



## Research note

# Pennsylvanian biota of the Sierra Agua Verde, Sonora, Mexico: biostratigraphic and paleogeographic considerations<sup>☆</sup>

## *Biota del Pensilvánico de la sierra Agua Verde, Sonora, México: consideraciones bioestratigráficas y paleogeográficas*

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## Abstract

The marine biota from the middle Pennsylvanian outcrops of the Sierra Agua Verde, located in mid-eastern Sonora, consists of phylloid algae of the genera *Komia* and *Eugonophyllum* and a number of invertebrates. These species include bioaccumulations of chaetids; brachiopods of the genera *Dielasma* sp., *Reticulariina* sp., *Anthracospirifer* sp., *Antiquatonia* sp.; bryozoans of the genus *Thamniscus*; tabulate corals such as *Syringopora* and solitary corals such as *Zaphrentis*; fusulinid foraminifera such as *Pseudostaffella*, *Eoshubertella texana*, *Fusulinella llanoensis*, and *Zellerella*; gastropods of the genus *Euomphalus* and *Donaldina*; and the crinoid genera *Cyclocaudex*, *Cyclocrista*, *Heterosteleschus*, *Lamprosterigma*, *Mooreanteris*, *Pentagonopternix*, *Preptopremium*, *Cyclocaspus*, and *Pentaridica*. The material was collected from outcrops in the first 512 m of the La Joya Formation, and their sediments have a total thickness of 780 m and consist of limestone interbedded with calcareous mudstone and sandstone lenses. The age of the middle Pennsylvanian strata corresponds to that of the Atokan stage (311 million years). The species assemblages are typical of a shallow tropical marine benthos. The analysis of the distribution of the species allowed for the determination of their paleogeographic relationships with the components of the biota of the Carboniferous strata of Texas and Kansas in the United States of America, which belong to the province of the North American Craton.

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**Keywords:** Carboniferous; NW Sonora; Pennsylvanian; Upper Paleozoic

## Resumen

La biota marina procedente de afloramientos del Pensilvánico medio de la sierra Agua Verde localizada en la región centro este de Sonora, está conformada por algas filoides de los géneros *Komia* y *Eugonophyllum*, por numerosos invertebrados entre ellos bioacumulaciones de chaetétidos,

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braquiópodos de los géneros: *Dielasma* sp., *Reticulariina* sp., *Anthracospirifer* sp., *Antiquatonia* sp., briozoarios fenestélidos del género *Thamniscus*, corales tabulados como *Syringopora* y solitarios como *Zaphrentis*, foraminíferos-fusulinidos entre ellos *Pseudostaffella*, *Eoshubertella*, *Fusulinella*, *Zellerella*, gasterópodos de los géneros *Euomphalus* y *Donaldina*, y numerosos géneros de crinoideos *Cyclocaudex*, *Cyclocrista*, *Heterosteleschus*, *Lamprosterigma*, *Mooreanteris*, *Pentagonopternix*, *Preptopremium*, *Cycloscaspus*, *Pentaridica*. El material fue recolectado en afloramientos de los primeros 512 m de la formación La Joya, cuyos sedimentos tienen un espesor total de 780 m y están formados por caliza intercalada con lodolita calcárea y lentes de arenisca. La edad de los estratos corresponde al Pensilvánico Medio (Atokano) con una antigüedad de 311 millones de años. La tanatocenosis es típica del bentos de mares tropicales someros. El análisis de la distribución de las especies permitió establecer relaciones paleogeográficas con componentes de la biota del Carbonífero de Texas y Kansas en los Estados Unidos de Norteamérica, pertenecientes a la provincia del Cratón Norteamericano.

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**Palabras clave:** Carbonífero; NO de Sonora; Pensilvánico; Paleozoico Superior

The Paleozoic rocks of Sonora consist of carbonate rocks from a warm, shallow marine environment. These rocks are believed to be between approximately 250 and 540 million years old and contain a diverse biota composed of phylloid algae, fusulinid foraminifera, sclerosponges, corals, bryozoans, brachiopods, and crinoids. Relatively few studies of the Pennsylvanian inner shelf of the Sierra Agua Verde have been conducted (Peiffer, Echevarría, Salas, & Rangin, 1980). Previous research includes the publications of Almazán-Vázquez, Buitrón-Sánchez, Vachard, Mendoza-Madera, and Gómez-Espinosa (2007); Buitrón-Sánchez, Almazán-Vázquez, Vachard, and Gómez-Espinosa (2006); Buitrón-Sánchez, Gómez-Espinosa, Almazán-Vázquez, and Vachard (2007); Mendoza-Madera, Almazán-Vázquez, Buitrón-Sánchez, and Vachard (2004); Stewart, Madrid, Poole, and Kernet (1988); Stewart, Poole, and Roldán (1990) and Stewart et al. (1999). The abundance and variety of the biota have been the subjects of paleontological study (Gómez-Espinosa, 2010; Ochoa-Camarillo & Sosa-León, 1993).

The State of Sonora is located in northwest Mexico and is bordered on the north by the United States of America, on the

east by the State of Chihuahua, on the south by the State of Sinaloa, and on the west by the Gulf of California and the State of Baja California. The state's geographic coordinates are latitude 32°29' N, 26°17' S; longitude 108°25' E, 115°03' W (Fig. 1). The Sierra Agua Verde falls within the following coordinates: latitude 29°19' N and longitude 109°56' W, latitude 29°19' N and longitude 109°49' W, latitude 29°10' N and longitude 109°55' W, and latitude 29°10' N and longitude 109°46' W. The area is located 110 km north-east of the state capital of Hermosillo (Fig. 1).

The geology of the Paleozoic era in the mid-eastern region of Sonora is characterized by a calcareous platform and basinal siliciclastic deposits (Ochoa-Camarillo & Sosa-León, 1993) spanning the interval from the Cambrian to the Permian (Stewart, & Poole, 2002). The fossil biota comes from the limestone and shale of the La Joya formation, found in the outcrops of La Joya and Agua Caliente that form parts of the Sierra Agua Verde, which have thicknesses of approximately 294 and 780 m, respectively. The lower contact of the bed is contiguous with the Santiago formation, and the upper contact is formed by a normal fault with the Tuntunudé formation. The base of this

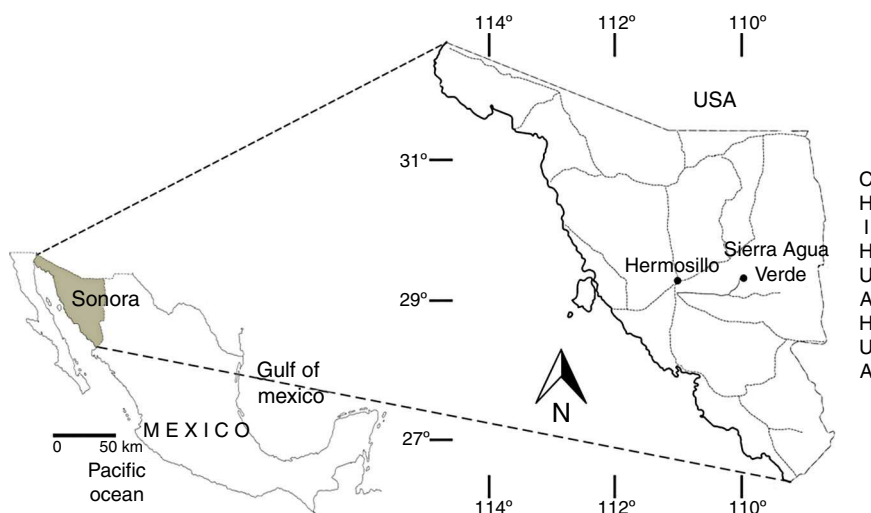


Figure 1. Location of the Sierra Agua Verde (Almazán-Vázquez et al., 2007).

formation mainly consists of fossiliferous limestone in thick to medium strata, sandstone, mudstone, and lenses of sandstone and chert. Limestone is found throughout the entire sequence but occurs mainly in its lower portion, where it is light gray to reddish-brown color and forms medium-to-thick bands to massive levels with thin layers of interbedded calcareous mudstone. The limestone also features black and red chert nodules on its weathered surface and gray chert nodules on its fresh surface. The stratification of the limestone is gradual. At the sequence's base, it ranges from thick to massive strata with chert nodules and lenses. This portion of the sequence can be seen in the western foothills of La Joya. Next, there is a block of limestone, light gray on its unexposed surface and blue-gray on its weathered surface, which contains interbedded calcareous mudstone of a reddish color in strata of up to 3 m in thickness, with small quartz crystals occurring in the mudstone. Present in both the limestone and the mudstone are tabulate corals of the genus *Syringopora* and numerous plates and columnar fragments of crinoids of the genera *Pentameridica*, *Pentagonopternix*, *Cyclocaudex*, *Mooreanteris*, *Lamprosterigma*, *Cyclocrista*, *Preptopremnum*, *Heterosteleschus*, and *Cycloscapus*, as well as the shell remnants of gastropods and fenestellid bryozoan colonies. The upper part of the sequence consists of limestone strata of medium thickness, interbedded with calcareous mudstones, nodular chert, and lenses. The limestone is a light gray to reddish-brown color on its weathered surface and a light to dark gray on its fresh surface, the mudstone is a reddish-brown color, and on both the weathered and fresh surfaces, the nodular chert and lenses are white to reddish-brown with small bands of dark color; sandstone lenses and nodules are also present. This portion contains specimens of the bryozoan genus *Thamniscus*, the brachiopod genus *Anthracospirifer* and the sclerosponges genus *Chaetetes* of the middle Pennsylvanian strata.

The fossil biota comes from the limestone and shale rocks of the La Joya formation, in the outcrops of La Joya that form part of the Sierra Agua Verde, which have thicknesses of approximately 294 m and 780 m, respectively (Ochoa-Camarillo & Sosa-León, 1993). The lower contact of the bed is contiguous with the Santiago formation, and the upper contact is formed by a normal fault with the Tuntunudé formation. The base consists of fossiliferous limestone, sandstone, mudstone, and sandstone and chert lenses. The limestone exhibits gradual stratification. At the sequence's base, it ranges from thick to massive strata with chert lenses and nodules. This portion of the sequence can be seen in the western foothills of La Joya. Next, there is a block of limestone with interbedded calcareous mudstone; the mudstone contains small quartz crystals. Present in both the limestone and the mudstone are tabulate corals and numerous plates and columns of crinoids, as well as the fragment shells of gastropods and fenestellid bryozoans. The upper part consists of limestone with interbedded calcareous mudstones, chert nodules, and lenses strata (Fig. 2).

The biota identified in the La Joya formation contains algae of the genera *Eugonophylum* and *Komia* (Figs. 3 and 4), fusulinid foraminifera of the species *Fusulinella llanoensis* Thompson, 1935 (Fig. 5); *Zellerella* sp. (Fig. 6); *Chaetetes* sp. (Figs. 7–9); *Syringopora* sp (Fig. 10), and solitary corals such as *Lophophyllidium* sp., (Figs. 11–12), and fenestellid bryozoans

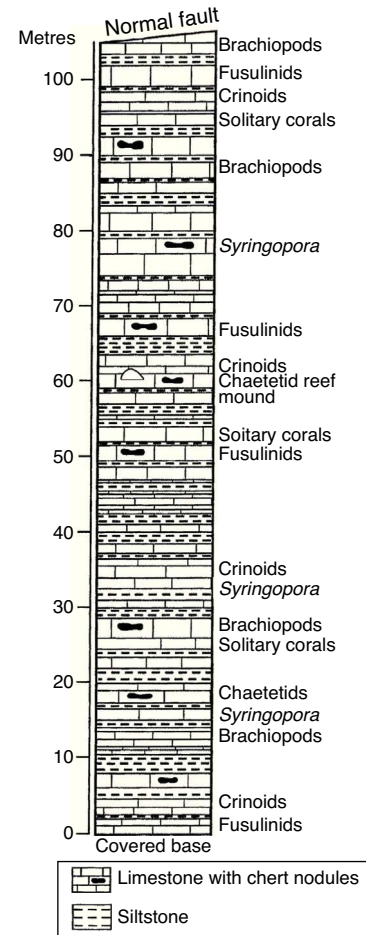


Figure 2. Stratigraphic column of the La Joya formation in Sierra Agua Verde (from Ochoa-Camarillo & Sosa-León, 1993).

of the genus *Thamniscus* (Fig. 13). Brachiopods are represented by the species *Reticulariina* sp., (Fig. 14), *Dielasma* sp. (Fig. 15), *Anthracospirifer* sp. (Fig. 16), *Antiquatonia* sp., (Fig. 17). Two gastropods were identified: *Straparollus* (*Euomphalus*) sp. (Fig. 18), and *Donaldina* cf. *D. robusta* (Stevens, 1858) (Fig. 19). The crinoids are widely represented by numerous plates and columnar fragments from the species *Pentagonopternix insculptus* Moore & Jeffords, 1968 (Fig. 20), (21) *Pentameridica simplicis* Moore & Jeffords, 1968 (Fig. 21); (22) *Cyclocaudex* sp. (Fig. 22), *Mooreanteris waylandensis* Moore & Jeffords, 1968 (Fig. 23), *Lamprosterigma mirificum* Moore & Jeffords, 1968 (Fig. 24), *Cyclocrista martini* Moore & Jeffords, 1968 (Fig. 25), *Preptopremnum rugosum* Moore & Jeffords, 1968 (Fig. 26), *Preptopremnum leave* Moore & Jeffords, 1968 (Fig. 27), *Heterosteleschus keithi* Moore & Jeffords, 1968 (Fig. 28). Reconstruction of biotopes (Fig. 29)

Paleogeographic considerations of the Paleozoic central-eastern region. The Sonoran territory was located southwest of the Laurentian continent and south of the Equator during the middle-late Paleozoic era. Sedimentary facies occur in the mid-eastern region and predominantly consist of a calcareous platform with basinal siliciclastic deposits.

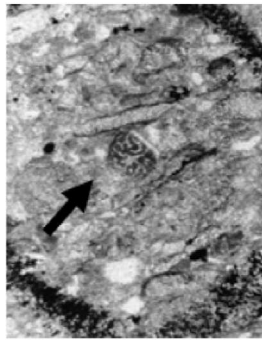


Figure 3

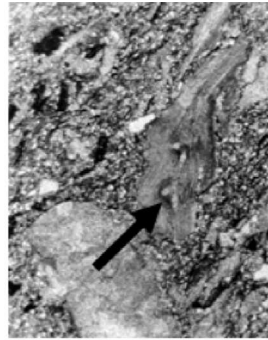
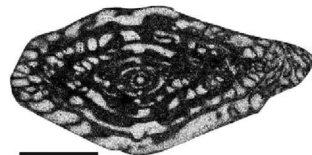


Figure 4



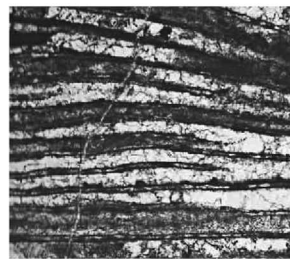
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Figure 5



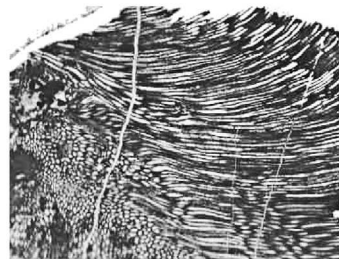
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Figure 6



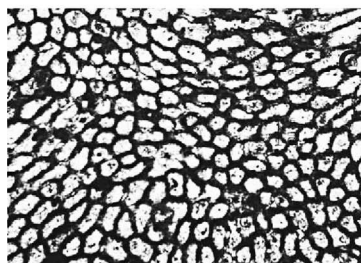
0.1 cm

Figure 7



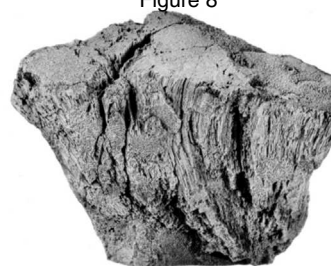
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Figure 8



0.1 cm

Figure 9



5 cm

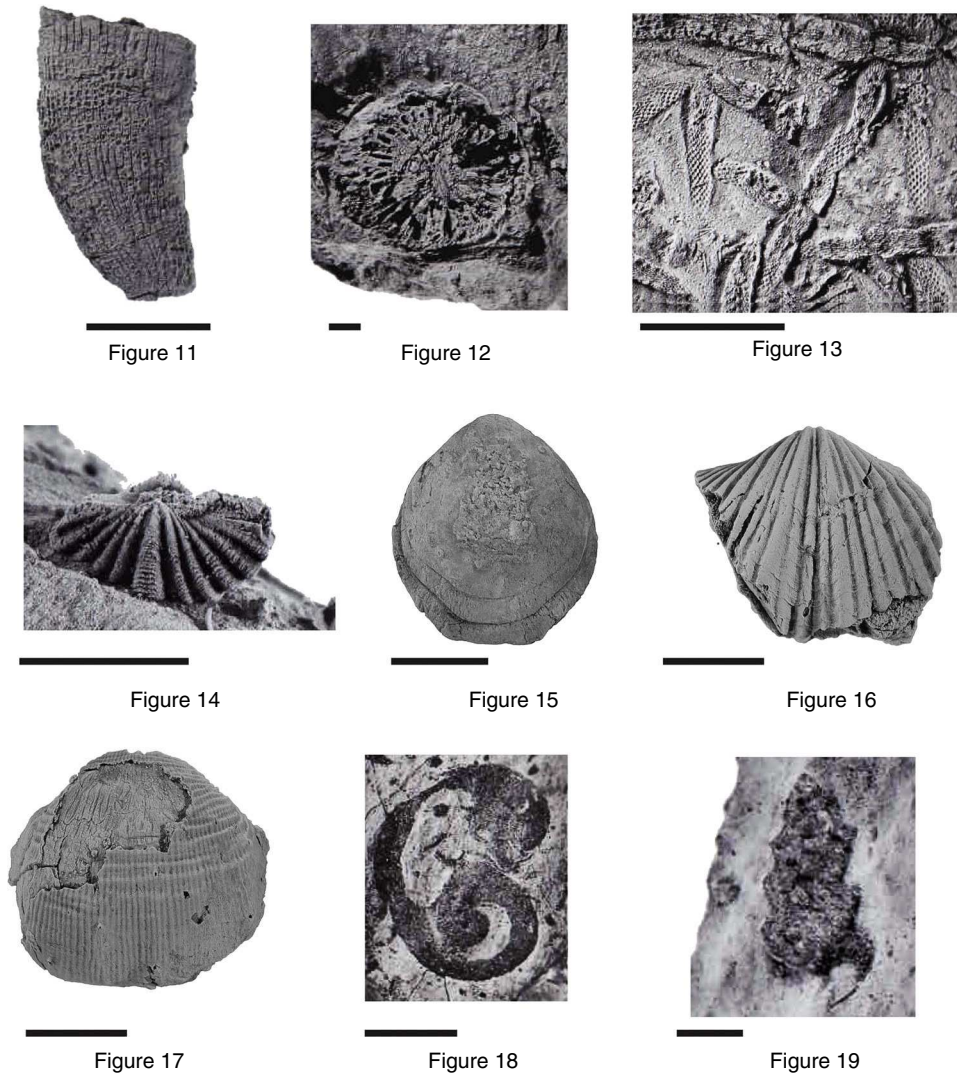
Figure 10

Figures 3–10. (3) *Eugonophyllum* sp.; (4) *Komia* sp.; (5) *Fusulinella llanoensis* Thompson, 1935; (6) *Zellerella* sp.; (7–10): *Chaetetes* sp.: (7) view of the colony; (8) microscopic view of the longitudinal section, and (9) microscopic view of transverse section; (10) lateral view.

The limestone sequences are outcrops of rocks whose ages range from the Cambrian to the early Permian. Since the year 2000, interest in the mid-eastern region of Sonora has increased, particularly for the Sierra Agua Verde, as shown by the studies of Buitrón-Sánchez, Almazán-Vázquez, and Vachard (2004); Buitrón-Sánchez, Almazán-Vázquez, Vachard, Gómez-Espinosa, and Mendoza-Madera (2005), and Mendoza-Madera et al. (2004). The algae, fusulinids, and sponges of the Pennsylvanian strata in Sonora show an affinity with the biota of Arizona, New Mexico, Texas, and California, USA. A

possible connection between Mexico and the Ural Mountains and/or the Paleo-Tethys (Ocean) has been reported previously by Buitrón-Sánchez, Vachard, Almazán-Vázquez, and Palafox-Reyes (2012), Vachard, Flores-de Dios, Buitrón-Sánchez, and Grajales-Nishimura (2000), Vachard, Flores-de Dios, Pantoja, Buitrón-Sánchez, Arellano, and Grajales-Nishimura (2000), and Vachard, Vidaurre-Lemus, Fourcade, and Requena (2000).

The regional geodynamic problem in Sonora is simplified, as the assemblages are similar between the North American Craton and the Caborca land form (González-León, 1989; Sedlock,



Figures 11–19. (11–12) *Lophophyllidium* sp, longitudinal (11) and transversal (12) views; (13) *Thamniscus* sp.; (14) *Reticulariina* sp.; (15) *Dielasma* sp.; (16) *Anthacospirifer* sp.; (17) *Antiquatonia* sp.; (18) *Straparollus* (*Euomphalus*) sp.; (19) *Donaldina* cf. *D. robusta* (Stevens, 1858).

Ortega-Gutierrez, & Speed, 1993). The North American Craton was separated from Gondwana and South America by a remnant of the Rheico Ocean, where some land was tectono-stratigraphically separated by carbonated platforms such as the Mixteco and Oaxaquia platforms while a number of basins were developed in the middle parts of Mexico (Almazán-Vázquez et al., 2007; Buitrón-Sánchez et al., 2007; Gómez-Espinosa, Vachard, Buitrón-Sánchez, Almazán-Vázquez, & Mendoza-Madera, 2008) (Fig. 30).

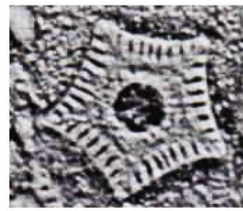
Paleozoic marine outcrops of Mexico are rare compared to terrestrial extensions, as these formations are often covered by a thick sequence of Mesozoic and Cenozoic sediments. However, there are a number of localities where these sedimentary Carboniferous marine rocks, containing crinoid fossils of the Mississippian and Pennsylvanian, are exposed. In Mexico, these

areas are found in the northern states of Sonora and Tamaulipas, in the central states of Hidalgo and Puebla, and in the southern states of Guerrero, Oaxaca, and Chiapas. The biota identified in the La Joya formation contain algae of 2 genera, *Eugonophylum* and *Komia*; fusulinid foraminifera of the species *Pseudostaffella* sp., *E. texana*, *F. llanoensis*, and *Zellerella* sp.; sclerosponges of the genus *Chaetetes*; tabulate corals such as *Syringopora* and solitary corals such as *Lophophyllidium* sp., and fenestellid bryozoans of the genus *Thamniscus*. The brachiopods are represented by the species *Dielasma* sp., *Reticulariina* sp., *Anthracospirifer* sp., *Antiquatonia* sp.; 2 genera of gastropods were also identified, *Euomphalus* and *Donaldina*. The crinoids are widely represented by numerous columns and articulated plates of the genera *Pentaridica*, *Pentagonopternix*, *Cyclocaudex*, *Mooreanteris*, *Lamprosterigma*,



0.25 cm

Figure 20



0.25 cm

Figure 21



1 cm

Figure 22



0.5 cm

Figure 23



1 cm

Figure 24



0.25 cm

Figure 25



0.25 cm

Figure 26



0.25 cm

Figure 27



0.25 cm

Figure 28

Figures 20–28. (20) *Pentagonopternix insculptus* Moore & Jeffords, 1968; (21) *Pentaridica simplicis* Moore & Jeffords, 1968; (22) *Cyclocaudex* sp.; (23) *Mooreanteris waylandensis* Moore & Jeffords, 1968; (24) *Lamprosterigma mirificum* Moore & Jeffords, 1968; (25) *Cyclocrista martini* Moore & Jeffords, 1968; (26) *Preptopremnum rugosum* Moore & Jeffords, 1968; (27) *Preptopremnum leave* Moore & Jeffords, 1968; (28) *Heterosteleschus keithi* Moore & Jeffords, 1968.

*Cyclocrista*, *Preptopremnum*, *Heterosteleschus*, and *Cycloscapus*. The exact locations of these genera can be seen in the stratigraphic column. The present study relates the age of the layers that contain the biota of the Sierra Agua Verde, Sonora, to the stratigraphic index layers of Kansas, Colorado, and Texas in the United States of America. The age of the Sonoran strata corresponds to that of the Atokan stage, the floor of the Upper Pennsylvanian strata, which is 311 million years old. The specimens of the species comprising the biota found in the outcrop deposits occurred close to the coast, as interpreted by the presence of organisms that typically inhabited the shallow, warm waters of a coastal marine environment.

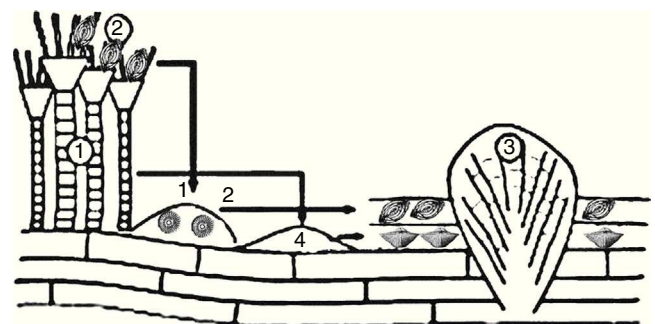


Figure 29. Reconstruction of biotopes of crinoids (1) fusulinids (2) and chaetetids (3).

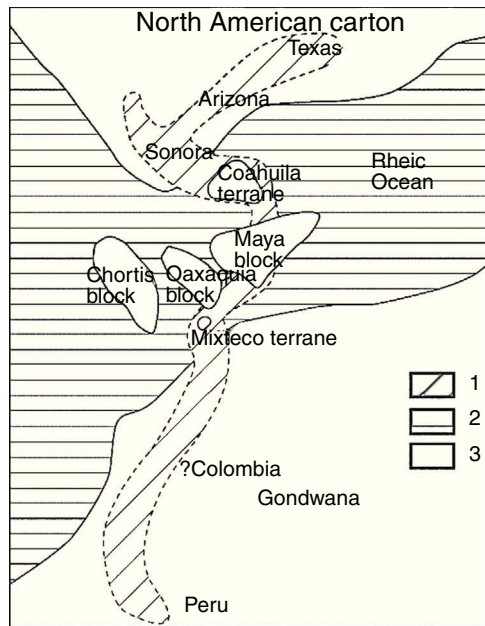


Figure 30. Paleogeographic reconstruction showing the connection between Sonora, the North American Craton (Arizona, Texas) and South American domain through different Mexican terrains (Coahuila, Maya, Mixteco, and Oaxaquia). 1, Carbonate platforms; 2, flysch basins; 3, islands and continents (Gómez-Espinosa et al., 2008).

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