of Great Britain and Belgium) described by Muir-Wood & Cooper (1960, pl. 118, figs. 4, 13). The elongate-oval ventral valve, ears at right angle to visceral disc, very fine costae which are bifurcated in the anterior margin, occurring about 30 in a space of 10 mm at midlenght and absent on ears, and spines scattered on ventral valve are features that indicate a similitude between Mexican and European specimens. Nevertheless, due to the presence of clustered spines on ears and the lack of interiors and dorsal valves was not possible to make an accurate specific determination. This is the first record of *Undaria* in Mexico.

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