

FOSSIL CONTENT AND STRUCTURAL RELATIONSHIPS OF THE SAN LUIS ZONE AND THE CABORCA ZONE OF NW SONORA, MEXICO. SUPPRESSION OF THE PRECAMBRIAN Z OF CABORCA

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ABSTRACT

In the Caborca region of western Sonora a Precambrian Z does not cover a unique Precambrian socle as previously believed. Two tectonic zones occur there instead : the San Luis Zone and the Caborca Zone. The first is comprised of the Precambrian San Luis socle of gneiss and granite, crossed by 1.1 Ga old anorthosites, the San Luis sedimentary cover, and, above it, a Lower Jurassic volcano-sedimentary sequence. The Caborca Zone consists of the Precambrian Bamori socle of parametamorphic rocks crossed by 1.1 Ga old Aibo granite, and of the Gamuza sedimentary cover. 1.1 Ga ago the two zones were far away from each other. They have been brought together by the Nevadian orogeny. Both zones are allochthonous, and the Caborca Zone is a nappe upon the San Luis Zone. The lowermost units of the Gamuza cover furnished psammocorals and a possible *Pterophyllum jageri* (?). Accordingly, its geological age is either Palaeozoic or Triassic. The San Luis cover furnished *Nematophites* [*Prototaxites* (?) and *Nematothallus*] from its lower part; *Calcispongiae*, *Cardaicarpus* seeds, and *Artisia* from its upper part. Thus, it is a Devonian-Carboniferous unit. The study area belongs in the « Baja-Borderland » block, which underwent, an Eocene northwards drifting of about 900 – 1000 km, and a 30° to 40° clockwise rotation relative to the main part of Sonora.

Keywords: Sonora, Caborca, Caborca Zone, San Luis Zone, Precambrian socle, phanerozoic cover, nappe, Baja-Borderland block.

CONTENIDO FOSILIFERO Y RELACIONES ESTRUCTURALES DE LA ZONA SAN LUIS Y DE LA ZONA CABORCA DEL NOROESTE DE SONORA, MEXICO. SUPRESION DEL PRECAMBRICO Z DE CABORCA.

RESUMEN

En la región de Caborca, Oeste de Sonora, no existe un Precámbrico sedimentario Z cubriendo un único zócalo precámbrico como generalmente admitido. En cambio, se encuentran allí dos zonas tectónicas: la Zona San Luis y la Zona Caborca. La primera consiste de un zócalo de neises y granitos precámbricos atravesados por anortositas de 1.1 Ga y de la cubertera sedimentaria San Luis, sobre la cual ocurre una secuencia volcano-sedimentaria del Jurásico Inferior. La Zona Caborca incluye el zócalo precámbrico Bamori de metamorfitas atravesadas por el granito pegmatítico Aibo de 1.1 Ga y la cubertera Gamuza. Hace 1.1 Ga las dos zonas estaban ampliamente separadas y han sido juxtapuestas por la Orogénesis Nevadiana. Ambas zonas son alóctonas y la Zona Caborca constituye una cobijadura (napa) arriba de la Zona San Luis. En las unidades basales de la cobertura Gamuza se descubrieron psamocorales y un posible *Pterophyllum jageri* (?). Por lo tanto su edad geológica es Paleozoica o Triásica. En la parte inferior de la cobertura San Luis se descubrieron *Nematophites* [*Prototaxites* (?) and *Nematothallus*]; y en su parte superior *Calcispongiae*, semillas de *Cardaicarpus*, y *Artisia*. Se trata entonces de una unidad devonico-carbonífera. El área estudiada pertenece al Bloque “Baja-Borderland” que en el Eoceno sufrió una deriva hacia el Norte de aproximadamente 900 a 1000 km y una rotación de 30° a 40° con relación a la parte principal de Sonora.

Palabras clave: Sonora, Caborca, Zona Caborca, Zona San Luis, Precámbrico, zocalo, cobertura fanerozoica, cobijadura (napa), Bloque “Baja-Borderland”.

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INTRODUCTION

The interest of the geologists on the stratigraphy of the Caborca region was raised by the discovery of its Cambrian, made classic by the works of Cooper and Arellano (Cooper and Arellano, 1946; Cooper and Arellano, 1956; Cooper et al., 1952; Longoria et al., 1978; Longoria y Gonzalez, 1979; Gamper y Longoria, 1978). Geometrically, this Cambrian occurs over a detrital and dolomitic sequence, the Gamuza Series, which is the cover of a Precambrian Socle, the Bamori Socle. Then, the stratigraphic nature of the limit between the Cambrian and the Gamuza Series has been admitted axiomatically, and, as a consequence, the Gamuza Series has been considered as Precambrian. In fact, it became “the Sedimentary Precambrian (Precambrian Z) of Caborca” (Longoria, 1980, 1981; Longoria y Perez, 1978; Maytorena y Durazo, 1982; Livingstone and Damon, 1968; Stewart et al., 1984). Later on, because of their similar facies such a Precambrian age has been assigned as well to the detrital and dolomitic series cropping out eastwards in the areas of Trincheras, Curiel Ranch, Felix Gomez and Los Chinos (Vega et al., 1991), and southwards (Fatima Ranch, Sierra de la Jojoba). In doing this it was forgotten that in a report of 1922 written for an oil company Keller and Wellings had assigned the dolomites of Sierra de la Jojoba, south of Caborca to the Carboniferous (in Weber et al., 1979). On the other hand, it appears from a study of the already cited literature that it was considered that all of these sequences rested upon a unique basement.

One of the formations of the Gamuza Series, the dolomitic Gamuza Formation, is rich in stromatolites, which have been studied by several paleontologists (e.g.: Cevallos-Ferriz, 1981; Cevallos-Ferriz et al., 1982; Cevallos-Ferriz y Weber, 1980; Weber et al., 1979). A Precambrian age of the sequence bearing them having been already admitted and accepted, as indicated here-above, these authors assigned such an age to their stromatolites as well, in spite of several difficulties related to such an idea (Radelli et al., 1997). This same idea has been followed as well when the hypothesis of the Sonora-Mojave Megashear (Anderson and Silver, 1979) gave way to new geological works (Anderson et al, 1979; Anderson and Silver, 1981; Anderson and Schmidt, 1983) made in view of establishing a correlation between the Series of Caborca and certain series of Nevada-California, on either side of that hypothetical line.

Some pseudo-fossils and trace fossils of the Gamuza Series were assigned to the Ediacara (McMennamin, 1996; McMennamin et al., 1983), for the only reason that said series was supposed to belong in the Precambrian Z. However, the Cambrian of Caborca occurs as a tectonic nappe (Radelli, 1990). As a consequence, the position of the Gamuza Cover under it is not proof of a Precambrian age of that same Gamuza Series, an age that, on the other hand, cannot be established based on its stromatolites (Radelli et al., 1997). On the contrary, some fossils discovered in the Caborca Formation of the lower part of the Gamuza Series allowed Radelli et al. (1997) to assign a phanerozoic age to it. For said series, considered within the regional framework, a Triassic age could be speculated (Radelli, 1990; Radelli et al., 1993; Radelli et al., 1997). In this regard, it is also worth notice (i) that in the Spring Mountains of Nevada Triassic stromatolites are known (Schubert and Bottler, 1992) that, at least on photographs, look identical to those of the Gamuza Formation; and (ii) that at La Monarca Ranch in the San Luis Cover (see below) columnar stromatolites occur together with *Nematophytes*.

For these facts, we resumed the study of the sedimentary formations covering the Precambrian crystalline ones cropping out, roughly, between the meridians of Sierra del Viejo on the West and Sierra de Santa Rosa on the Est (FIGURE 1).

Here we present the results of this research, and in particular the paleontological discoveries we made, including the contributions of two Theses of the University of Sonora (De la Cruz y Dórame, 2000; Dórame, 2003).

TWO SOCLES, TWO COVERS

Even though the study of the Precambrian igneous and metamorphic rocks of the region considered is far from being completed (Anderson et al., 1979; Anderson and Silver 1981) two socles can be recognized there the *Bamori Socle* and the *San Luis Socle*, each one with its own petrographic sequence and its own cover.

San Luis Socle and San Luis Cover

The names of San Luis Socle and San Luis Cover are taken from that of a Ranch where both are cropping out (FIGURE 1). The San Luis Socle is made up, essentially, of granitic or granitized rocks, and of granitic orthogneisses. In several places these rocks are intruded by huge anorthositic bodies.

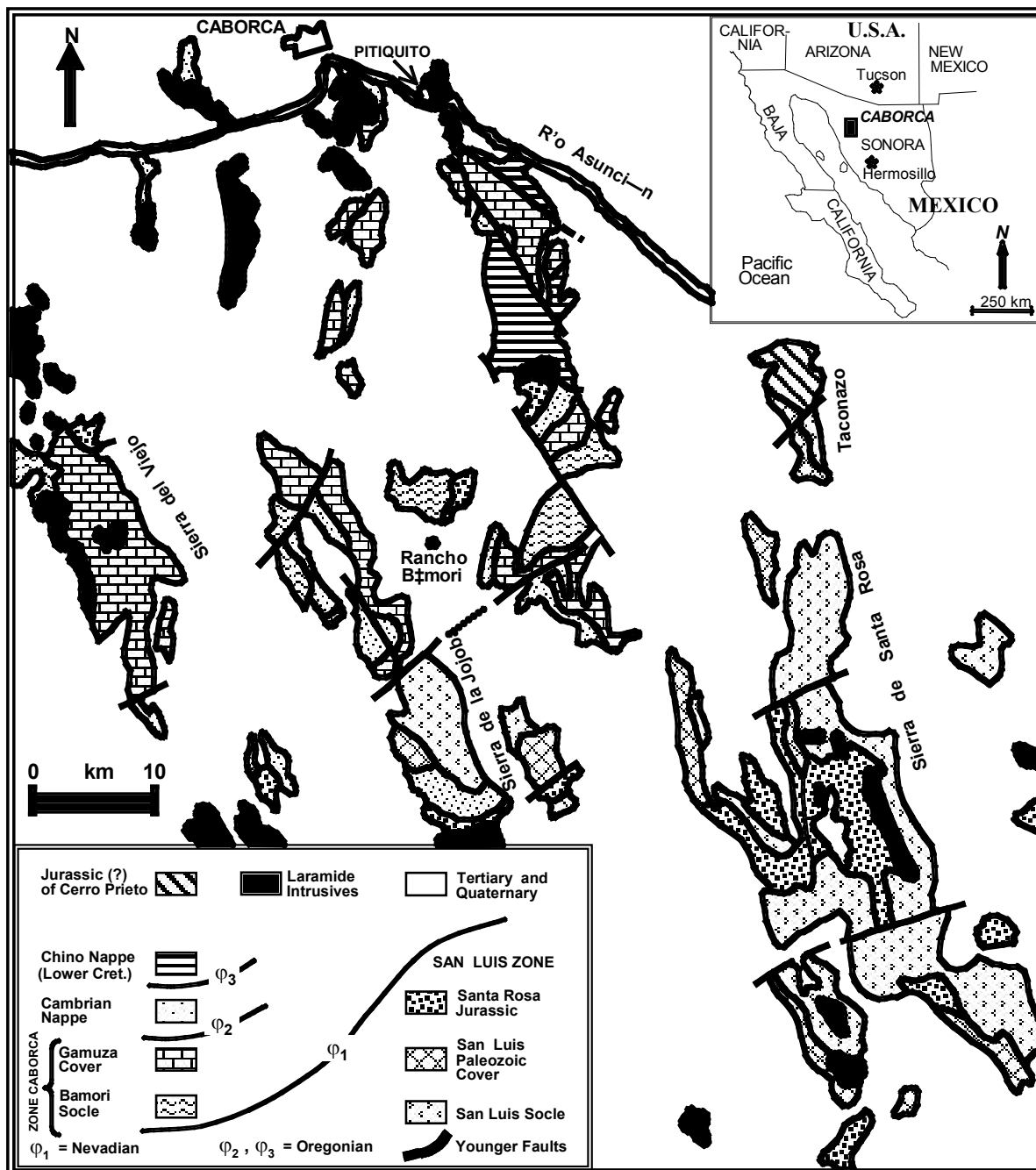


FIGURE 1. Structural map of the study area.

In the past had been assigned to this Socle a radiometric age of 1.4 Ga but new results [SHRIMP on zircon] rather suggest a radiometric age of 1.7 Ga for the protolithes of its granitic facies (Anderson and Silver, 1971 ; Castiñeiras et al., 2004) and a radiometric age of 1.1 Ga for its anorthosites.

The *San Luis Socle* is covered by the *San Luis Series* and this in turn by the *Santa Rosa Series*. The base of *San Luis Socle*, and as a consequence its structural position are not well defined yet. However, its allochthonous character is clearly indicated by regional structural data (Radelli et al., 1993 ; De la Cruz and Dórame, 2000 ; Dórame, 2003). Also it is suggested locally by certain unmetamorphosed conglomerates, of unknown age, intersected at depth by old mining works (Mina El Tiro), under the San Luis Socle.

The *San Luis Series (San Luis Cover)* is made up, upwards, by basal clastics (microconglomerates, some conglomerate containing clasts of the crystalline socle and reddish sandstones), and then by a sequence of dolomites and limestones with interbedded sandstones and quartzites. The thickness of these different individual facies, as well as that of the San Luis Cover as a whole, change strongly from one point to the other, so that it is impossible to furnish a representative general stratigraphic column of it. But the indicated sequence - with a detrital to dolomitic lower part, and an upper part of limestone and dolomites, with interbedded clastic facies - is found all over the zone. The San Luis Cover is folded, but the Socle San Luis does not enter its folds, which means that the San Luis Cover is detached from the San Luis basement - hence the terms of Socle and Cover.

The Santa Rosa Series, that covers the San Luis Series, is a folded and detached Lower Jurassic volcano-sedimentary sequence, which contains clasts of the underlying San Luis Series (Hardy, 1984, Radelli, 1990; Radelli et al., 1993; De la Cruz and Dórame, 2000; Dórame, 2003).

Bamori Socle and Gamuza Cover

The *Bamori Socle* (FIGURE 1) is made up of igneous and amphibolite facies metamorphic rocks. Its metamorphic rocks include para and orthometamorphic, granitized, facies. They are intruded by a graphic, pegmatitic granite, the Aibo granite.

The metamorphic rocks of Bamori furnished a U/Pb on zircon radiometric age of ± 1.7 Ga for their protolithe (Anderson and Silver, 1971; Castiñeiras et al., 2004a ; Castiñeiras et al., 2004b ; Navarro et al., 2004 ; Dórame and Iriondo, 2005 ; Castiñeiras et al., 2005). On the other hand, for the Aibo granite a K/Ar radiometric

age of 1.1 Ga has been determined by Damon et al. (1962). Recently, both these ages have been confirmed by SHRIMP on zircon measurements (Castiñeiras et al., 2004a; Navarro et al., 2004).

It is worth noting, however, that the radiometric age of 3 Ga furnished by certain detrital zircons of the Bamori Socle (Dórame and Iriondo, 2005) raises the problem of the original geographic location of this socle, because an american source of said zircons can hardly be supposed.

When it is cropping out, at the base of the Bamori Socle one finds either ultrabasic-basic rocks (serpentinites, gabbros), as along the western edge of Sierra de la Vibora and of Sierra del Viejo (El Plomito); or Lower Jurassic volcano-sedimentary rocks of Santa Rosa Series, as at the eastern edge of Sierra de la Berruga and the north-eastern edge of Sierra del Viejo (Radelli, 1990); or, finally, the anorthosites of the San Luis Socle.

The *Bamori Socle* is covered by the *Gamuza Series* or *Gamuza Trilogy* (Radelli et al., 1997 and references therein), which from top to bottom consists of:

- the Papalote Formation: ± 400 m of grey dolomite
- the Gamuza Formation: ± 135 m black dolomite
- a reddish detrital basal unit with:
 - Pitiquito Formation : ± 80 m of quartzite with interbedded dolomites;
 - Clemente Formation: ± 200 m of fine grained sandstone with interbedded dolomites and one interbedded limestone in its middle part;
 - Caborca Formation: ± 120 m of dolomite, dolomitic limestone, oolitic dolomite and some fine grained sandstone;
 - El Arpa Formation: ± 90 m of arkose derived from the Socle, sandy dolomite, quartzite, dolomitic limestone and fine grained sandstone.

The Gamuza Series is folded, but the rocks of the crystalline Bamori sequence are not involved in its folds so that the Gamuza and the Bamori Series are detached from each other - hence the terms of Socle and Cover applied to them (instead of basement and stratigraphic cover). Thanks to the colour of its three major terms, it is easy to recognize, also from afar, the Gamuza Trilogy in the field, where it crops out continuously over a great distance. South of Caborca-Pitiquito the Gamuza Series is covered by the Nappe of the Cambrian (Radelli, 1990).

In what follows we shall call *Caborca Zone* the ensemble of Bamori Socle + Gamuza Cover; and *San Luis Zone* the ensemble of San Luis Socle + San Luis Cover + Santa Rosa Series.

What ought to be underlined here is the geochemical contrast between the igneous rocks of same 1.1 Ga age but different facies cutting across the two socles: pegmatitic graphic Aibo granite across the Bamori Socle, and anorthosites across the San Luis Socle. This fact suggests that 1.1 Ga B.P. the two socles were away from each other, and have been brought together later on.

The geological age of the Santa Rosa Series, involved in the building up of the actual structure of the two socles, is Lower Jurassic. Younger, Upper Jurassic and Cretaceous formations which occur eastwards do not exist within the Caborca and San Luis Zones. Thus, it is possible to conclude that the Caborca and San Luis Zone, as well as the overriding of the first upon the second took place during the Nevadian Orogeny. The resulting building has been reworked by the phases of the Oregonian, also called “Mid-Cretaceous” (Radelli, 1990; Radelli et al., 1993; De la Cruz y Dórame, 2000; Dórame, 2003), and Eocene (Radelli and Navarro, 2005), tangential tectonics. Then, the final structure has been affected by several roughly vertical Tertiary faults, that juxtaposed different parts of the two zones.

PALEONTOLOGY

Geological age of the Gamuza and San Luis Covers

The Precambrian age of the Gamuza Cover of the Caborca Zone has been questioned since 1990 (Radelli, 1990). Following the discovery of some fossils in its lowermost part that age has been squarely denied, and a Phanerozoic age has been suggested instead for it (Radelli et al., 1997). Since then, we continued with the study of the fossiliferous content of the Gamuza Series (Caborca Zone) and we expanded our field of research both East- and Southwards to include the San Luis Zone.

Gamuza Cover (Caborca Zone)

The psammocorals

Of the fossils discovered in an outcrop of the Caborca Formation in the area of Cerro Clemente (Radelli et al., 1997), we resumed the study of those that are exposed there as more or less hemispheric structures with a diameter of 30-35 cm (FIGURES 2 and 3).

Such structures contain forms that appear as *decimeter sized colonies whose sections show parallel prismatic columnar tubes 1,5 – 2 cm high and, on their surface,*

a waffle weave structure (translated from Radelli et al., 1997). Then these colonies had been interpreted as possible Tabulata (Coelenterata, Anthozozaria) and/or as Stromatoporides (Coelenterata, Hydrozoaria). A different interpretation seems possible, however. In such interpretation the fossils would be not only the tubular colonies they contain but the whole of the above mentioned hemispheric structures.

In a cross section of these structure, from their centre towards their border, one finds: a circular dark central nucleus 15 to 20 cm in diameter, made up by dolomitic sandstone; and then a ring of clear dolomite that contains the above indicated waffle weave structures.



FIGURE 2. Outcrop of the hemispheric structures interpreted as psammocorals.



FIGURE 3. Detail of the hemispheric structures interpreted as psammocorals. Note the waffle weave structure of the light coloured outer part of the fossil, and the dark dolomitic sandstone of its inner part: it is the “rock in a sock” model discussed by Fedonkin and Runnegar (1990).

The overall resulting structures look very much as those that Fedonkin and Runnegar (1990, 1992), and Seilacher (1992) considered as psammocorals: *Protolyella* of the Cambrian of Sweden (and maybe the Vendian *Beltanelliformis brunsae*), and *Alpertia santacruzensis* of the Devonian of Poland. It is the model of the “rock in a sock”.

The organically cemented sandstone filling the organism constitutes its “sandstone skeleton” anchoring the whole structure to the bottom but allowing it to oscillate under the influence of the currents, as at present time is the case of certain coelenterata close to the actinies. Concerning the herein studied fossils it ought to be noted that these organisms are never superposed on each other, which suggests that they had an endo-skeleton. Such endo-skeleton should be the “skeleton of sandstone” of their dark grey nucleus of dolomitic sandstone. On the other hand, they are found in association with mud marks showing a deformation due to a pressure by rigid bodies. On the other hand, they are found in association with mud marks showing a deformation due to a pressure by rigid bodies. Therefore, it seems permissible to think that such frail and delicate structures as those described have been preserved thanks to a fast burial generated by tempestites.

For both their general structure and the mode of their preservation the fossils in question appear as psammocorals. With respect to the psammocorals discussed by Fedonkin and Runnegar (1990, 1992), and Seilacher (1992) the forms of the Caborca Formation show important differences, however: diameter of some 30 cm which compare with that of 2 cm of *Protolyella*, and that of 5 cm of *Alpertia*; and tubular colonial structures appearing in relief. These differences seem to suggest, at least, that they belong to a new genus of a higher evolution, that will have to be given a name.

Thus, the previous conclusion on the Phanerozoic age of the Caborca Formation, and therefore of the Gamuza Cover (Radelli et al., 1997) is confirmed. And under the circumstances it seems permissible to conclude as well that the psammocorals of the Caborca Formation are of a younger, and possibly much younger geological age than those of the Devonian discussed by Fedonkin and Runnegar (1992), and those of the Cambrian discussed by Seilacher (1992).

A possible Pterophyllum

In the same outcrops of the Caborca Formation, some 10 m below the strata that furnished the psammocorals, there occurs a bed, about one decimetre thick, of fine grained, ochre yellowish, terrigenous sandstone. It

contains several desiccation marks and some poorly preserved structures which appear as vestiges of plants carried there during the sedimentation.

These structures consist of small stems, up to 3 cm long, and with a diameter of 2–3 mm, to which are perpendicularly connected small, some 2 cm long and 1 mm wide leaves. They compare with Benetitales, and particularly with *Pterophyllum*, and possibly with *Pterophyllum jageri* (FIGURE 4). *Pterophyllum* is known to occur from the Stephanian to the Lower Cretaceous, but it shows an important development in the Upper Triassic; *Pterophyllum jageri* is a Triassic species.

This new discovery appears to confirm once more the Phanerozoic age of the Caborca Formation, and therefore of the Gamuza Cover, indicated as well by its psammocorals. Besides, if the observed forms really correspond to *Pterophyllum jageri*, the Triassic age already suggested (Radelli, 1990; Radelli et al., 1997) for the Gamuza Cover would be confirmed as well.

San Luis Cover (San Luis Zone)

The Nematophites : Prototaxites (?) and Devonian Nematothallus.

At different places - Cerro Taconazo, Cerro Colorado, Cerros of Rancho Piedra Parada, Cerro of the Boludo, Sierra de la Jojoba, Rancho Curiel, Rancho La Monarca (FIGURE 1) – large fossils have been found in the dolomites and the sandstones of the lower part of the San Luis Cover. Such fossils always occur on the bedding surfaces, and at first glance they remind of remains of a vegetable origin. The best preserved are those of Cerro Taconazo, which will constitute the base of our descriptions.

Cerro Taconazo. A specimen (specimen 1T) exceptionally well preserved and well exposed by the erosion occurs on the eastern slope of Cerro Taconazo, on the upper part of a block of dolomite fallen from the crest of that cerro. Excluding the contact of its base leaning on the dolomite, the erosion has completely released the fossil from its former dolomitic envelope (FIGURES 5 a, b, c). For its cylindrical aspect and its general structure, the fossil looks like a tree trunk. Its preserved part is 65 cm long; at one end it has a diameter of 18 cm, which towards the other end decreases progressively until it terminates as a somewhat flattened cone (FIGURE 5a). On its surface, the specimen shows a number of fine streaks (FIGURE 5b), but nothing that could point either to some secondary branching off, to

pores, stomates or other similar structures. There is trace neither of leaves and their stems, secondary branches, nor of any structure that could have surged from the walls of the specimen. At the natural section (a fracture ?) at its end of maximum diametre and perpendicular to its lengthening the structure of its different parts can be observed. Its exterior part is a cuticle with two walls: the outer one 0.4 cm thick, the inner



FIGURE 4. A possible *Pterophyllum jageri* of the Caborca Formation. The coin has a diametre of 1.5 cm.

One 0.8 cm thick, divided from each other by a cavity of 0.8 cm, interrupted by septa roughly perpendicular to the two walls (FIGURE 5c). A concentric set of irregular cavities occurs within the second wall of the cuticle. Such cavities extend longitudinally resembling, thus, channels.

However, with regard to the reference specimen 1T, other specimens show also important differences of both shape and size. Several specimens have an ellipsoidal shape rather than a cylindrical shap. We believe this is due to a tectonic flattening, for where this occurs contiguous specimens are laterally joined with each other (FIGURE 7). As for the size we measured: for the specimen 33T, a diametre of 44.2 cm, an outher cuticle of 1.5 cm, a layer with tubes of 2.5 cm, a spongy nucleus of 8 cm; for the specimen 44T, a diametre of 66.7 cm, an outer cuticle of 2.5 cm. As pointed out above, the preserved part of the reference specimen 1T is 65 cm long, with a maximum diametre of 18 cm. Comparing with such measurements those of the specimens 33T and 44T it can be concluded that the latter ones were more than 2 m, and probably several metres long.

Piedra Parada Ranch. Similar fossils, with a diameter of 20 cm, have been found within Piedra Parada Ranch. Although they are poorly preserved, they show a structure which is the same as that of the specimens of Cerro Taconazo.



FIGURE 5. The specimen 1T of the *Nematophites* of Cerro Taconazo.

- a – The specimen described in the text.
- b - Detail of its thicker part; note its very thin streaks
- c - Frontal view of its section.



FIGURE 6. *Nematophite*, specimen 19 T, Cerro Taconazo. Note its concentric structure. Discussion in the text.



FIGURE 7. *Nematophytes* deformed by tectonic flattening at Cerro Taconazo: ellipsoidal shape of laterally joined contiguous specimens.

Also, in a thin section of one of these samples it has been possible to recognize, under the microscope, some tubes as those found by Arnold (1952) in some *Prototaxites* of Ontario, Canada (FIGURE 8).

Cerro Colorado. At Cerro Colorado, east of Cerro Taconazo, the dolomites of the lower part of the San Luis Cover furnished two types of fossils. On the one hand, there have been found fossils as those of Piedra Parada and Cerro Taconazo. And, on the other hand, in association with these, there occur globular bodies with a diameter of about 6 cm that sometimes are deformed and acquire an elliptic section, with a maximum diameter of 10 cm. Their macroscopic structure look like that of the *Pachythea*, which occurs in association with the *Prototaxites* of Ontario. According to Sir Dawson (1859, 1871, 1880, 1882) such forms might correspond to seeds of *Prototaxites*, but according to other authors (Hooker, 1889; Jonker, 1979; Lang, 1937; Krausel, 1964; Voitech et al., 1989) they would be ancient algae. It ought to be noted, however, that the sized of these forms of Cerro Colorado is from 10 to 20 times bigger than that assigned to *Pachythea* in the literature. Thus, a more precise determination should be awaited.

Cerro del Boludo. The dolomites of this Cerro, south of Cerro Taconazo, furnished remnants of fossils with a macroscopic morphology as that of the fossils of this last Cerro, in which poorly preserved tubes have been recognized in thin section under the microscope.

Rancho Fatima (Sierra de la Jojoba). Also within this ranch, the dolomites of the lower part of the San Luis Cover furnished fossils that compare with those of Cerro Taconazo and of the other above discussed localities.

Rancho Curiel. The dolomites of the lower part of the San Luis Cover of this ranch furnished fossils of two types: on the one hand, flattened specimens with an elliptic section of 8 cm x 6 cm, that in spite of their deformation compare with those already discussed here above; and, on the other hand, forms with a circular section with a diameter of about 5 cm. In the thin sections of these latter we could recognize, under the microscope, tabular structures virtually identical to those considered as typical (Lang, 1937) of the *Nematophytes* of genus *Nematothallus*, to which, therefore, we assigne such forms of Rancho Curiel.

Rancho La Monarca. The dolomites of La Monarca Ranch, north of Felix Gomez village, contain fossils that are poorly preserved but compare with those of Cerro Taconazo, Cerro del Boludo and Sierra de la Jojoba, and others which are very similar to the *Nematothallus* of Rancho Curiel. Besides, they contain as well some specimens of poorly preserved columnar stromatolites.



FIGURE 8. One of the tubes typical of *Nematophytes* (*Prototaxites*) observed in a thin section of a specimen of Piedra Parada Ranch.

We believe that on the whole their above mentioned characters point at these fossils as to *Nematophytes*, similar to the no-vascular plants of Late Silurian to Late Devonian geological age. In fact, same as the *Nematophytes*, these fossils appear to show nematodes (organisms that, as filaments and/or tubes, live within the tissue of another organism). They might correspond either to a symbiosis of a phycobiont (cyanobacteri or chlorophytes) and one or two organisms of *fungi* type with filaments and hyphae, or to two microbionta (*fungi*). Excluding the *Nematothallus* of Rancho Curiel, for certain characters - in particular their streaks and their elliptical sections due to a tectonic flattening - the herein presented fossils compare with the *Prototaxites*, of dubious affinity, of the Devonian of Gaspé (Quebec, Canada) reported for the first time by Sir Dawson in 1859 (the year « The Origin of Species » was published) which could reach a diameter of 1 m and a height of more than 4 metres.

Calcispongiae, Seeds and a plant of the Carboniferous

Fatima Ranch (Sierra de la Jojoba). The limestones overlying the *Nematophytes* bearing dolomites contain *Calcispongiae* (FIGURE 9) that very much compare with *Girtyocoella* and/or *Amblysiphonella* of the Carboniferous. They are found together with as yet undetermined fossils with a circular section 2-3 cm in

diameter, with an outer 5 mm thick ring, which could also be spongiae. Finally at the top of the calcareous section we found poorly preserved and still undetermined fossils that might be seeds.

Curiel Ranch. In the uppermost part of the calcareo-dolomitic sequence of this ranch, stratigraphically above the level with the already discussed *Nematophytes*, we found fossils of two type, of which none has been found elsewhere in the study area. The fossils of the first type have a circular section 2-3 cm in diameter. In previous literature similar forms have been presented (Voitech et al., 1989) as seeds of *Cardaicarpus* sp. of the Upper Carboniferous, and we adopted such an interpretation for those of Curiel Ranch (FIGURE 10).

Beside such forms, we discovered an impressive fossil (FIGURE 11). We have assigned this specimen to the plant *Artisia* of the Late Carbonifère, for it is virtually identical to the one discussed as such by Voitech et al. (1989).



FIGURE 9. *Calcispongiae*, cf. *Girtyocoella* and/or *Amblysiphonella* (Carboniferous) of Sierra de la Jojoba (Rancho Fatima),

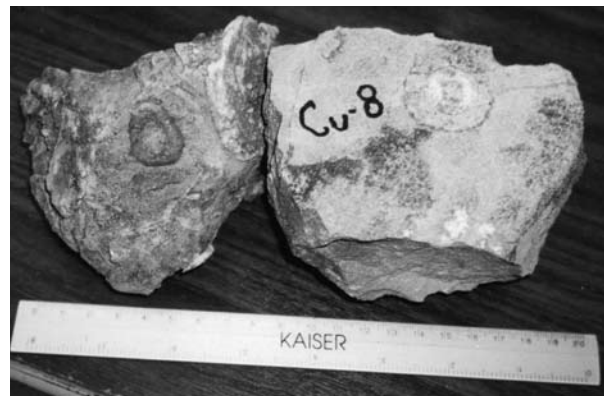


FIGURE 10. *Cardaicarpus* (Upper Carboniferous) of Curiel Ranch. The ruler is 20 cm long.



FIGURE 11. A form interpreted as *Artisia* (Upper Carboniferous). Rancho Curiel.

CONCLUSIONS

This study of the fossil content of their sedimentary covers confirms that the Caborca and the San Luis Zones correspond to two independent paleogeographic units, as already suggested by the nature of their crystalline socles. It is worth to dwell upon this point. As well as that of the Caborca Zone (Keller and Wellings, 1922; Cevallos-Ferriz, 1981), the cover of the San Luis Zone is made up by neritic, and partly intertidal, deposits. Possibly this has been the reason why in previous literature these two zones have been considered just as two parts of a sole, large tectono-paleogeographic unit. However, such an interpretation does not explain the fact that the “trunks” of the *Nematophytes* are found only within the sedimentary deposits of the San Luis Cover. In our interpretation the San Luis Cover is Devonian to Carboniferous, whereas the Gamuza Cover (Caborca Zone) is Phanerozoic and possibly Triassic in geological age. The previous idea of a Precambrian Z, and thus of a Ediacaran fossil fauna, within the region object of this study ought to be abandoned.

We have assigned a Devonian age to the lower part of the San Luis Cover based on its *Nematophytes*. The habitat of the *Nematophytes* in general, and of the *Prototaxites* in particular, was a continental one. Therefore, since they are found within a dolomitic environment, it is

permissible to think that those of the San Luis Cover were transported there by currents probably set in motion by storms and/or hurricanes. Two observed facts fit well with this interpretation: at Cerro Taconazo (i) these “trunks” are iso-oriented, and (ii) never show their roots.

The previously known *Nematophytes* (*Prototaxites* in particular) occur within fine grained clastic deposits, most of the time within black shales, and only occasionally in fine grained sandstones. In these rocks some organic matter is normally preserved. There it is easy to recognize their characteristic tubes and hyphae. This, on the contrary, is exceptional in these fossils of Sonora, preserved within dolomites – and for this reason we had to determine them based essentially on their macro-morphologic characters.

Prior to their discovery in Sonora (this paper), *Nematophytes* were known in Ontario (Gaspé), in the State of New York, in Ohio, Virginia, Carolina, England, Germany, Belgium, in the old Czechoslovakia, Arabia, and Morocco (Cross et al., 1996 ; Pratt et al., 1975a ; Pratt et al., 1975b ; Burgess and Edwards, 1988 ; Altmeyer, 1969, 1971, 1975, 1978a ; 1978b ; 1993 ; Chitaley, 1990, 1992 ; Agashe, 1997 ; Penhallow and Dawson, 1888 ; McMennamin and McMennamin, 1994 ; Rossat, 1952 ; Stockman and Williere, 1938 ;

Arbey and Koeniguer, 1979). Thus, these *Nematophytes* of Sonora are the first discovered within dolomites, and towards the Pacific margin of North America. It seems worth noting, however, that these *Nematophytes* are not the sole Devonian fossils of Sonora to have an equivalent in Morocco. The Late Devonian benthonic brachiopod *Dzieduszickia* also occurs in an allochthonous formation of Central Sonora and in Morocco (Radelli et al., 1987).

Thanks to the discovery within its carbonate facies of certain *Calcispongiae*, seeds and a plant we could assigne the upper part of the San Luis Cover to the Carboniferous; thus, after more than 80 years Keller and Wellings (1922) were rightly vindicated.

We confirm here the Phanerozoic age of the Gamuza Cover of the Caborca Zone (Radelli et al., 1997). As already noted, we think that in fact it might be Triassic. This idea might be supported by the possible Benetital *Pterophyllum*, and maybe *Pterophyllum jageri*, we have found in its Caborca Formation – although the specimen is too poorly preserved to allow a conclusive determination. A Palaeozoic age of both the San Luis Cover and the Gamuza Cover cannot be excluded however. Since 1987 three Palaeozoic sequences have been known to occur in Sonora: that of an “american” platform, that of a tethysian platform, and that of an allochthonous deep water sequence (Radelli et al., 1987; De la Cruz and Dórame, 2000). As a consequence it was difficult to “find a place” for more Paleozoic sequences as those of the Caborca and San Luis Zones. But we know now that this problem does not exist. As a matter of fact, as shown by Abbott and Smith (1989), the Caborca and San Luis Series occur in the “Baja-Borderland” block (Baja California and westernmost part of Sonora). During the Eocene this block was moved some 900 to 1000 km from South to North and rotated 30° to 40° towards the NE (Radelli and Navarro, 2005). It is therefore an exotic block with respect to the main part of Sonora where its other Palaeozoic series occur.

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Trabajo recibido: octubre 7 de 2008

Trabajo aceptado: noviembre 10 de 2008