

A review of the crinoid columnals (Echinodermata-Crinoidea) from the Carboniferous of Mexico

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Abstract: The fossil crinoids and associated fauna from the Carboniferous (Mississippian–Pennsylvanian) of Mexico (Sonora, Tamaulipas, Hidalgo, Puebla, Guerrero, Oaxaca and Chiapas States) are described. Data are based on a combination of field and published sources, including seven previously studied localities from the central and southern areas, and four new localities from the northwestern part of the country. A total of 28 morphospecies are reported, seven from the Mississippian and 21 from the Pennsylvanian. Eleven are recorded for the first time in Mexico. These crinoid columnal morphospecies have been reported from the United States of America (Iowa, Illinois, Kentucky, Kansas, Oklahoma, Colorado and Texas), and there are doubtful reports from Poland, and several Eurasian provinces (Western Siberia, Southern Kazakhstan, Pribalkhash and the Czech Republic). Taxa distribution falls within the northwestern Mid-Continent Realm Tropical Climate Zone. The faunal assemblage comprises fusulinids, corals, bryozoans, brachiopods, trilobites, ammonites and conodonts. Fusulinids (e.g. *Fusullinella*, *Triticites*, and *Parafusulina*) have a Tethyan distribution, are also typical of the American Mid-Continental region, and are similar to fauna of the Eurasian-Arctic Province. Corals (*Lophophyllidium*, *Neozaphrentis*, *Caninia*, *Caninophyllum*, and *Lithostrotionella*) are present in the Cordilleran province of North America, and in various Eurasian provinces. Whereas fenestellid bryozoans (*Fenestella*) and brachiopods (*Neospirifer*, *Avonia*, *Wellerella*, *Composita*, and *Hustedia*) have a cosmopolitan distribution, the ammonite *Peritrochia* is distributed in the USA, Sicily, Crimea-Urals- central Asia-Timor. Trilobites (*Griffithides*) and conodonts (*Idiognathoides* and *Neognathodus*) are common in Europe, Australia, and Asia. Rev. Biol. Trop. 56 (Suppl. 3): 1-12. Epub 2009 January 05.

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Benthic stalked crinoids were highly successful animals during the Paleozoic. Remains of Paleozoic crinoid columnals are very common worldwide and, in some instances, represent the major macrobenthic fossils in the strata at many localities. In traditional taxonomy, dissociated stem remains are neglected (Gluchowski 2002). This fact necessitates the

use of a separate classification based on the crinoid columnals and pluricolumnals.

The study of crinoid remains is important, due to the extraordinarily large variety of fossils, their usefulness for biostratigraphic purposes, and because regional encrinites have been amply studied in sedimentology. Recent comments of the use of the classification of

crinoids, on the basis of disarticulated ossicles, has been performed by Stiller (2000) and Donovan (2001).

The classification for crinoid columnals was developed, independently, by Yeltysheva (1956), Stukalina (1966, 1988) and Moore and Jeffords (1968). Historically, the former was used more in Asia, and the latter in North America, for this reason, it is very difficult to estimate the approximate geographical distribution based on the columnal fragments. Moore and Jeffords' classification follows the ICZN rules. The aim of this paper is to link the Mississippian and Pennsylvanian crinoids from Mexico with the knowledge regarding Carboniferous crinoid faunas documented in another localities and to use the associated biota (fusulinids, brachiopods, bryozoans, ammonoids, and conodonts) in a wider stratigraphic context.

MATERIALS AND METHODS

Marine Paleozoic outcrops in Mexico are scarce, because they are commonly covered by thick Mesozoic and Cenozoic sedimentary sequences. Nevertheless, there are some localities with Carboniferous marine sediments that contain fossils such as crinoid columnals and pluricolumnals. The paleontological data used in this study come from eleven Carboniferous Mexican localities in: Sonora and Tamaulipas States in the northern part of the country; Hidalgo and Puebla States in the central portion; and Guerrero, Oaxaca, and Chiapas States in the southern region. The data are based on a combination of field (Sonora localities) and published sources. Taxonomic identification of crinoids is based on the parataxonomical classification proposed by Moore and Jeffords (1968).

The crinoidal fauna from the Carboniferous of Mexico has been documented in several previous reports, mostly from the central and southern parts of the country. Publications on crinoid morphospecies used in this report are Buitrón (1977), from the Chicomuselo-La Concordia, Chiapas state; Buitrón *et al.*

(1987), from Calnali, Hidalgo State; Velasco and Buitrón (1992) and Esquivel-Macías *et al.* (2004), from San Salvador Patlanoaya, Puebla state; Buitrón, *et al.* (1998) from Cañon de la Peregrina, Tamaulipas State; Buitrón, *et al.* (2000) from Nochixtlan-Ixtaltepec, Oaxaca, State; Esquivel *et al.* (2000, 2004) from Olinalá, Guerrero State; López-Lara (2002), from Pemuxco, Hidalgo State, and Buitrón *et al.* (2004, 2007), from Sonora State.

The present paper includes four new localities, thus extending the studies of crinoidal columnals into the northwestern part of Mexico. Unpublished data comes from Sierra Las Trincheras, Sierra Agua Verde, Sierra Mesteñas, and Cerros El Tule; all located in Sonora State.

RESULTS

The Carboniferous crinoid fauna in Mexico (Fig. 1, Table 1) is described by locality, general lithological features of the strata are given in Table 2.

Mississippian fossiliferous localities Sierra Las Trincheras, Sonora. New Report

Mississippian crinoid columnal morphospecies from Sierra Las Trincheras are *Rhysocamax cristata* and *Gilbertsocrinus aequalis*.

Rhysocamax cristata was also reported in Iowa and Alabama, USA (Raymond 2003), and the Tournaisian of Poland (Gluchowski 1981, 2001) and Western Siberia (Dubatolova and Dubatolova 1984) and the Moscovian (Pennsylvanian) of NE Pribalkhash (Dubatolova 1976); and *Gilbertsocrinus aequalis*, mentioned in Kentucky, USA (Moore & Jeffords 1968).

In this assemblage are also present corals from the species *Caninia corniculum* and *Caninophyllum sonorensis* (Easton *et al.* 1958), which are also distributed in the North America Cordillera, and several Euroasiatic provinces. The faunal association is typical of shallow tropical seas.

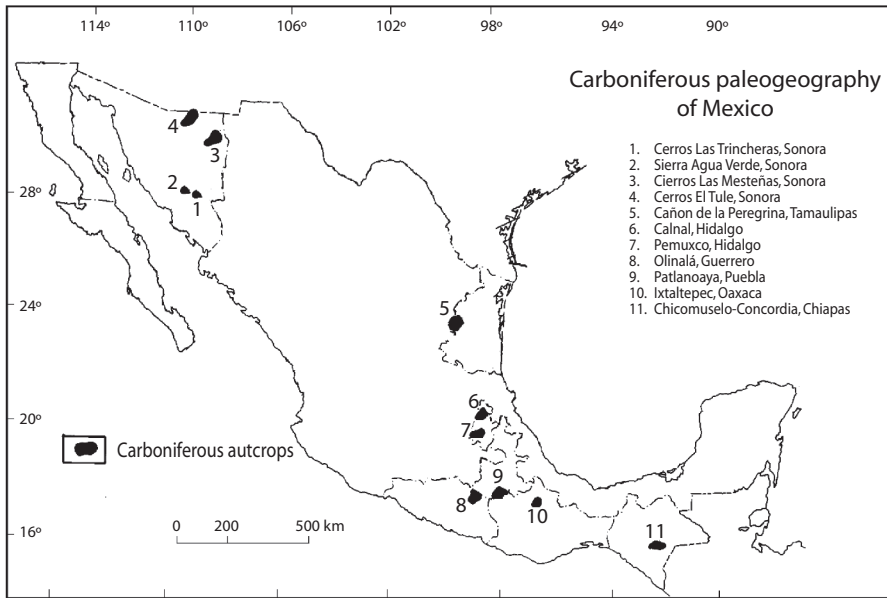


Fig. 1. Carboniferous crinoid localities in Mexico.

Fig. 1. Localidades carboníferas con crinoideos en México.

**Mississippian-Pennsylvanian
fossiliferous localities
San Salvador Patlanoaya, Puebla**

Mississippian fauna

The crinoids identified at Basal part of the Patlanoaya Formation are: *Stiberotaurus aestimatus*, *Ampholenium apolegma*, *Cyclostelechus turritus*, *Lomalegnum hormidium*, and *Pentagonomischus plebeius* (Velasco and Buitrón 1992), which are also distributed in Iowa, Illinois, and Kentucky, USA (Moore and Jeffords 1968, Webster 1973, 2003).

From these crinoids two species were reported from Poland: *A. apolegma* from Tournaisian (Gluchowski 1981, 2001) and *P. plebeius* from Tournaisian-Namurian (Gluchowski 1981).

The assemblages are dated from the Early Mississippian, based on the presence of the coral *Neozaphrentis*. Also are present sponges, corals, bryozoans, brachiopods, mollusks, and echinoderms (Villaseñor et al. 1987, Velasco and Buitrón 1992). Species of brachiopods

included: *Actinoconchus squamosus*, *Actinoconchus planosulcatus*, *Martinothyris lineatus*, *Sinuatella sinuata*, *Asyrinxia lata*, *Spirifer gregeri*, and the genera *Unispirifer*, *Punctospirifer*, *Chonetes*, *Ambocoelia*, *Barroisella*, *Rugauris*, *Rhytiophora*, *Orbiculoidea*, and *Prospira* (Villaseñor et al. 1987). These genera have a cosmopolitan distribution (Ager et al. 1965, Muir and Alwin 1965). The Mississippian strata also contains remains of continental plants in interbedded layers (Villaseñor et al. 1987, Velasco and Buitrón 1992).

Pennsylvanian fauna

The Unit III of the Patlanoaya Formation contains numerous Pennsylvanian crinoid morphospecies, such as *Cyclocaudex jucundus*, *Cyclocaudex insaturatus*, *Mooreanteris waylandensis*, *Mooreanteris perforatus*, *Cylindrocauliscus fiski*, *Plumeranteris sansaba*, and *Heterosteleschus keithi* (Velasco and Buitrón 1992), which have also been reported in Kansas, Ohio, Colorado, and Texas in the USA (Moore

TABLE 1
Carboniferous crinoids and their localities

CUADRO 1
Crinoideos Carboníferos y sus localidades

SPECIES n = Mississippian 5=Pennsylvanian	UNITED STATES OF AMERICA													MEXICO					EURO-ASIA					
	Alabama	Iowa	Illinois	Kentucky	Kansas	Ohio	Oklahoma	Colorado	Texas	Sierra Las Trincheras	Sierra Agua Verde	Cerros Las Mestizas	Cerros El Tule	Cañon La Peregrina	Calnali	Pemuxco	Patlanoaya	Olinala	Ixtaltepec	La Concordia	Poland	Czech Republic	Kazakhstan, PibalKhash	Western Siberia
<i>Ampholenium apolegma</i>				●													●					●		
<i>Baryschr anosus</i>							○								○									
<i>Cyclocaudex costatus</i>									○			○	○	○										
<i>C. insaturatus</i>					○					○	○	○		○		○	○		○					
<i>C. jucundus</i>					○	○		○				○	○		○	○								
<i>C. plenus</i>					○						○				○							●		
<i>Cyclocrista martini</i>						○		○	○	○												●		
<i>Cycloscapus laevis</i>								○	○															
<i>Cyclostelechus turritus</i>	●																●							
<i>Cylindrocauliscus fiski</i>							○				○			○		○	○	○	○					
<i>Gilbertocrinus aequalis</i>				●					●															
<i>Heterostelechus texanus</i>								○		○														
<i>H. jeffordsi</i>						○		○		○												●		
<i>H. keithi</i>						○		○	○	○	○			○		○						●		
<i>Lamprosterigma erathense</i>								○	○													●		
<i>L. mirificum</i>					○					○	○	○											○	
<i>Lomalegnum hormidium</i>	●																●							
<i>Mooreanteris perforatus</i>								○							○	○								
<i>M. waylandensis</i>								○	○					○		○								
<i>Pentagonomischus plebeius</i>				●													●					●		
<i>Pentagonopternix inscultus</i>								○		○														
<i>Pentaridica simplicis</i>								○	○													●		
<i>P. pentagonalis</i>							○		○															
<i>Plumeranteris sansaba</i>								○						○		○								
<i>Preptopremnum laeve</i>								○	○	○	○													
<i>P. rugosum</i>								○	○	○												●		
<i>Rhysocamax cristata</i>	●	●							●													●	○	●
<i>Stiberostaurus aestimatus</i>				●													●							

TABLE 2
Localization and lithological features of the Mexican localities

CUADRO 2
Localización y rasgos litológicos de las localidades mexicanas

LOCALITY	Formation/age	LITHOLOGY
1 Sierra Las Trincheras, Sonora (29° 03' 35" N, 110° 35' 55" W).	Mississippian. (Stratigraphic units in study)	Thick to massive layers of gray limestone of coarse texture, partially recrystallized and with nodules and irregular chert bodies.
2 San Salvador Patlanoaya, Puebla (between 18° 30' to 18° 34' N, and 98° 13' to 98° 18' W).	Patlanoaya Formation. Mississippian- Pennsylvanian	Variation in the lithology within the unit mainly consists in sandstone, tufaceous shale, siltstone, fine grained sandstone, and tufaceous sandstone (Vachard <i>et al.</i> 2000).
3 Sierra Agua Verde. Sonora (between 29° 17' 45" N to 29° 08' 37" N, 109° 56' 24" W to 109° 47' 09" W).	La Joya Formation. Pennsylvanian	Sequence of limestone and siltstone. (Ochoa-Camarillo & Sosa-León 1993, Stewart <i>et al.</i> 1999).
4 Cerros Las Mesteñas, Sonora (31°01' 30" N, 31° 02' 00" W).	Pennsylvanian (Stratigraphic units in study)	Sequence of limestone and siltstone.
5 Cerros El Tule, Sonora (between 37° 17' 00" N to 31° 18' 30" N and 110° 16' 00" W to 110° 19' 00" W).	Pennsylvanian (Stratigraphic units in study)	Varying from thick to massive bedded bluish gray micritic limestone with nodules and irregular chert bodies, alternate with thin layers of calcareous shale.
6 La Peregrina Canyon. Tamaulipas (between 24° 23' 00" N to 24° 13' 00" N and 99° 29' 00" W to 99° 19' 00" W).	Del Monte Formation. Pennsylvanian	Dark gray limestone, sandy limestone, sandstone and greenish gray shale (Carrillo-Bravo, 1961).
7 Calnali, Hidalgo (between 20° 50' N to 21° 80' N to 98° 30' W to 98° 45' W).	Del Monte Formation. Pennsylvanian	Constituted of limestone, sandstone, and shale (Moreno & Patiño 1981).
8 Pemuxco Region, Hidalgo (between 98° 27' N to 98° 35' N and 20° 36' W to 20° 45' W).	Guacamaya Formation Pennsylvanian	Constituted of limestone and sandstone (Arellano <i>et al.</i> 1998).
9 Olinala, Guerrero (between 17° 54' N to 17° 42' N and 98° 48' W to 98° 32' W).	Olinala Formation. Pennsylvanian	Black shale with abundant calcareous-limonitic nodules interlayered with dark limestone (Flores & Buitrón 1982).
10 Nochixtlan-Santiago Ixtaltepec. Oaxaca (between 97° 10' N to 97° 20' N, and 17° 15' W to 17° 30' W).	Ixtaltepec Formation. Pennsylvanian	Marine sequence composed of shale, mudstone, and sandstone, interbedded with limestone lenses (Pantoja-Alor 1970, 1993).
11 Chicomuselo-La Concordia. Chiapas (92° 03' 06" N, 15° 60' 12" W).	Santa Rosa Inferior Formation. Pennsylvanian	Slates with interlayers of fine grain metacuarcita, phyllite, schist, and conglomerate (Hernández-García 1973)

and Jeffords 1968, Simon and Geizer 1976), and it has also reported from Visean (Mississippian) of Poland (Gluchowski 2001).

Also found are Middle Pennsylvanian conodonts (*Idiognathodus*, *Idiognathoides*, and *Neognathodus*), common in Europe, Australia, and Asia (Brunner 1987), and fusulinids of the genus *Triticites* (Vachard *et al.* 2000).

Pennsylvanian fossiliferous localities Sierra Agua Verde, La Joya Formation, Sonora

Morphospecies of crinoids identified from Sierra Agua Verde at la Joya Formation were: *Cyclocaudex insaturatus*, *Cyclocrista martini*, *Heterostelechus keithi*, *Lamprosterigma erathense*, *Lamprosterigma mirificum*, *Mooreantheris waylandensis*, *Pentagonopterix inscultus*, *Preptopremnum laeve*, *Preptopremnum rugosum*, *Cycloscapus laevis*, and *Pentaridica simplicis* (Buitrón *et al.* 2007).

From these species *P. simplicis* and *C. martini* were reported from Visean - Namurian (Mississippian) while *P. rugosum* and *L. erathense* were registered from Visean (Mississippian) of Poland (Gluchowski 1981, 2001).

Crinoids, bear affinities to species from Kansas and Texas, USA (Moore and Jeffords 1968, Buitrón *et al.* 2007), and some species also are found in Poland (Gluchowski 1981, 2001).

There exists an abundant and diverse biota, such as chaetetids, many species of brachiopod spiriferids (*Spirifer*, *Cyrtospirifer*, and *Composita*), productids (*Antiquatonia coloradoensis* and *Avonia* sp.), fenestellid bryozoans, tabular corals (*Michelinea*), solitary corals (*Lophophyllidium*), scarce gastropods of the genus *Donaldina*, abundant fusulinids of the species *Fusulinella thompsoni* and *F. llanoensis*, and incrustant and phylloid algae like *Komia*, *Eugonophyllum*, *Kamaena*, and *Zidella*.

Cerros Las Mesteñas, Sonora. New Report

In the Cerros Las Mesteñas there are numerous crinoid columnals and pluricolumnals

identifies as the species: *Cyclocaudex plenus*, *Cyclocaudex insaturatus*, *Cylindrocauliscus fiski*, *Heterostelechus keithi*, *Heterostelechus jeffordsi*, *Heterostelechus texanus*, *Preptopremnum laeve*, *Preptopremnum rugosum*, *Lamprosterigma mirificum*, and *Cyclocrista martini*. These species are distributed in Colorado, Ohio, Kansas and Texas (Moore and Jeffords 1968, Simon and Geizer 1976), and some of them also in the Mexican localities of Sierra Agua Verde, Sonora; Calnali and Pemuxco, Hidalgo; Patlanoaya, Puebla; and Chicomuselo-La Concordia, Chiapas (Buitrón 1977), (Table 1). *H. jeffordsi* has also been reported from the Namurian (Mississippian) of the Czech Republic (Grygar and Vascek 1983), and with *Lamprosterigma mirificum* was reported from Kazakhstan and Pribalkhash (Dubatolova and Dubatolova 1984). *C. plenus* was also reported from Tournaisian (Mississippian) of Poland (Gluchowski 1986, 2001).

The fossil association also contains fenestellid bryozoans, gastropods from the Euomphalidae family, spiriferid brachiopods from the genera *Punctospirifer* and *Composita*, productids of the species *Antiquatonia coloradoensis*, the rhynchonellid *Wellerella*, colonial and tabular corals of the genus *Michelinia*, solitary corals of genus *Lophophyllidium*, and fusulinids from the genus *Fusulinella*.

Cerros El Tule, Sonora. New Report

In the Cerros El Tule were identified crinoid of the species: *Cyclocaudex insaturatus*, *Cyclocrista martini*, *Heterostelechus keithi*, *Lamprosterigma mirificum*, *Preptopremnum laeve*, *Cyclocaudex costatus*, and *Cyclocaudex jucundus*, which have also been reported in Ohio, Texas, and Kansas in the USA (Moore and Jeffords 1968), and Kazakhstan and Pribalkhash (Dubatolova and Dubatolova 1984).

The fossil assemblage is characterized by spiriferid (*Anthracospirifer*), productid (*Antiquatonia coloradoensis*), uncommon terebratulid brachiopods, solitary corals (*Syringopora*), fragments of fenestellid bryozoans, and very scarce gastropods, and chaetetids. Some limestone layers contain the

fusulinids *Beedeina* and *Triticites primarius*, and both index fossils are of a Desmoinesian to Missourian age for this part of the section.

Cañón La Peregrina, Tamaulipas

Reported from Moscovian in the Del Monte Formation at Cañón la Peregrina are the crinoid species such as *Cyclocaudex costatus*, *Cyclocaudex jucundus*, and *Cylindrocauliskus fiski* (Buitrón *et al.* 1998).

The foraminifers *Millerella*, *Eostafella*, *Stafella*, *Profusulinella*, and *Fusulinella* (Carrillo-Bravo 1961); and the ammonite *Peritrochia* (Carrillo-Bravo 1961), distributed in the USA, Sicily, Crimea-Urals-M Asia-Timor (Miller *et al.* 1957).

Calnali, Hidalgo

The Del Monte Formation also crops out in Hidalgo at Calnali, containing several species of crinoids, such as *Barychyr anosus*, *Cyclocaudex costatus*, *Cyclocaudex insaturatus*, *Cyclocaudex jucundus*, *Mooreanteris waylandensis*, *Plumeranteris sansaba*, and *Heterosteleschus keithi* (Moreno and Patiño 1981, Buitrón *et al.* 1987, Arellano *et al.* 1998). The crinoids have been reported from one or more of the following localities: Oklahoma, Texas, Kansas, and Ohio in the USA (Moore and Jeffords 1968, Simon and Geizer 1976).

The brachiopod *Neospirifer*, and the algae *Komia* had also been reported for this locality (Moreno and Patiño 1981).

Pemuxco, Hidalgo

Common Virgilian crinoid species from Pemuxco are *Cyclocaudex plenus*, *Cyclocaudex jucundus*, *Mooreanteris perforatus* and *Preptopremnum rugosum* (López-Lara 2002); the first species was reported from Tournasian and the last one from the Visean (both Mississippian Series) of Poland (Gluchowski 1981, 2001).

Accompanying fauna are fenestellid bryozoan, brachiopods, algae (*Tubiphytes*, *Epimastopora*) microforaminifers (*Diplosp*

haerina/Eotuberitina, *Eurladia*, *Endothyra*, *Tetrataxis*, *Climacammina*, *Globivalvulina*, *Calcitornella*, “*Arenovidalina*”, and fusulinids (*Stafella* and *Skinerella*); the last named genus has been reported from the Glass Mountains, Hess Mountains, and Sierra del Diablo in Texas, and has also been reported from Mexico, Guatemala and Belize (Arellano *et al.* 1998, Vachard *et al.* 2004).

Olinalá, Guerrero

Pennsylvanian strata in Olinalá are represented by the Olinalá Formation that comprise an encrinite that contains the crinoids of the morphospecies *Petaridica pentagonalis*, *Cyclocaudex costatus*, *Cyclocaudex insaturatus*, and *Cyclocaudex jucundus* (Flores de Dios and Buitrón 1982, Esquivel *et al.* 2000). This species are distributed in some of the following localities: Colorado, Texas, Kansas and Ohio, in the USA (Moore and Jeffords 1968, Simon and Geizer 1976).

Nochixtlan-Santiago Ixtaltepec, Oaxaca

In the basal part of the Ixtaltepec Formation at Santiago Ixtaltepec there are crinoid columnals of the species *Cylindrocauliscus fiski* and *Cyclocaudex insaturatus*; fusulinids as *Skinnerella biconica* and *Parafusulina brookensis* (Buitrón *et al.* 2000); abundant brachiopods of the species *Echinaria semipunctata*, *Linoproductus echinatus*, *Linoproductus planiventralis ixtaltepensis*, *Neochonetes granulifer*, *Orthotetes mixteca*, *Sinuatella oaxacensis*, and *Anthracospirifer occiduus* (Pantoja-Alor 1970, 1993, Morales-Soto and Commas-Rodríguez 1984, Sour and Quiroz 1989, Sour *et al.* 1997); accompanied by bryozoa such as *Fenestella mimica texana*, *F. plummerae*, *F. spinilifera*, *Fistulipora incrustans regularis*, and *Rhombopora corticata* (Ortiz-Lozano, 1996); trilobites of the species *Griffithides ixtaltepencensis* (Moron and Perrilliat 1988); gastropods such as *Anomphalus*, 18 species of bivalves, among them: *Phestia bellistriata*, *Parallelodon tenuistriatus*, *Astartella concentrica*, *Edmondia ovata*,

Ectogrammysia prolata, *Permphorus spinulosa*, and *Myalinella meeki* (Quiroz and Perrilliat 1998), and coelenterates like *Paraconularia* (Buitrón *et al.* 2000). Crinoids from Oaxaca also occur in Colorado and Kansas (Moore and Jeffords 1968), the majority of the rest of the fauna are found in North America and Europe, and some of them, like the bivalves, are cosmopolitan (Quiroz and Perrilliat 1998).

Chicomuselo-La Concordia, Chiapas

In the Santa Rosa Inferior Formation at Chicomuselo- La Concordia have been reported the crinoids *Cylindrocauliscus fiski?* and *Lamprosterigma mirificum* (Hernández-García 1973, Buitrón 1977).

The crinoids are characteristic of the Pennsylvanian of Kansas and Texas, USA (Moore and Jeffords 1968) and *L. mirificum* is also in Kazakhstan and Pribalkhash, Russia (Dubatolova, and Dubatolova, 1984).

The fossiliferous strata of the unit contains a great variety of invertebrates, consisting of bryozoans, corals and bivalves (*Aviculopecten*, *Paleolima*). The bivalve *Aviculopecten* is similar to *Aviculopecten occidentalis* of the Carboniferous of Nebraska and Missouri (USA) (Shimer and Shrock 1949), the bivalve *Paleolima* lived from the Mississippian until

the Triassic in Europe, Asia and North America (Cox *et al.* 1969).

Biogeographic significance

The occurrence of fossil crinoids in marine upper Paleozoic outcrops in Mexico suggests a moderately shallow-water epicontinental setting. Further, crinoids are excluded from environments with low levels of oxygen, and depend on environments with water currents (Simms 2000, Ausich *et al.* 2002).

The Carboniferous crinoid associations of Mexico bears affinities to faunas described from the United States, in Iowa, Illinois, Kentucky, Kansas, Oklahoma, Ohio, Colorado, Alabama, and Texas. This has been mentioned previously by Buitrón *et al.* (1987, 1998, 2000, 2004, 2007), and Esquivel-Macías *et al.* (2004).

This distribution can be explained by the fact that the Rheic ocean served as a link between the Panthalassic Ocean and Paleo-Tethys 325 million years ago (Fig. 2). This situation permitted the wide distribution of the marine fauna with planktonic larvae into the shallow tropical region.

The typical bioassociation of tropical and shallow Carboniferous seas in Mexico included encrusting and phylloid algae (*Komia*, *Eugonophyllum*, *Kamaena* and

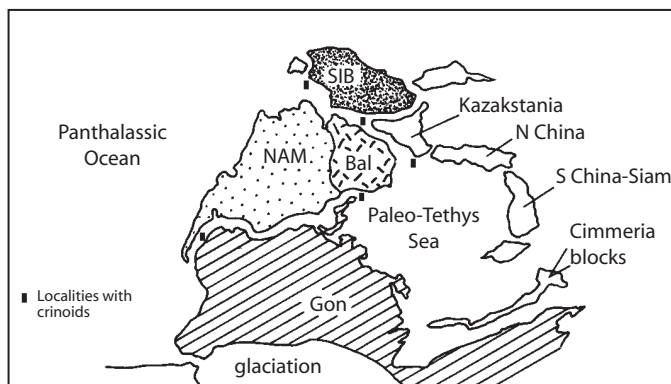


Fig. 2. Paleogeographic map of the Carboniferous (300 My) with the distribution of the crinoids (modified after Scotese 2001 and Blakey 2005).

Fig. 2. Mapa paleogeográfico del Carbonífero (300 Ma) con la distribución de los crinoideos (modificado de Scotese 2001 y Blakey 2005).

Zidella), fusulinids (*Triticites*, *Fusulinella*), and corals (*Lophophyllidium*, *Neozaphrentis*, *Caninophyllum*, *Cyathaxinia*, *Lithostrotionella*), all with a Tethyan distribution and, typical of the American Mid-Continental region. Crinoid species also are similar to faunas of Midcontinent region. Fenestellids, brachiopods and bivalves, on the other hand, have a cosmopolitan distribution.

DISCUSSION

A total of 28 crinoid morphospecies were recorded from the Carboniferous of Mexico; seven from the Mississippian and 21 from the Pennsylvanian. For Mexico, eleven crinoid species are newly reported: for the Mississippian, *Rhysocamax cristata*, and for the Pennsylvanian, *Cyclocrista martini*, *Cycloscapus laevis*, *Heterosteleschus texanus*, *H. jeffordsi*, *Lamprosterigma mirificum*, *Pentagonopternix insculptus*, *Pentaridica simplicis*, *P. pentagonalis*, *Preptoprennum leave*, and *Rhysocamax cristata*.

The Carboniferous crinoid association bears affinities to the faunas described from the United States, in Iowa, Illinois, Kentucky, Kansas, Oklahoma, Ohio, Colorado, Alabama and Texas. Nevertheless the use of a varied taxonomical classifications make difficult the comparison between crinoid faunas based on columnals and pluricolumnals.

The affinity between crinoids of Mexico, Poland and Czech Republic are doubtful, because there is inconsistency in the age. *Rhysocamax cristata* registered from the Mississippian of North America (Alabama and Iowa in USA and Sierra Las Trincheras, Mexico), Poland and Western Siberia, are reported from the Pennsylvanian of Pribalkhash by Duvatolova (1976). While seven species (*Cyclocaudex plenus*, *Cyclocrista martini*, *Heterosteleschus jeffordsi*, *H. keithi*, *Lamprosterigma erathense*, *Pentaridica simplicis* and *Preptoprennum rugosum*) described and cited from the Pennsylvanian of North America were registered from the Mississippian of Poland and Czech Republic. There are some difficulty on

the interpretation of the distribution, if Poland reports are considered, because the localities are found in different tectonics blocks.

The Carboniferous fossil association that includes algae, fusulinids, corals, bryozoans, brachiopods, gastropods, trilobites, and crinoids, strongly suggests that the deposits occurred in a tropical shallow sea. The biota mentioned has a high stratigraphic and paleogeographic significance due to close relations with North America. The wide distribution of taxa implies that a diverse marine faunal province existed, and that it included parts of the northwestern, central and southern areas of Mexico, and regions of North America.

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RESUMEN

Se describe la fauna de Crinoideos fósiles del Carbonífero (Misisípico-Pensilvánico) de México (Sonora, Tamaulipas, Hidalgo, Puebla, Guerrero, Oaxaca y Chiapas) y su fauna asociada. La información se basa en datos de campo nuevos y datos ya publicados, incluyendo siete localidades previamente estudiadas de las áreas central y sur de México. Se añaden cuatro nuevas localidades de la parte noroeste de México en el Estado de Sonora. Se reportan un total de 28 morfoespecies: siete del Misisípico y 21 del Pensilvánico. Once especies son nuevos reportes para México. Estas morfoespecies de placas columnares de crinoideos han sido reportadas de los Estados Unidos de Norteamérica, (Iowa, Illinois, Kentucky, Kansas, Oklahoma, Colorado y Texas), y hay dudosos registros de Polonia y varias provincias Euro-asiáticas (Siberia Occidental, Sur de Kazakhstan, Pribalkhash y la República Checa). La distribución de los taxa analizados cae dentro de la Zona Centro Continental de clima tropical. Las asociaciones faunísticas comprenden fusulinidos, corales, briozoarios, trilobites, amonites y conodontos. Los fusulinidos (por ejemplo *Fusulinella*, *Triticites* y *Parafusulina*) que se distribuyeron en el mar de Tethys, también son típicos de la Región Americana Central y son

similares a la fauna de la Provincia Euroasiática-Ártica. Los corales (*Lophophyllidium*, *Neozaphrentis*, *Caninia*, *Caninophyllum* y *Lithostrotionella*) están presentes en la Provincia de la Cordillera de América del Norte, y en varias Provincias Euroasiáticas, mientras que los briozoarios fenestélidos (*Fenestella*) y braquiópodos (*Neospirifer*, *Avonia*, *Wellerella*, *Composita* y *Hustedia*) son de distribución cosmopolita. El género de amonite *Peritrochia* se distribuye en EUA, Sicilia, Crimen, Montes Urales, Asia-Timor. Los trilobites (*Griffithides*) y conodontos (*Idiognathoides* y *Neognathodus*) son géneros comunes en Europa, Australia y Asia.

Palabras claves: placas columnares de crinoideos, Carbonífero, México, distribución paleogeográfica.

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