First report on seeds dispersed in Tuzancoa Formation, Hidalgo

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Abstract: *It describes for the first time impressions of four Cyssusallian morphotaxones corresponding to the oldest records of these structures in Mexico. Three of them were assigned according to their morphology, type of symmetry, presence-absence of wing, type of apex and shape of the seed to the genera Cordaicarpus and Cornucarpus. The fourth and final morphotaxon describes an incomplete structure where the apex was not preserved, so it remains if taxonomic allocation. Despite being scattered seeds, members of the genus Cordaicarpus have been associated with the cordaitales, coniferal, Callistophytal and Peltaspermal orders. Meanwhile, the seeds of the genus Cornucarpus have been linked with Glossopteridals and Coniferales. Most of the orders present in the macroflora reported for the Tuzancoa Formation.*

Keywords: *Megaspore, Platispermic, Permian, Mexico.*

1. INTRODUCTION

Seeds are the main reproductive organ of the vast majority of current plants. They represent their most complex and most efficient habit of reproduction since they play a fundamental role in the renewal, persistence, and dispersal of their populations and also intervene in the regeneration of communities and ecological succession (Gerrienne, 2004). The origin of the plants with seeds was one of the most significant events in the evolution of the vegetation since the presence of this structure allowed them to colonize habitats that were not previously accessible to the plants that reproduced by spores (DiMichele, Phillips and Olmstead, 1986). The oldest seeds date from the Devonian and are innovations of the evolution of vascular plants, (Gillespie et al., 1981). The spermatophytes of the Carboniferous (Lyginopteridales, Medullosales and Gigantopteridales) together with the spermatophytes-lignophytes such as the Coniferales constituted the rainforests of the Carboniferous and left a record of their seeds. For the Permian macrofloras whose seeds are usually isolated, as they are rarely found in organic connection with the rest of the plant.

In Mexico, the oldest continental cover corresponds to the upper Paleozoic and is represented by sediments of four lithostratigraphic units where fossils of Permian plants were preserved; Matzitzi, Patlanoaya, Todos Santos and Tuzancoa. The first works carried out in the latter were done by Carrillo-Bravo (1965), and since then the study of this formation has been biased, superficially and intermittently. However, recently the Paleobotany team of the Faculty of Higher Studies Zaragoza, UNAM (FES Zaragoza) collected in the strata of this unit the first seed fossils with an approximate age of 298-290Ma. So this work aims to document the presence of the oldest reproductive structures of spermatophytes collected in strata of the lower Permian of Mexico. Floras of this age have been reported for Antarctica (Taylor and Taylor 1987, 1992; Klavins et al., 2001; McManus et al., 2002), Australia (Nishida et al., 2003) and China (Tian et al., 1996; Wang1998; Hilton et al., 2001a, 2001b, 2004; Wang et al., 2003a, 2003b) and North America (Miller and Brown, 1973; Mamay et al., 1984).

2. METHODOLOGY

The collected material is accompanied by coniferous macrofossils and other gymnosperms. It comprises four specimens of seeds preserved as impressions and carbonaceous compressions in fine-grained, yellowish-brown sandstones. It is deposited in the Paleontological Collection of the FES Zaragoza with the acronym CFZ Tuz. The specimens were observed with an Olympus stereoscopic microscope and photographed with a Nikon D500 camera.

Because they are dispersed seeds and these structures are preserved as impressions or carbonaceous compressions, the specimens were described using the terminology proposed by Millan 1974 as modified from Archangelsky 2000. Understanding of megaspore, the central body of the seed, which is protected by a membrane called the nucellus, is in turn surrounded by one, two or three tegumentary layers that cover it, leaving it exposed only in the micropyle, defined as a channel to through which pollination is performed. The hilum is the scar left at the base of the seed by the vascular bundle of the peduncle after the detachment from the mother plant (Figure 1).

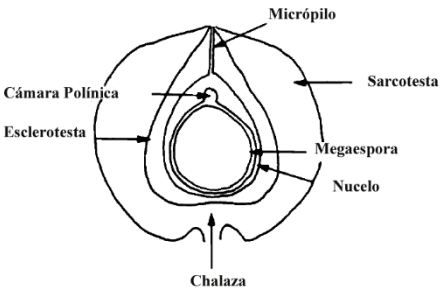

Fig 1. *Structure of a gymnosperm seed*

For the morphological description of the different types of seeds the following abbreviations were used: LT, the total length of the seed; AT, total seed width; LN, the total length of the nucellus; As, the width of the sarcotesta; AS/AN, the relationship between the maximum width of the sarcotesta and the nucellus.

2.1 Study area

The municipality of Calnali is located north of the state of Hidalgo, 28km from Escamilla Molango, on the banks of the Calnali River, the Tuzancoa Formation outcrops which extends to the central and southern portions of the state of Hidalgo (Figure 2). This stratigraphic unit is part of the Huayacocotla Anticlinorio (Carrillo-Bravo, 1965).

Rosales-Lagarde (2005) formally proposes to the Tuzancoa Formation describing it as a siliciclastic sequence with basal andesitic gaps, interspersed with sandstone and shale, fossil carriers of plants of the genus *Pecopteris* Brogniart, *Neuropteris* Brogniart, *Odontopteris*, *Gangamopteris* Mc Coy, *Taeniopteris* Brogniart and *Calnalia* Hernández et al (Figure 3e). Describe fossils of crinoids, algae, foraminifera, bivalves and fusulinids with varying degrees of preservation, associated with them and in greater abundance (Carrillo-Bravo, 1965; Silva-Pineda et al., 2003; Quiroz-Barroso, 2012; Buitrón et al., 2017). These last ones allow establishing the age of the formation in the Cisuralian.

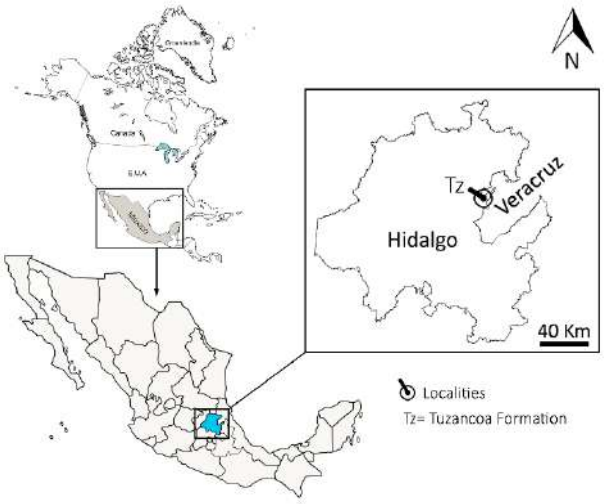

Figure 2. *Location of the study area*

2.2 RESULTS

The seeds recently collected in the Permian sediments of the Tuzancoa Formation were preserved as impressions and carbonaceous compressions, forming a poorly represented group, representing only 3.41% of the fossilized association of this stratigraphic unit. Three of the four seeds collected have been assigned to the morphogenera *Cornucarpus* Arber and *Cordaicarpus* Geinitz. The first describes a morphotaxon. While two morphotaxa of the genus *Cordaicarpus* are described, and finally, the morphological characteristics of one of the collected seeds have not allowed their assignment to one of the morphogenera described for the dispersed seeds of the Permian, so it remains unallocated.

Systematic descriptions

Genus: *Cornucarpus* Arber, 1914

Type species: *Cornucarpus acutus* (Lindley and Hutton) Arber, 1914.

Cornucarpus sp.

Description: Platispermic seed, with wing not oval in shape, slightly cordate base, the bifurcated apex in two spines, visible thread. The surface of the seed is covered with thin ridges that converge towards the apex. Undifferentiated teguments of greater thickness at the base. The maximum width of the seed is about one-third of its longitudinal length. The megaspore has an oval shape, an obtuse base, and an acute apex. The micropyle is not observed in Figure 3a.

Dimensions:

LT, 7.8mm; AT, 3.7mm; AN, 2.0mm; LN, 4.2mm. Apical Projection

0.5-1.5mm long by 1-2mm basal width, LT/AT, 1.15-2.00mm. Internal oval body 1-2mm long by 0.7 -1.0mm wide.

Material Studied and Origin: Tuzancoa Formation; Calnali River. Issue CFZ-Tuz 40.

Observations: This specimen was assigned to the *Cornucarpus* genus because it is a plastispermic seed, with bilateral symmetry with a bifurcated apex in two spines which are as or longer than the width, unlike the genus *Cordaicarpus* that has two apical spines.

Genus*: Cordaicarpus* Geinitz, 1862

Species Type: *Cordaicarpus cordai* (Gcinitz) Seward, 1917.

Cordaicarpus sp1

Description: Oval seed, the width is about two-third of its longitudinal length, incomplete base, accumulated apex that is divided into two small extensions that limit it and do not extend beyond the general outline of the seed. It is surrounded by an integument differentiated in two layers sarcotesta and sclerotesta. The thickness of the variable sarcotestas is widening towards the ends. The round-shaped oval megaspores with an acute apex. The chalaza is well developed, ends in a short and wide conical projection (Figure 3b).

Dimensions:

LT, 8mm. AT, 6mm; AN, 2.5mm; LN, 5mm. Apical Projection

1.5mm long, LT/AT, 1.3, AS/AN 1/4. Internal oval body 1-2mm long by 0.6 -1.0mm wide.

Material Studied and Origin:

Tuzancoa Formation; Calnali River. Copy CFZ-Tuz 10.

Cordaicarpus sp2.

Description: Platyspermic seed, oval, non-winged, wider towards the distal end of the structure, with two small spines that crown a rounded apex, an acute base that ends in a short and wide conical peduncle. Undifferentiated tegument that uniformly surrounds the nuclei that has the same shape as the seed, with a round apex and an acute base (Figure 3c).

Dimensions:

LT, 9.6mm. AT, 4.6mm; AN, 3.5mm; LN, 6mm. Apical Projection

0.5mm long.

Material Studied and Origin: Tuzancoa Formation; Calnalli River. Issue CFZ-Tuz 19.

Observations: The CFZ Tuz 10 and 19 specimens were assigned to the genus *Cardiocarpus* because they are seeds of bilateral symmetry, winged or not, oval, with apices that end in two projections that do not significantly protrude from the main body of the seed. Unlike the species of the genus *Cornucarpus* that they present bifid appendages that protrude from the main body of the seed. In specimen CFZ Tuz 10, a difference is presented with a narrow sarcotesta (1/4) characteristic of the genus *Cardiocarpus*, different from the broad sarcotesta present in the species of the genus *Samaropsis*.

Example: CFZ Tuz-24.

Description: Incomplete seed, oval-shaped, widened towards the base, where it exhibits a projection of the testa that does not exceed half the length of the seed, its surface is striated. Acute apex, cordate base, observable thread, and groove. The testa is undifferentiated, striated and of variable thickness, the stretch marks run longitudinally on the surface and converge at the apex. The megaspore is also oval in shape, acute apex, round base, and striated surface, with observable micropyle (Figure 3d).

Dimensions: LT, 7.1mm. AT, 5.6mm; AN, 4.8mm; LN, 2.2mm.

Origin of the material: Tuzancoa Formation; Calnalli River.

Observations: The specimen was not assigned to the genus *Cornucarpus*, *Cordaicarpus* and *Eucerospermum* Feruglio because it is an incomplete specimen that does not preserve the apex, an essential characteristic to assign it correctly to these genera. On the other hand, it does not have a wide sarcotesta that evenly covers the entire length of the seed, so it does not belong to the genus *Samaropsis* either.

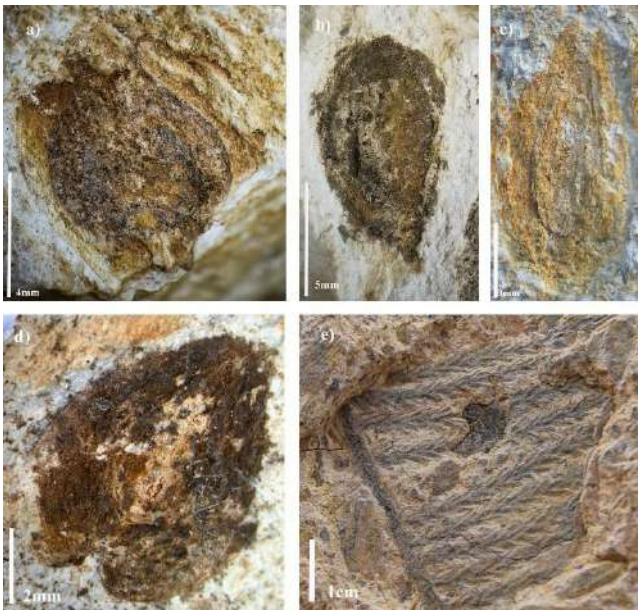

Figure 3. a) *Cornucarpus* sp. scale 4mm. b) *Cordaicarpus* sp1scale 5mm. c) *Cordaicarpus* sp2 scale 4mm. d) Example: CFZ Tuz-24 scale 2mm.e) Branches of the genus*Calnalia.*

2.3 DISCUSSION

The type of fossilization prevents comparing these specimens with permineralization, for example,*Cardiocarpus tuberculatus* Wang, Hilton, and Baolin; *C. spinatus* Roth and *C.oviformis*Leisman, since its vascular tissue and the type of epidermis cannot be observed. So its allocation is based on the presence of similar morphological characters and is not necessarily linked to the same gymnosperm groups: The morphotaxon description of the genus *Cardiocarpus*, for example, may have been produced by different groups such as Cordaitales, Coniferales, Callistophytales and even Peltaspermales, as *Autunia* (Trivett and Rotwell, 1991; Mapes and Rotwhwell, 1984; Rotwell et al., 1996, Kerp, 1988). While the species of the genus *Cornucarpus* have been linked to Glossopteridales (Millan, 1977a) and Coniferales (Oliveira and Yoshida, 1981; Oliveira, 1977). In the collection area, Coniferales, Cycadales, Marattiales, Peltaspermales, and Voltziales have been found. The seeds may have belonged to any of these orders; So the information obtained so far is about the degree of organization of these seeds rather than taxonomic since they are not in organic connection. The diversity found is low compared to the Permian locations of China, Brazil and North America (Miller and Brown, 1973; Mamay et al., 1984; Wang et al., 2003; Márquez of Souza and Iannuzzi, 2009), as well as those reported for the Carboniferous of Argentina where up to 10 morphotaxa sites have been reported

3. CONCLUSIONS

The presence of seeds for this locality is scarce since marine sedimentation prevailed during most of the

lower Permian. The registration for the first time of these structures for the Tuzancoa Formation represents the oldest report for Mexico and confirms that by this age their presence could favor the development of the plant community established in the region during the lower Permian.

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