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A palaeobiological window into the Lower Cretaceous Cupido Formation: Puerto México section, Nuevo Leon, Mexico

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Abstract: A rich geobiological record of Cretaceous biotic and abiotic interactions around the proto-Gulf of Mexico has been preserved in the massive Cupido carbonate platform, *i.e.*, in a sedimentary sequence that represents a depositional period of approximately 15 Myr. This work documents lateral facies variation on a dip slope reef from a new outcrop in the upper part of the Cupido Formation in the state of Nuevo Leon, Mexico. The measured transect is correlated with a stratigraphic column logged in a nearby section. The preserved fossil biota represents marginal reef facies dominated by abundant rudist shells such as *Douvillelia skeltoni*, *Toucasia* sp., *Offneria* sp., and *Amphitrocoelus* sp. associated with relatively large colonial corals (with diameters up to 25 cm) like *Stelidioseris* sp. and to a lesser extent, with stromatoporoids. Benthic foraminifers (miliolids and textularids) with associated dasycladalean algae such as *Salpingorella* sp. and *Terquemella* spp. dominate the microfossiliferous content in wackestones to packstones. This facies is overlain by a thin (15-30 cm) stromatolite horizon at the upper end of the measured section. This locality represents a new paleobiological and taphonomic window into one of the most extensive carbonate platform system developed along the margin of the Gulf of Mexico during the Cretaceous.

Key-words:

- Cretaceous;
- Cupido Formation;
- Puerto Mexico;
- rudists;
- corals;
- stromatoporoids

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Résumé : *Une fenêtre paléobiologique dans la Formation Cupido du Crétacé inférieur : la coupe de Puerto México, Nuevo León, Mexique.-* Un enregistrement géobiologique diversifié des interactions biotiques et abiotiques crétacées sur le pourtour du proto-Golfe du Mexique a été préservé au sein de l'imposante plate-forme carbonatée de Cupido, c'est-à-dire dans une séquence sédimentaire qui correspond à une période de dépôt d'une durée approximative de 15 Ma. Ce travail met en exergue la variation latérale des faciès récifaux sur le flanc long (faiblement pentu) d'un nouvel affleurement monoclinal correspondant à la partie supérieure de la Formation Cupido dans l'état de Nuevo León, Mexique. Le transect étudié est corrélé avec la colonne stratigraphique établie dans une coupe proche. Le biote fossile préservé correspond aux faciès de bordure du récif où abondent les coquilles de rudistes, tels que *Douvillelia skeltoni*, *Toucasia* sp., *Offneria* sp. et *Amphitrocoelus* sp., ces derniers y étant associés à des colonies relativement grosses (avec des diamètres atteignant jusqu'à 25 cm) de coraux tels que *Stelidioseris* sp. et, dans une moindre mesure, avec des stromatoporoïdés. Les foraminifères benthiques (miliolidés et textularidés), en association avec des algues dasycladales telles que *Salpingorella* sp. and *Terquemella* spp., dominent le contenu microfossilifère des wackestones à packstones. Ce faciès est surmonté à la partie sommitale de la coupe étudiée par un mince horizon stromatolithique (15-30 cm). Cette localité offre une nouvelle fenêtre paléobiologique et taphonomique au sein de l'un des plus vastes systèmes de plates-formes carbonatées développées sur le pourtour du Golfe du Mexique au cours du Crétacé.

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Mots-clefs :

- Crétacé ;
- Formation Cupido ;
- Puerto Mexico ;
- rudistes ;
- coraux ;
- stromatoporoïdés

1. Introduction

The Early Cretaceous was globally characterized by high tectonic and volcanic activity that introduced CO_2 into the atmosphere and raised global temperature up to 42°C in tropical latitudes (KELLEY, 2003; BICE *et al.*, 2006; HAY, 2011; HAQ, 2014). In response, massive carbonate platforms formed in low amplitude and high-frequency eustatic cycles (shallow carbonates cycles on the scale of 100s to 1000s to 10s of 1000s of years), composed of peritidal carbonates in the ancestral Gulf of Mexico from the Barremian to the Albian (LEHMANN *et al.*, 1999). Cretaceous sedimentary rocks are well-represented in several states of northeastern Mexico, particularly in Nuevo Leon, where massive limestones from the Cupido Formation crown the uppermost part of the Sierra Madre Oriental (SMO) and line up in superb scenic views around the area of Monterrey (Fig. 1). The Barremian-Aptian Cupido Formation crops out in the states of Nuevo Leon, Coahuila, Tamaulipas, and Durango and it is one of the most extensive carbonate systems in North America. It correlates with the Sligo-Hosston platform, only known in the subsurface of Texas, USA (SCOTT and HINOTE, 2007; LEHMANN *et al.*, 2000), and extends approximately 80,000 km^2 (LEHMANN *et al.*, 1999).

The Cupido Formation is a Lower Cretaceous limestone succession that represents part of such extensive carbonate platform systems developed in northeastern Mexico (MURILLO-MUÑETON and DOROBEK, 2003). The Cupido Formation developed as a reef-rimed carbonate platform composed of corals, stromatoporoids, sponges, rudists, green algae, and benthic foraminifera (WILSON, 1990). Although the large-scale platform paleo-configuration was proposed almost twenty years ago (GOLDHAMMER, 1999), little work has been devoted to lateral sedimentological and bathymetric variations at smaller scales. Most previous works (CONKLIN and MOORE, 1977), have reported the great variability in thickness of this formation, ranging from a few hundred meters of thickness near Saltillo to approximately 680 m near Monterrey (both cities separated by an approximate distance of 60 km) and up to 900 m at Minas Viejas (WILSON and PIALLI, 1977), located 40 km north of Monterrey. The aim of this work is to document the paleontological content of the reefal facies from a new locality of the Cupido Formation in Nuevo León, Mexico.

2. Geological background and methods

After the breakup of Pangea and during the subsequent rifting and drifting stages, several basins developed in northeastern Mexico in a process that also generated the Jurassic Louann Salt deposits in Texas and the Campeche Salt basin. The resulting accommodation space was filled by thick carbonate systems. In this way, the thermal contraction of tectonic plateaus allowed the development of carbonate platforms in this region. The Cupido platform, coeval with the Sligo platform in Texas (LEHMANN *et al.*, 1999; GOLDHAMMER and C.A. JOHNSON, 2001), is part of one of most extensive carbonate systems extending over an area of approximately 80,000 km^2 (LEHMANN *et al.*, 1999). This platform bordered the coast of the newly formed Gulf of Mexico from Louisiana across Texas (the Sligo Formation) and southwest into the Sierra Madre Oriental (WILSON, 1990; WILSON and WARD, 1993). As the main lithostratigraphic unit of the Barremian-Aptian carbonate platform, the Cupido Formation (hereafter CF), was defined by IMLAY (1937) on the 723.5 m northern wall of Cañon Mimbre, southeast of Parras, Coahuila, as a "thin to thick" non-fossiliferous gray limestone with pyrite and chert concretions.

Based on chronostratigraphic data and facies association, LEHMANN *et al.* (1999) suggested that the Cupido shelf-margin was deposited from the Barremian up to the early Aptian. Nonetheless, based on regional geology and stratigraphic relations observed around Monterrey-Saltillo and Bustamante, others consider that the Cupido Carbonate System (inner and margin platform, and open marine facies) began its development as prograding cycles from the Late Hauterivian through the Aptian, 30 myr (HUMPHREY and DÍAZ, 1956; ALFONSO-ZWANZIGER, 1978; MICHALZICK, 1988; GUZMÁN-GARCÍA, 1991; MCFARLAN and MENES, 1991; GOLDHAMMER, 1999; HERNÁNDEZ-TREJO, 2003; MURILLO-MUÑETON and DOROBEK, 2003; EGUILUZ DE ANTUÑANO, 2011).

The CF concordantly overlies sedimentary rocks of the Taraises Formation, which marks the progradation from an open shelf/homocline ramp to a restricted platform (MICHALZIK, 1988; LEHMANN *et al.*, 1999, 2000), and it is overlain by deep-water facies of the La Peña Formation, after a mid-Aptian drowning event (BARRAGÁN-MANZO and DIAZ-OTERO, 2004). The CF originated as an extensive coastal lagoon with peritidal carbonate cycles between the basement of the Coahuila

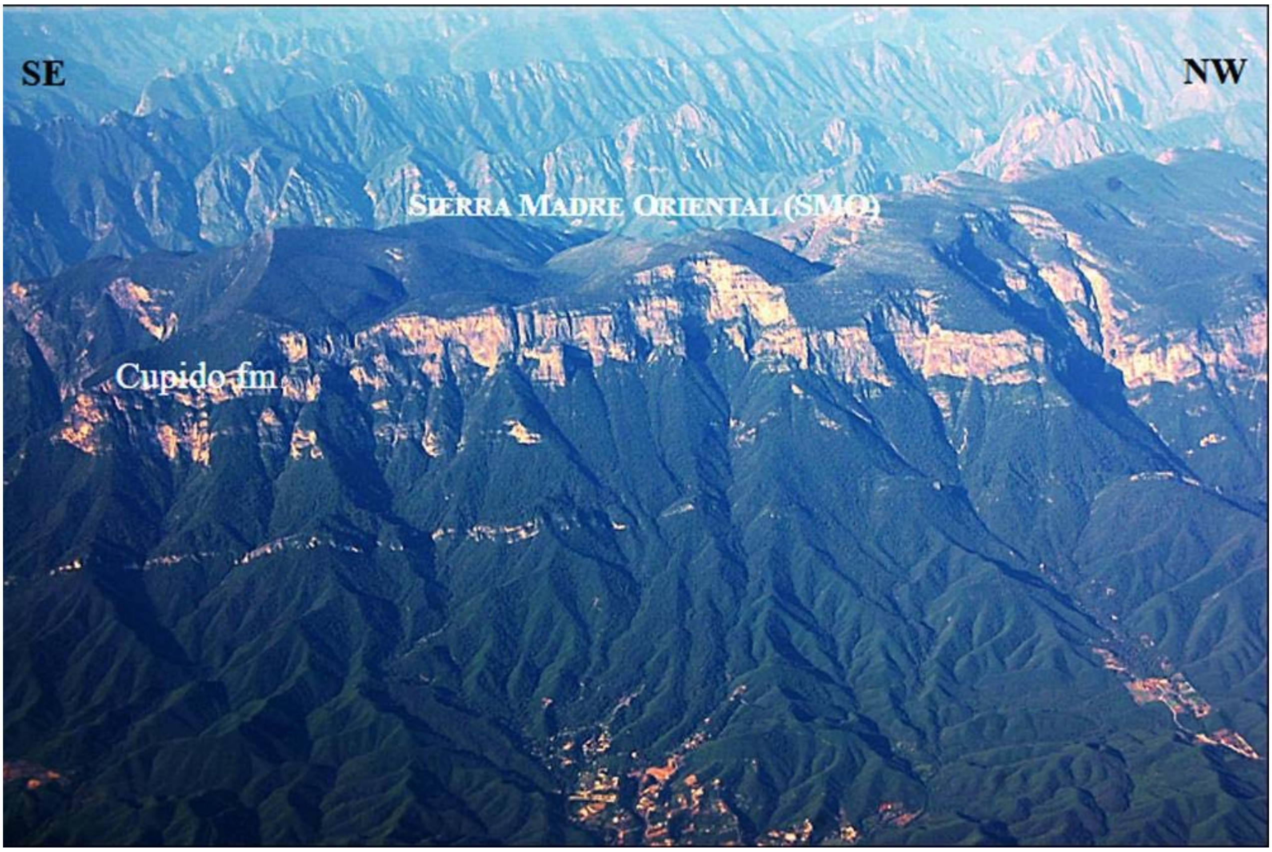


Figure 1: A westward panoramic view of massive limestones of the Cupido Formation crowning the Sierra Madre Oriental (SMO) in Nuevo León, Mexico, as observed through an airplane window.

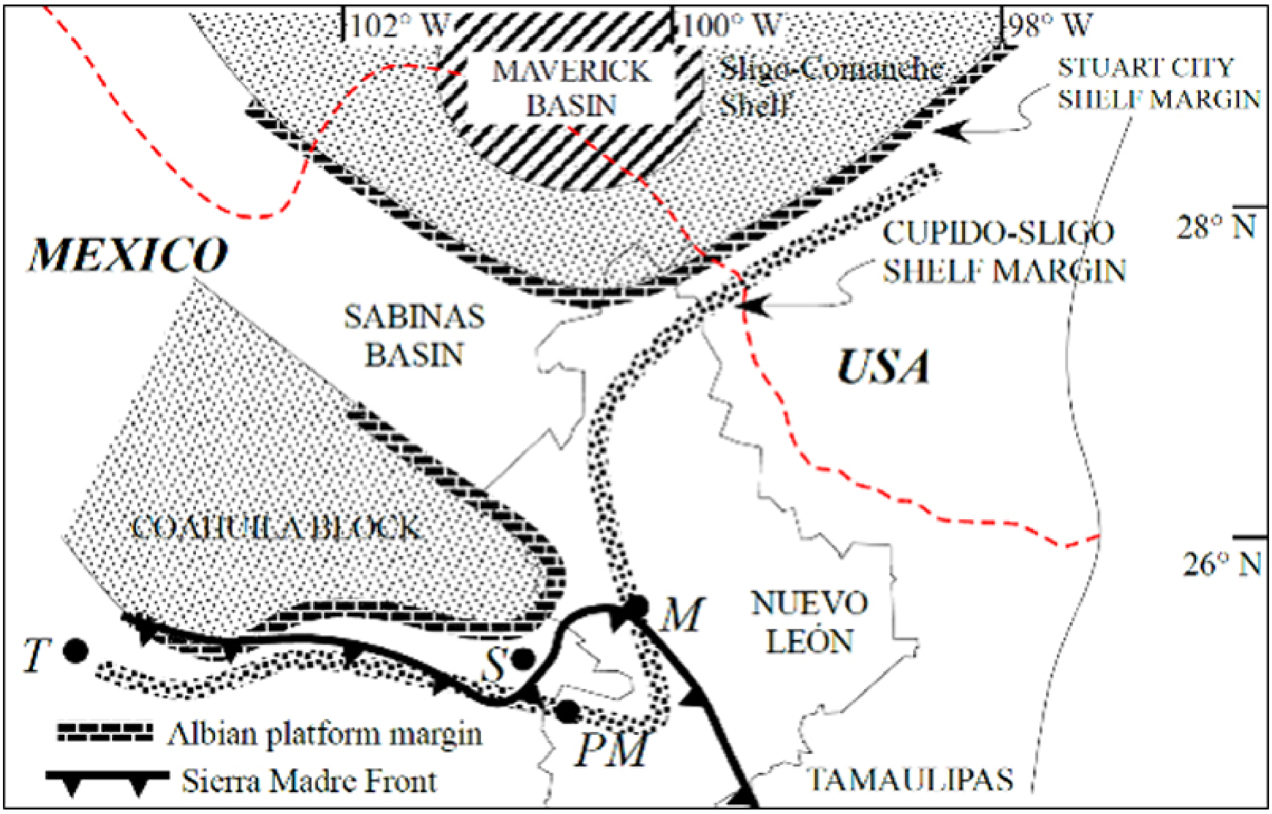


Figure 2: Paleogeography of the Cupido-Sligo shelf margin, with actual distribution as a dotted line (T= Torreón; S= Saltillo; M= Monterrey; PM= Puerto México; modified from LEHMANN *et al.*, 1999).

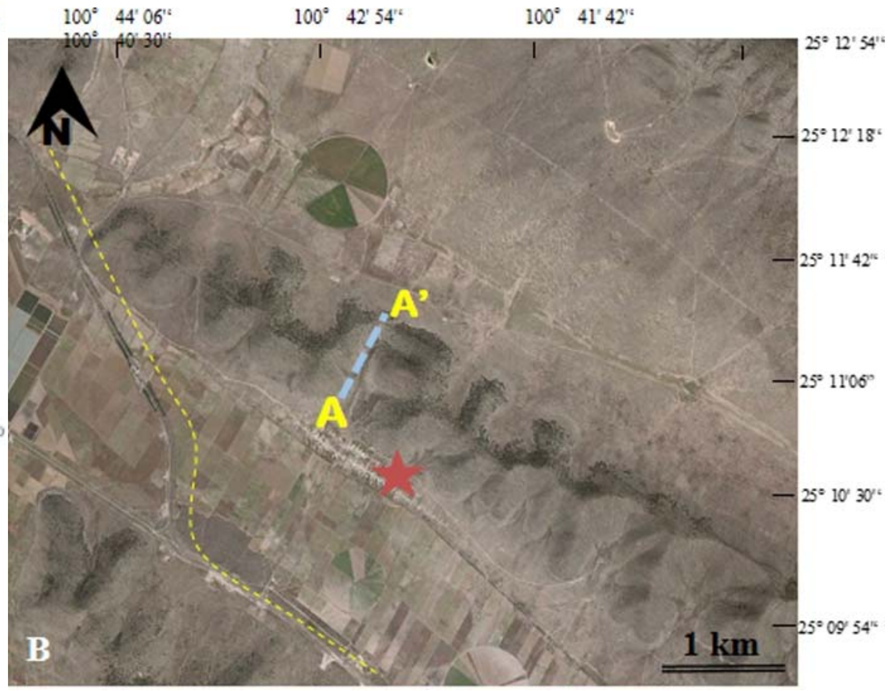


Figure 3: (**A**) Location of the study area in the state of Nuevo León (red area), México. (**B**) The locality of Puerto México with highway 57 in yellow dashed-line, and the measured transect represented by the A-A' blue line.

Block (Fig. 2) and a patch reef belt to a barrier-shoal margin (CONKLIN and MOORE, 1977; WILSON and PIALLI, 1977; SELVIUS and WILSON, 1985; GOLDHAMMER *et al.*, 1991; LEHMANN *et al.*, 1998).

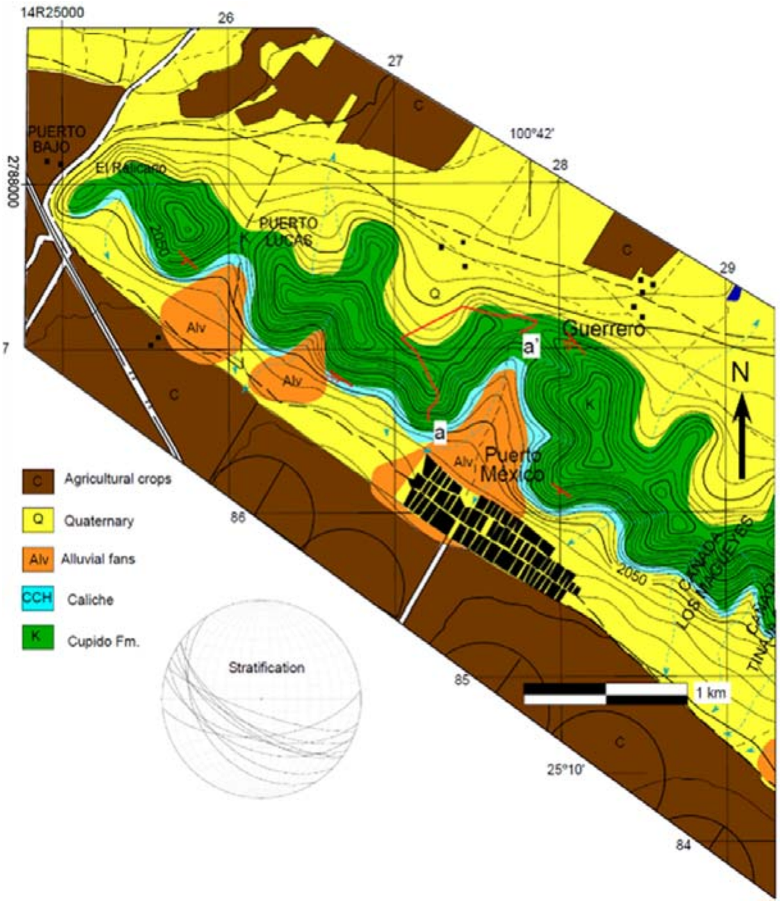
The area under study is the Puerto México outcrop (PM) located in Galeana County in the state of Nuevo Leon (25°11'20.29"N; 100°42' 36.18" W), where the CF crops out on the south-west flank of an anticline with an eroded north-east flank (Fig. 3). This small locality exposes fossiliferous limestones with sub-horizontal stratification but lacks any close stratigraphic references and follows a trend parallel to the land surface, precluding a good stratigraphic control. However, the abundance and size of fossils deserved a closer examination.

An approximate 431 m long SW-NE transect section A-A' (Fig. 3) was measured along a single irregular bedding plane on the southwest dipping slope. Even where massive grey strata were visible at the basal lateral side (at the western side of the outcrop), stratification is fully-covered by vegetation, by Quaternary sediments and by coquinas composed of reworked fossiliferous material from the Cupido.

All measurements were taken through the hill scarp, without further stratigraphic control during fieldwork campaigns (from February 2009 to 2012). In order to place this transect into the Cupido Formation, the outcrop has been correlated with a stratigraphic column that was logged on the west-facing hill less than one kilometer north-west of the transect. The measured section was located by 21 GPS (Global Positioning System) spots for reference; structural strike and dip data were taken for stratigraphic control (Fig. 4). Based on this reference profile, it is assumed that the studied section corresponds with the upper part of the Cupido and documents lateral facies variations along a dip slope bordered at one end by lagoonal facies and at the other by reef facies. About 50 petrographic thin sections were made for petrographic analysis. Where possible, macrofossils identified in the field were collected, but the largest rudists and corals remained in dolomitized limestones *in situ*.

3. Results

Grey and brown thick-bedded to massive limestones lie on an overturned-fold structure with a NW-SE-orientation. Alluvial fan sediments, Quaternary deposits, caliche and agriculture crops cover contacts with the Taraises and La Peña formations (Fig. 5). Stratigraphic data shows that the geological structure of Puerto México is an overturned fold with a westward dip of 67° at the base and 32° at the upper part of the structure with an average of 53°, taken at 10° dip data on the outcrop (Figs. 4-5). The stratification is interpreted as thick-bedded to massive upward, according with the calculation of the true thickness (>90 cm to ~2 m).



◀ **Figure 4:** Geologic map of the Puerto México locality. The geological open polygon on the A-A' blue line derives from structural data of the geological section (modified from Torres de la Cruz, 2011).

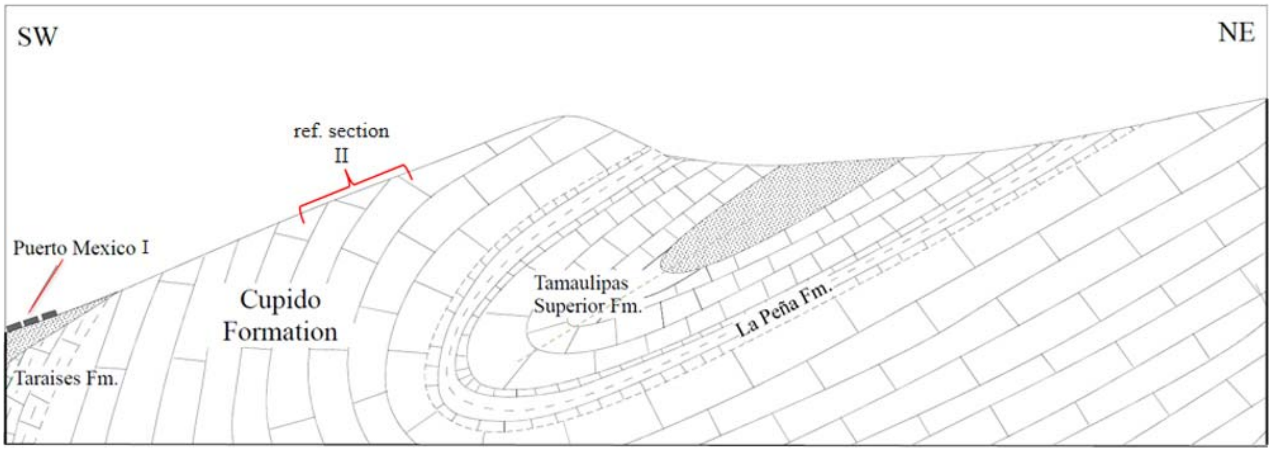


Figure 5: Overturned fold interpreted as the structure of the Puerto México locality (A-A' blue line from Figure 3).

The Cupido Formation conformably overlies sedimentary rocks of the Taraises Formation at its base and it is overlain by the La Peña Formation at the top (Michalzik, 1988). Even where these lower and upper stratigraphic contacts are not visible at this locality, the stratigraphic correlation shows that the PM outcrop is located in the upper part of the CF, near the contact with La Peña Formation. The stratigraphic data shows that the main structure of Puerto México is an overturned fold (Fig. 5).

The PM locality is located between two hills (as shown in the geologic map of Figure 4). The first vertical section was measured on the flat hill marked as I, and the second vertical section used as reference is located on the hill marked as II (Fig. 6.A-B). The outcrop slope exhibits a sub-horizontal trend parallel to the stratification, and a dip ranging from 5 to 10°. The dominant lithology is composed of highly-recrystallized and fractured light-brown limestone (Fig. 6.C-D), mostly fractured and filled with calcite. The description of the reference transect II (Figs. 6-7) will be followed by the description of the sampled transect I.

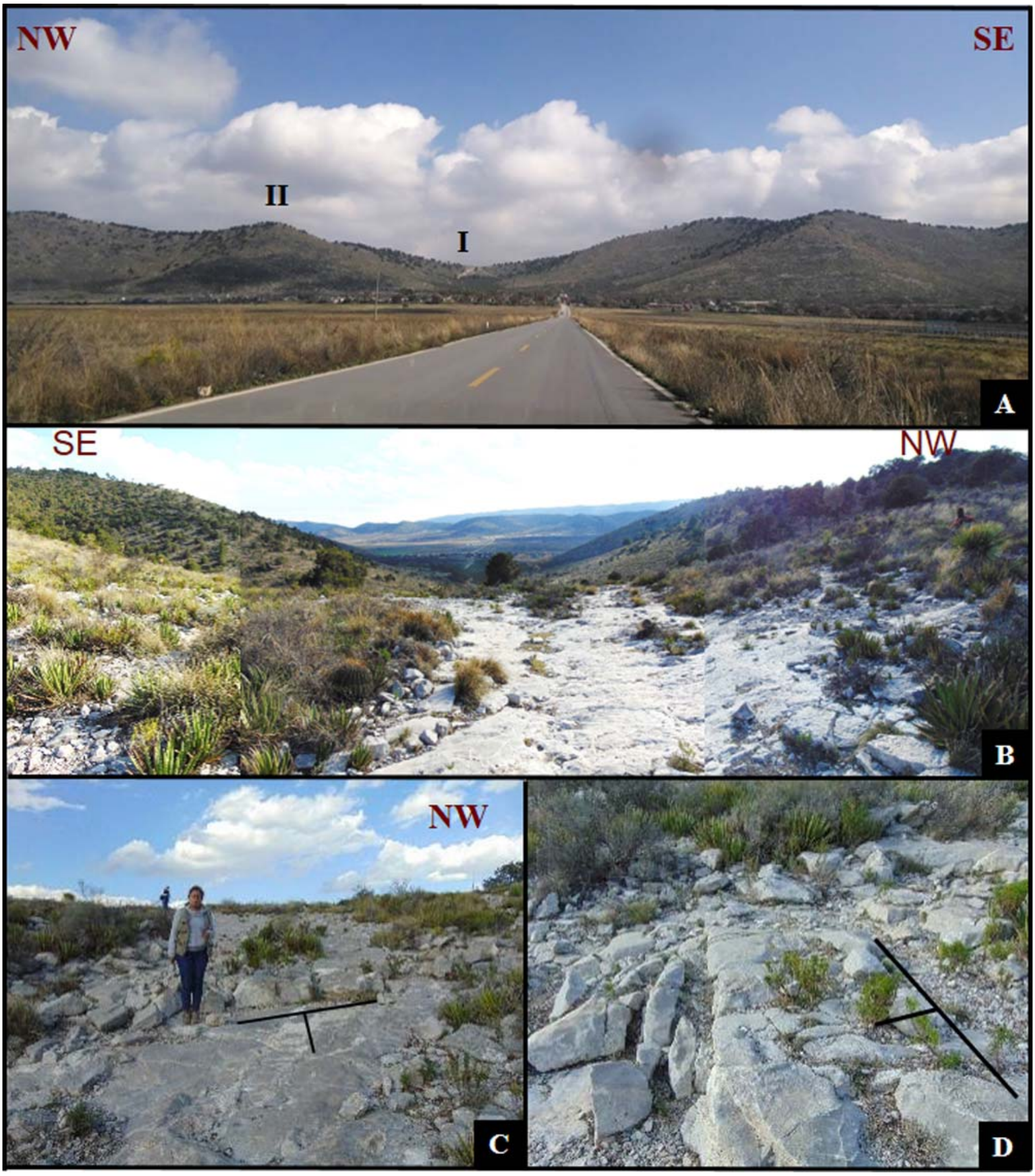


Figure 6: The reference section at the PM locality. (**A**) PM outcrop lies between two hills; the Puerto México dip slope fossiliferous outcrop is marked as I, and the measured reference section is indicated as II (Fig. 7). (**B**) A south-facing panoramic view from the PM outcrop. (**C** and **D**) Sub-horizontal stratification on the reference outcrop II.

According to lithology and fossil content the stratigraphic reference column at site II was subdivided into lower, middle and upper sections (Fig. 7). The lower section is characterized by the succession of thin bioturbated beds with bivalves and chert nodules. The middle section is dominated by bioturbation and calcite nodules. The upper part, which laterally correlates with the PM outcrop (I), is represented by fossiliferous limestone with rudists, stromatoporoids, corals and the local occurrence of calcareous algae.

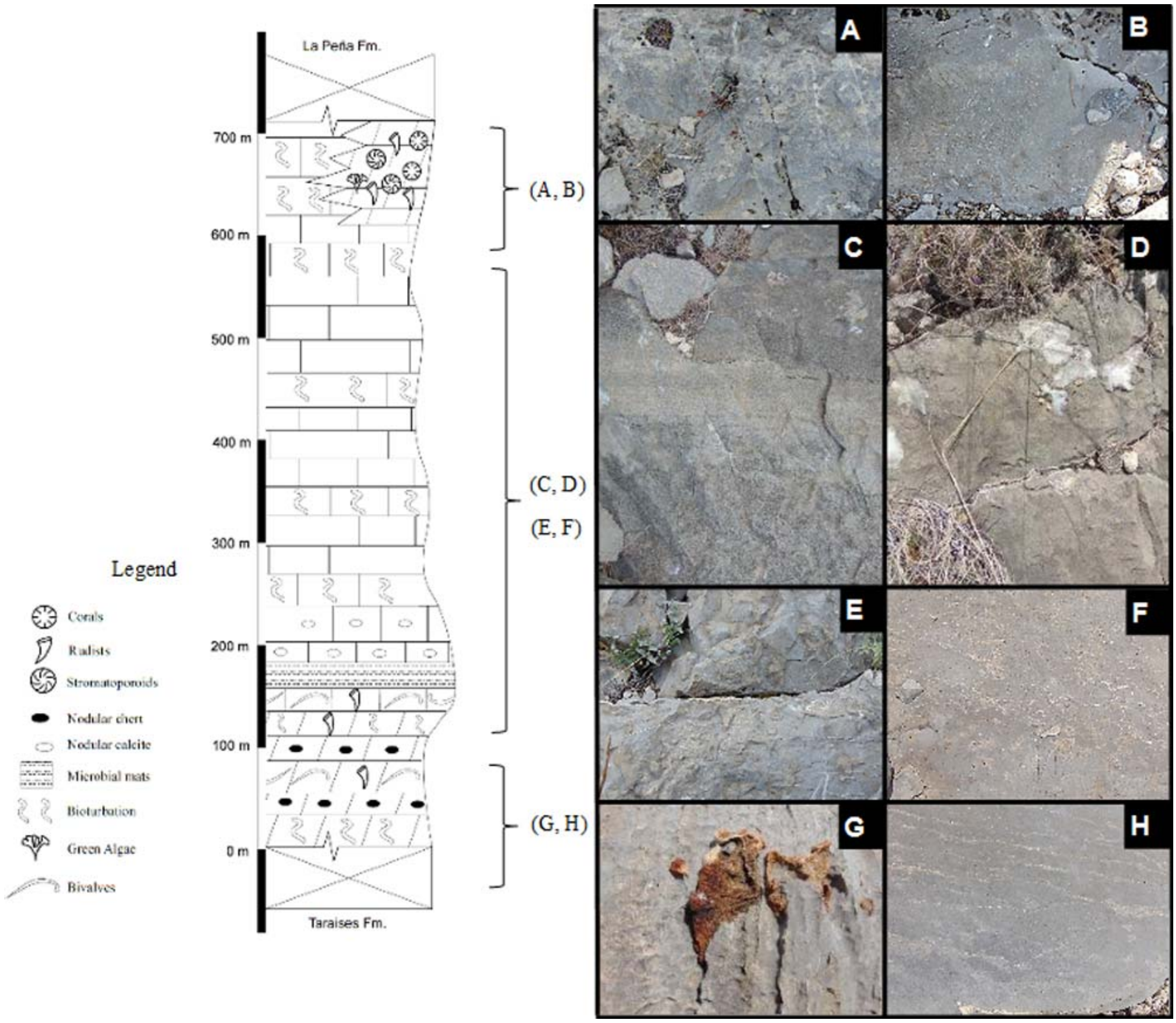


Figure 7: Site II. Reference stratigraphic column taken on the hill (II), to the west of the PM outcrop I. (**A-D**) Representative lithofacies of the three sections from the reference outcrop II at the Puerto México. (**A-B**) The upper member is dominated by rudist and coral bindstones preserved in gray limestones. (**C**, D, **E** and **F**) are examples of bioturbation horizons differentially preserved in limestones in the 500 m of the middle section. Bioturbation marks vary in orientation, diameter and preservation. (**G** and **H**) Examples of nodular chert (G) and bioturbated limestones (H) found in the lower section of the vertical profile site II.

At the PM outcrop (site I) light grey and brown 80-100 cm-thick massive limestones with variable fossil content are the dominant lithology. The dip slope was divided into five distinctive zones that were based on the fossil content and associations and their relative position on the measured transect. The most fossiliferous sampled area covers a 113 m transect and it is found within the 431 m long transect (Fig. 8). A lineal distance of 330 m covered by recent sedimentation is found between Zone 1 and Zone 2. Zone 2 (at 330 m) is the first sampling spot on the outcrop. Between Zone 2 (at 330 m) and Zone 5 (at 431 m) there are 101 m of lineal distance of a massif limestone over a massive structure that lacks clear stratigraphic control and that was correlated laterally with the 700 m stratigraphic column.

The western margin of the dip slope is partially covered by colluvium and caliche. Pink dolostones and light and dark gray massive limestones characterize the middle and upper zones. The basal Zone 1 is characterized by a cover of soil, caliche and conglomerates, and the local presence of diagenetic fossiliferous coquinas *in situ* of unknown age. Secondary sedimentary structures as stylolites, karren and dissolution fronts are evident in zone 1 (Fig. 8.A). These coquinas may be correlated with middle part of the stratigraphic column, described at the 0 m in the measured section, and may represent a lower stratigraphic stage than the rest of the zones. The observed microfossils in thin sections correspond to benthic foraminifera and algae. The main macrofossils in Zone 2 (at 330 m) are small rudists with benthic

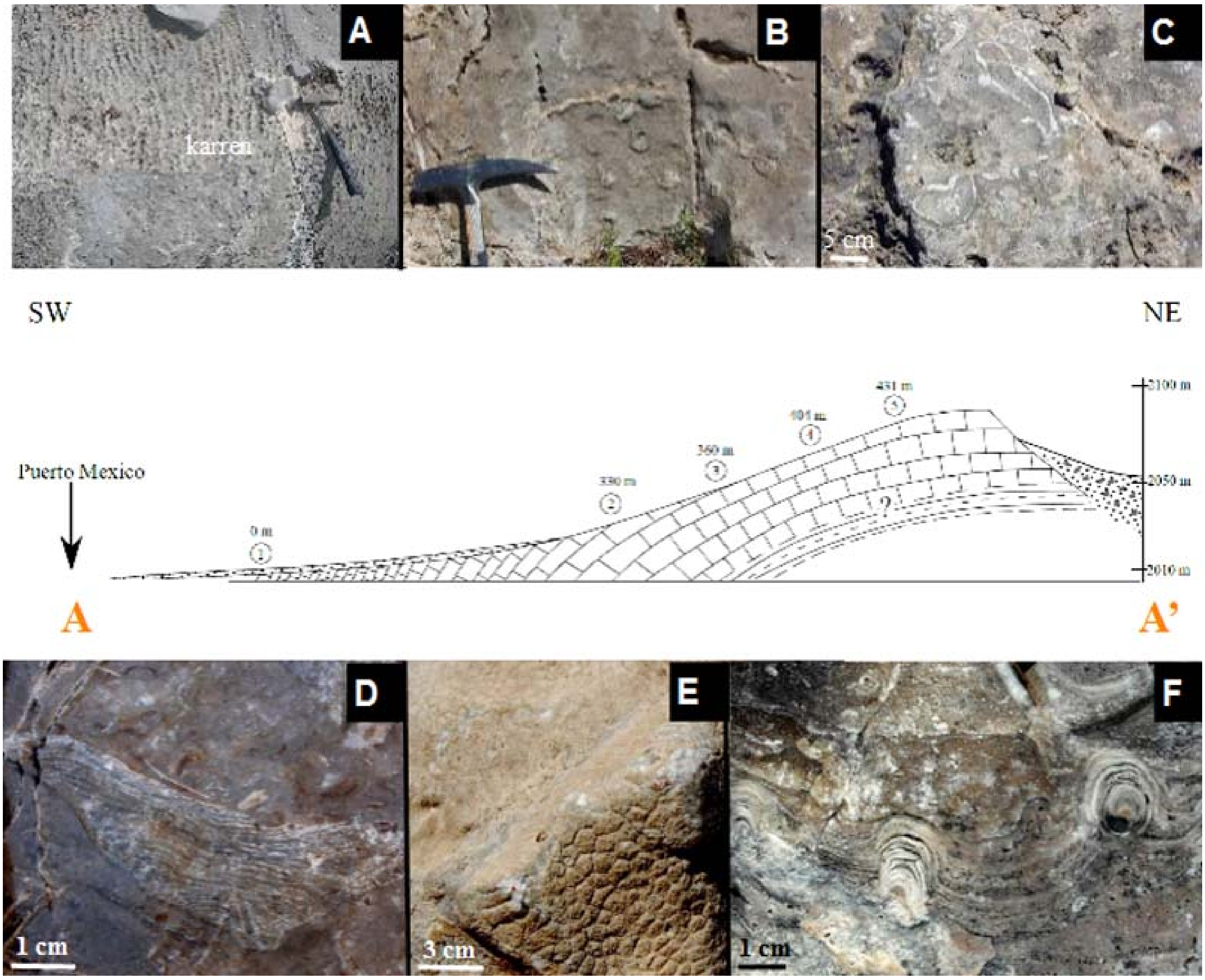


Figure 8: The Puerto México outcrop (site I) and the distribution of zones along the 431 m-transect. (**A**) Typical karren in Cupido limestones from Zone 1. (**B**) Rudist wackestones in Zone 2. (**C**) Rudist shells in different geometrical planes from Zone 3. (**D** and **E**) Stromatoporoid and coral fragments in Zone 4. (**F**) Small spheroidal stromatolites in Zone 5. Each image illustrates the most characteristic fossil in that specific zone. The A-A' section corresponds to the section mapped on Figure 2, while the right axis means the elevation above sea level.

foraminifera and few calcareous algae as microfossils (Fig. 8.B). Dolomitic limestone with abundant macrofossils dominates the middle section on Zones 3 (at 360 m) and Zone 4 (at 404 m). This zone is characterized by large rudists (Fig. 8.C) in close association with stromatoporoid fragments (Fig. 8.D) and large corals (Fig. 8.E). The petrographic lithologies of zones 1-4 consist of wackestones and packstones with green algae and benthic miliolids, but other bioclasts such as shells and echinoderm fragments are also common. Zone 5 (at 431 m) in the measured transect is characterized by the larger rudist shells in low density per square meter. At the upper limit of measured section (beyond zone 5) small laterally-linked-stromatolites (Fig. 8.F) usually known as LLS (laterally-linked-stromatolites) occur as a thin and discrete horizon.

Though the density of macrofossils found in the middle section is higher in zone 3, the size of rudist shells increases in zone 4 both laterally and vertically (from 3 to ~10 cm in shell diameter). A direct counting of small rudist shells (less than 3 cm in length; n=92) in zone 2 yielded 42 shells/m^2, and large rudist shells (10-13 cm long-shells; n=51) yielded 47/m^2 in zone 4. The preserved shells are found either parallel-oriented, but more commonly in erect positions (Fig. 9). Typically rudist shells from zones 3 to 5 show different categories of preservation: some shells are completely dark, bioeroded, recrystallized, and some others are neomorphosed. *Amphitriscoelus* sp. is the most abundant genus in zones 2, 3 and 4 at this outcrop (Fig. 9.A-C). These specimens are found as complete individuals in different orientations; more than 20 individuals can be counted every 20 cm^2. Shells of *Toucasia* sp. or similar morphotypes are also common in PM (Fig. 9.D-F) and are especially abundant at the margin of the outcrop; the size

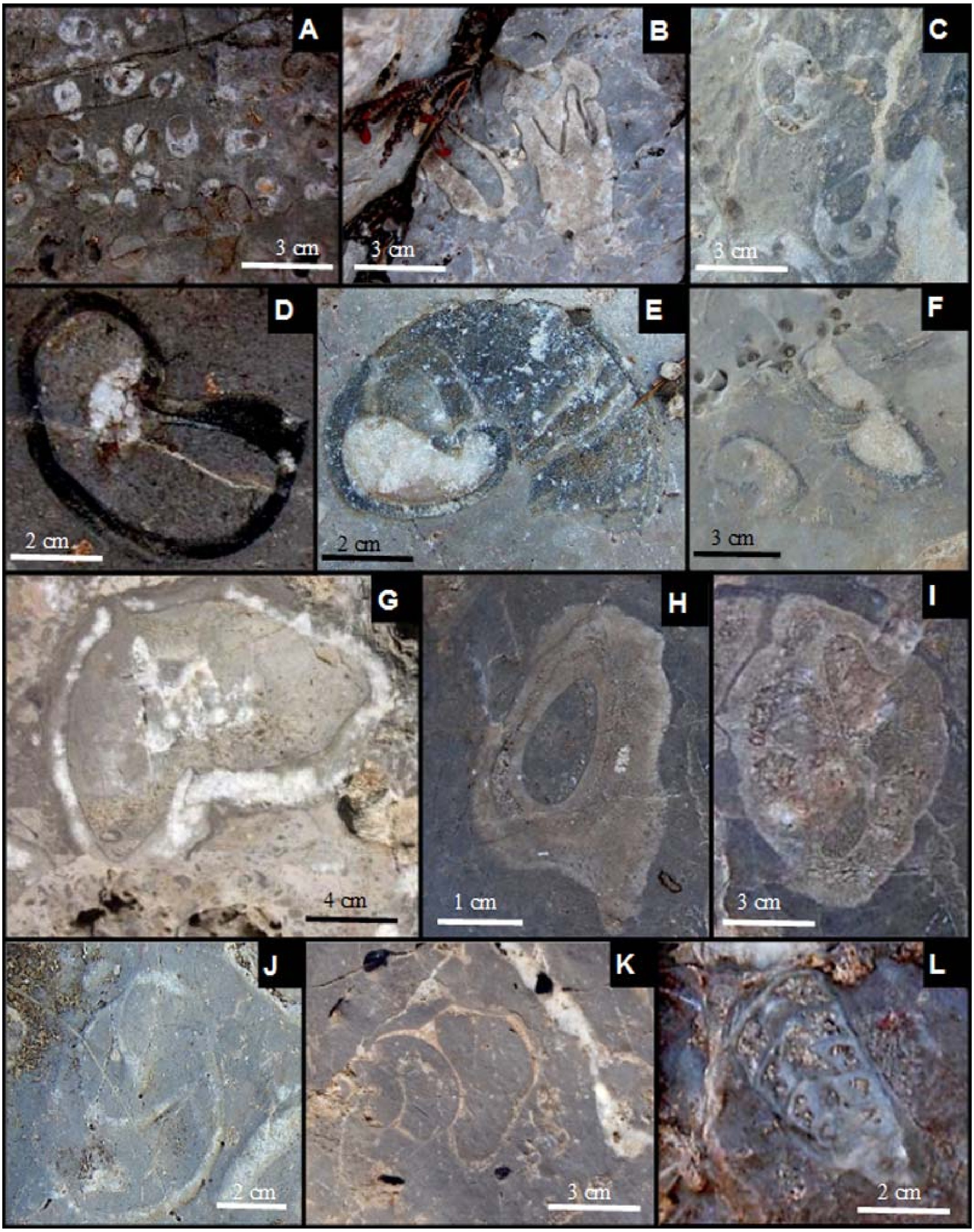


Figure 9: Typical rudists preserved in Cupido Limestone at Puerto México. (**A**, **B C**) *Amphitriscoelus* sp. (**D**, **E F**) Toucasid shells in different orientations. (**G**) *Douvillelia skeltoni.* (**H** and **I**) Other typical indeterminate rudists. (**J, K**) Associated gastropods. (**L**) A nerineid similar to *Diozoptyxis* (Blanca E. BUITRON, personal comm., 2018).

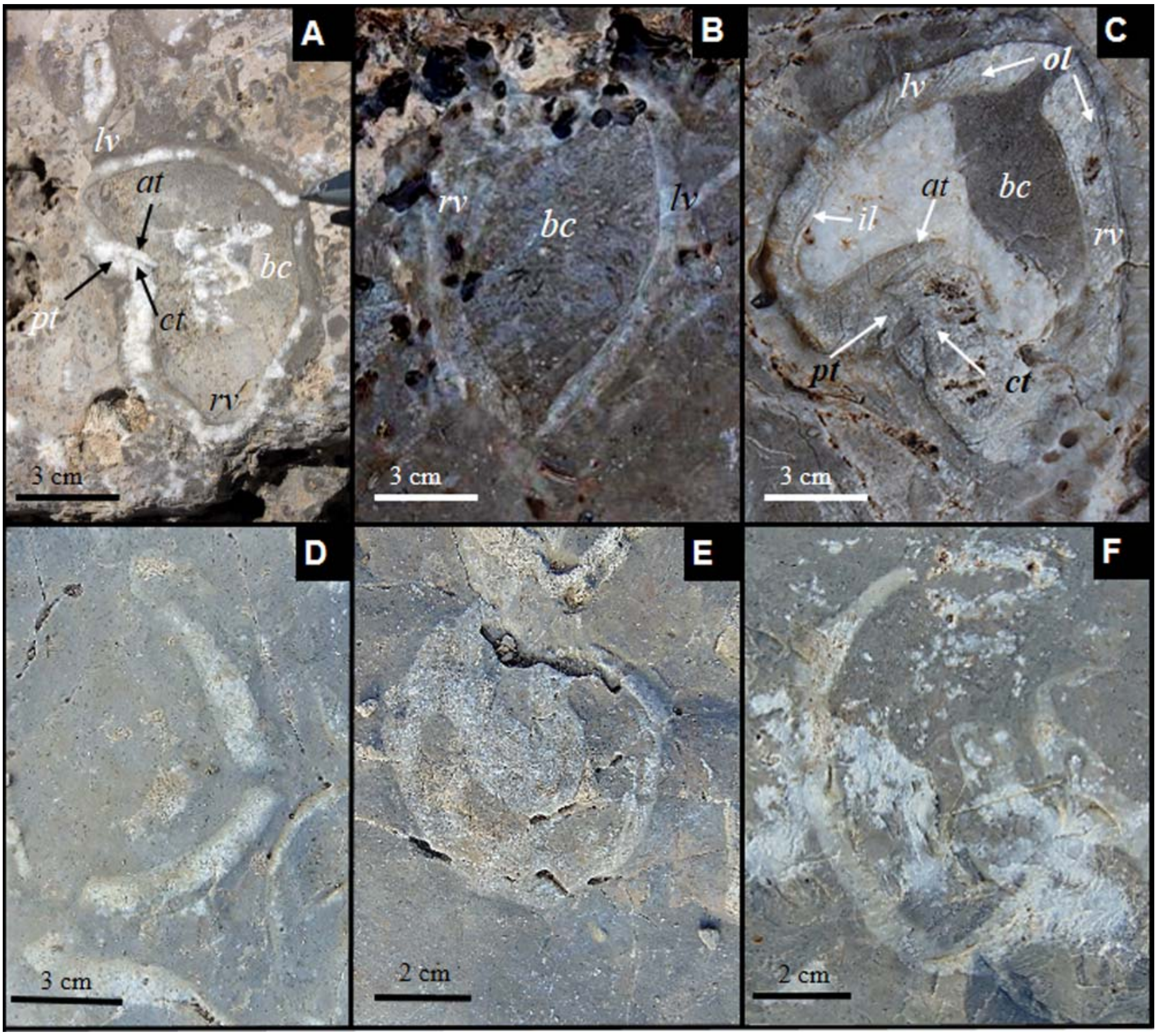


Figure 10: Internal morphology of *D. skeltoni* preserved incompletely and fragmented. (**A**, **B, C**) and internal structure of gastropod shells (**D**, **E, F**). Symbols: *at*, anterior tooth; *bc*, body cavity; *ct*, central tooth; *ol*, outer shell layer; *il*, internal shell layer; *pt*, posterior tooth; *lf*, left valve; *rv*, right valve.

of this rudist ranges between 3 to 5 cm. *Toucasia* sp. shells have an external dark calcite layer and an inner spar layer and the internal cavity is filled with recrystallized sparite or micritic cement. The examples illustrated in Figure 9.E-F are very similar to shells of *Pseudotoucasia. Douvillelia skeltoni* (Fig. 9.G) and other less abundant rudist shells are part of the PM macrofossils (Fig. 9.H-I). Some shells are similar to *Offneria* sp. (Fig. 9.H). Gastropod shells (up to 8 cm in length) from the middle and upper section (Fig. 9.J-L) with the probable occurrence of the nerineid *Diozoptyxis* sp., distinguished by its rhomboidal whorls, are associated fauna (Fig. 9.L).

Douvillelia skeltoni in zone 4, a rudist from the Family Polyconitidae, is the largest fossil at this outcrop. Some shells of *D. skeltoni* have recrystallized calcite (aggrading neomorphism) with geopetal cement in the internal cavity (Fig. 10.a, C). Less well-preserved are gastropod shells larger than 5cm long (Fig. 10.D-F).

Large colonial corals in light brown, grey, pink and red colors occur as discrete masses in zones 3 and zone 4 (Fig. 11). The complete diameter of each coral may be as large as 30 cm (Fig. 11.A). The morphology of *in situ* corals (Fig. 11.A-E) bears similarity with members of the genera *Stelidioseris* (Tomes, 1893). Corals occur in association with scarce stromatoporoid fragments in zone 3 (Fig. 11.F) and ostreoid shells (Fig. 11.G). Even where their preservational stage (strong dolomitization and recrystallization) precludes a detailed taxonomic determination, the general morphology and size are evident. Other fossils in this zone correspond to large fragments of stromatoporoids (Fig. 11.F) and to mollusk specimens similar to *Chondrodonta* sp. (Fig. 11.G), with a shell length of approximately 10 cm.

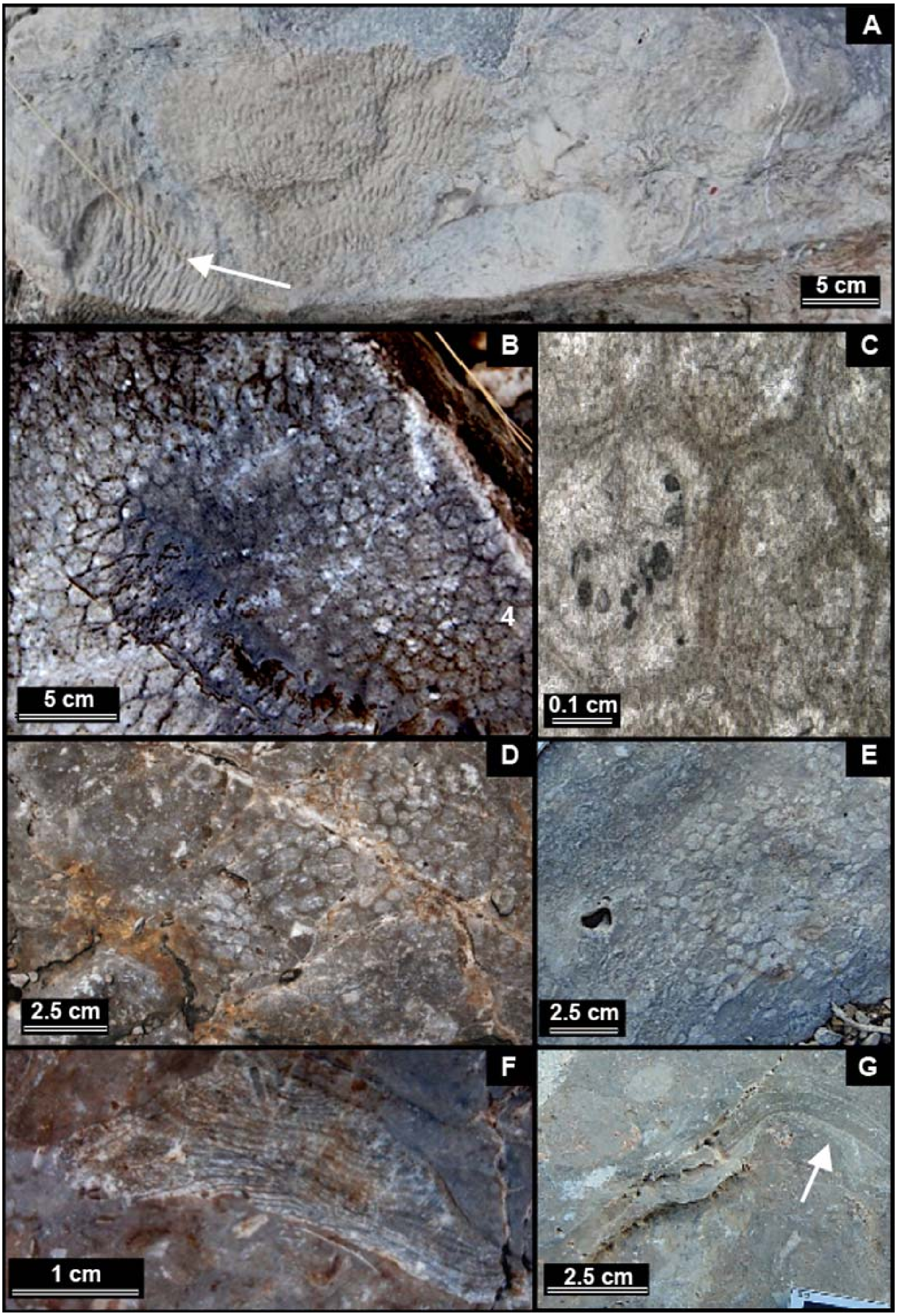


Figure 11: Common *in situ* macrofossils from zones 3 and 4 at PM. (**A**) Coral three-dimensionally preserved showing a longitudinal plane (white arrow). (**B**) Coral fabric preserved in limestones. (**C**) Individual pentagonal corallites similar to *Stelidioseris* (TOMES, 1893). (**D, E**) Corallites from the probable *Stelidioseris* sp. found in zone 3 and 4, respectively. (**F**) Stromatoporoid fragment from zone 3. (**G**) Probable shell of *Chondrodonta* sp.

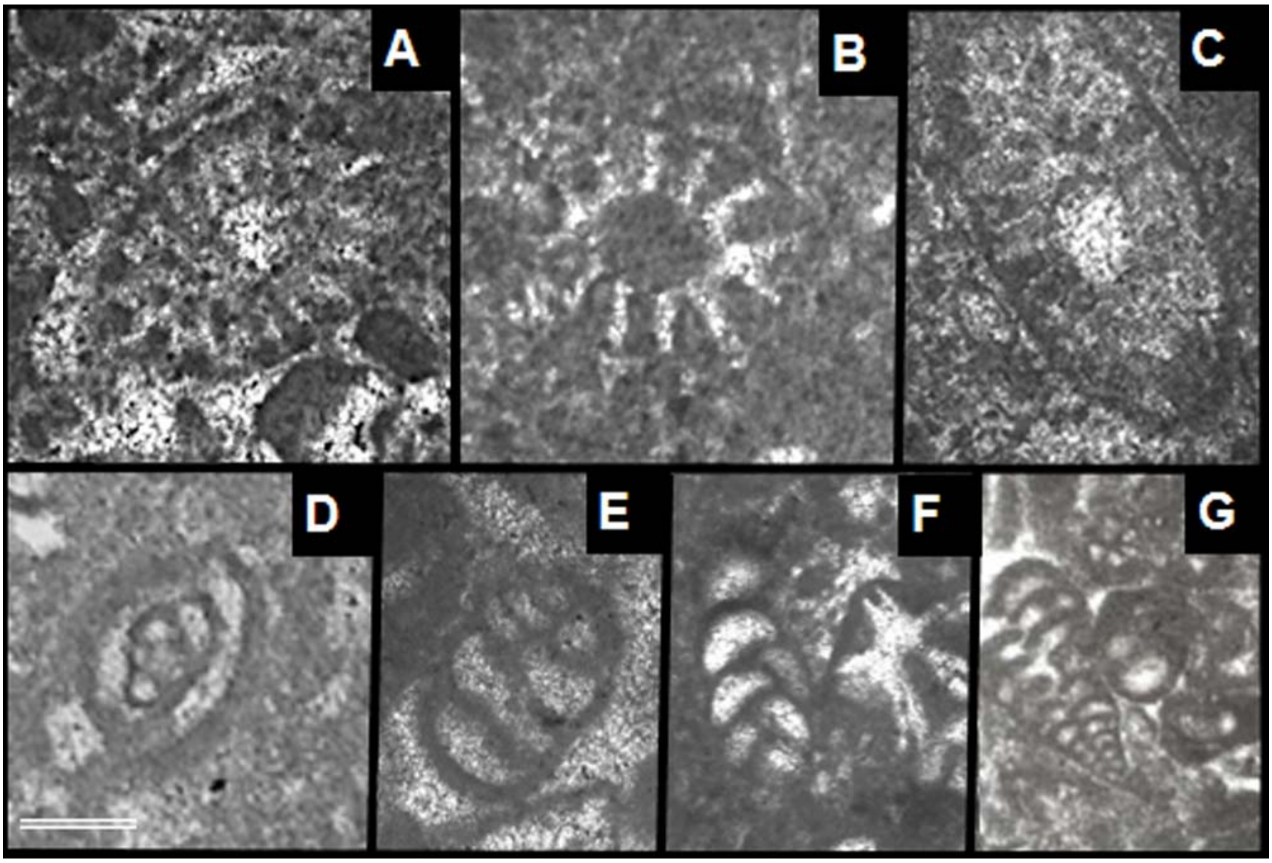


Figure 12: Common microfossils in Puerto México. (**A, B** and **C**) Calcareous green algae (Dasycladales) in random sections; (**D, E**) Common miliolids in zone 2, 3 and 4; (F, **G**) Foraminifer tests in zone 4. Scale bar in all figures = 5 mm.

Microfossils are represented by calcareous green algae and benthic foraminifera (Fig. 12). Echinoids and mollusk shell fragments are common components in the represented textural variations (from mudstone and wackestones to packstones). The petrographic analysis of zones 3-5 mainly shows algal associations, with the Dasycladales *Salpingoporella* sp. and *Terquemella* spp. as the most represented algae (Fig. 12.A-C). Calcareous algae occur in oblique and transversal sections. Other abundant benthic foraminifera are mainly miliolids and arenaceous tests. Shells from invertebrates are predominantly derived from gastropods with a wide size range (Fig. 12.D-G).

4. Discussion

Because structural geological data taken with a Brunton compass at three independent points (one point taken at the other side of the mountain hill) are consistent and similar, the possibility of a lenticular lithosome is totally excluded. The fossil biota represented at Puerto México consists of typical reef-builders of the Early Cretaceous: rudists, corals, stromatoporoids (TUCKER, 1992) from zones 3 and 4 associated with gastropod and bivalve shells, some of them very similar to *Chondrodonta* sp. Although Cretaceous gastropods are seldom reported, they were common elements in rudist-coral assemblages of subtropical to tropical Tethyan provinces (AYOUB-HANNAA and FÜRSICH, 2011). The presence of stromatoporoids has been restricted to the reefal belt at the east of the Coahuila Block (WILSON, 1999). The representative green algae and benthic foraminifera are typical of microfossil associations of back-reef communities (ACCORDI *et al.*, 1982), which are mainly concentrated at the base of the outcrop zones 1 and 2. Although previous works have mentioned their individual or associated occurrences at several localities (C.C. JOHNSON, 1984; CONKLIN and MOORE, 1977; WILSON and PIALLI, 1977; MURILLO-MUÑETÓN and DOROBEK, 2003), there is still need for a detailed fossil description relative to their diagnosis, sizes, distribution and associations. The lateral fossil distribution observed, and their relative size increment in zones 3 and 4 along the measured transect are here interpreted as small-scale lateral facies variation.

This facies variation indicates that even under similar local environmental conditions at any given time, the fluctuating shoreline and biotic interactions may depend on their closeness and exposition relative to the marginal slope, as well as leeward or windward variations. All observed rudist shells show a clear trend toward larger sizes and greater shell calcification toward zones 3 and 4 (Fig. 8), which probably corresponds to zones where wave impact and/or competition is higher in comparison to surrounding lower areas. The observed dolomitized shells of large rudists could also indicate a high Mg availability during dissolution, cementation and re-precipitation processes that together with other factors, promoted fossilization. Not only are dissolution processes more evident in the middle area of the vertical profile but also the diagenetic alteration of each individual shell.

The largest rudist found in this outcrop corresponds to *Douvillelia skeltoni*, as the only specimen of the Polyconitidae (SKELTON, 2013) observed at PM. This species was first described from the lower Aptian Comburindio Formation (ALENCASTER and PANTOJA-ALOR, 1998) in the Huetamo region, southwestern Mexico. This species has been also reported in the massive limestone reefal facies from the mid-Cretaceous Morelos Formation (GUZMÁN, 1950; C.A. JOHNSON, 1990) and in facies from the El Abra Formation (AGUILAR-PÉREZ, 2008). Recently, it has been found in lower Albian strata in South America in the central Andes of Chile (MASSE *et al.*, 2015). SCOTT and HINOTE, (2007) reported *Douvillelia skeltoni* in the *Huetamia buitronae* zone (Barremian-Lower Aptian) in cores from the Friederich and McElroy wells on the shelf margin upper Sligo Formation in Texas. The fossil members of the caprinidae and requieniidae represent the most abundant macrofossils preserved in Puerto México (TORRES DE LA CRUZ, 2011). Caprinids are represented by two genera: *Offneria* sp. and *Amphitriscoelus* sp., both fossils from the early Aptian reported from the Cumburindio Formation in Michoacán State (ALENCASTER and PANTOJA-ALOR, 1996). Because extraction of these shells was not possible, their taxonomic identity remains elusive. However, both fossils are widely distributed with occurrences in Texas, Cuba, Venezuela, and Trinidad (PERKINS, 1969; SKELTON, 1982; ROJAS *et al.*, 1992; HARRIS and HODSON, 1922; HEDBERG and PYRE, 1944; MASSE and ROSSI, 1987). *Offneria simplex* has been documented in several localities worldwide, as in the Tumbadero locality from the Barremian of Cuba-Holguìn, together with *Amphitriscoelus waring* (CHARTROUSSE and MASSE, 1998). In Central America, it has been reported from the classical Mt. Harris outcrop in Trinidad and Tobago (HARRIS and HODSON, 1922), and from Barremian strata in the Barranquin Formation in Venezuela (MASSE and ROSSI, 1987). In Mexico *Amphitriscoelus* has been found in the lower Aptian San Lucas Formation in Huetamo (ALENCASTER and PANTOJA ALOR, 1996), the El Cajón Formation of similar age, and the Comburindo Formation also in Huetamo (ALENCASTER and PANTOJA ALOR, 1998). In Nuevo Leon the first reported example dates back as early as 1930 (BURCKHARDT, 1930), and later it has also been reported from the Cupido Formation in Cerro de Labradores, Galeana, Nuevo Leon (AGUILAR-PÉREZ, 2008). The requieniidae *Toucasia texan*a is characteristic of Lower Albian strata (IMLAY, 1944; ALENCASTER and PANTOJA-ALOR, 1986; ALENCASTER and OVIEDO-GARCÍA, 1998; AGUILAR-PÉREZ, 2008). It has also been reported from the upper member from the Mural Limestone formation in southeastern Arizona as part of coral-algal-rudist patch reefs of early Albian age (SCOTT, 1981) and from reefal facies from the El Abra Formation on the San Luis Potosi platform (AGUAYO-CAMARGO, 1998; AGUILAR-PÉREZ, 2008), and from the Morelos and Cupido formations at localities in central Mexico (AGUILAR PÉREZ, 2008). The morphospecies shown in Figure 9.E-F are very similar to *Pseudotoucasia* sp. *Toucasia* sp. was reported as regular members of peri-reefal restricted environments as from shelf lagoon sediments from the Quitman Formation, from the Benigno Formation, from the Cox Formation in Texas, and from the Lágrima Formation in Sierra de Juárez, Chihuahua (GOLDHAMMER, 1999). Recently, KRUPNIK *et al.* (2016) reported *Toucasia* sp. as an important macrobuilder of biohermal build-ups from the Upper Albian Edwards Formation in the Lake Georgetown Spillway in Williamson County, Texas.

The morphology of *in situ* corals is similar to members of the genera *Stelidioseris* (TOMES, 1893), a widely distributed genus in Cretaceous strata from Mexico, which generally confused with *Actinastrea* (LÖSER, 2006, 2012, 2013), and which has a wide stratigraphic range (LÖSER, 2012). *Stelidioseris* has a long stratigraphic range from the Bathonian to the Campanian (LÖSER, 2016). Another probable coral type from Cupido may be fossil examples similar to members of the genus *Cladophyllia* (?). This genus ranges from the Aptian to Albian and it is reported in reef facies of the Cupido Formation (CONKLIN and MOORE, 1977) and by FILKORN and PANTOJA-ALOR (2009) from the San Lucas Formation in Michoacan. In fact, the occurrence of corals has been documented from reef facies in previous works of the CF (WILSON and PIALLI, 1977; CONKLIN and MOORE, 1977; MURILLO-MUÑETÓN and DOROBEK, 2003; C.C. JOHNSON, 1984). As in several other reported outcrops from this age (LÖSER, 2006, 2012, 2013), corals are not particularly large and they do not form reefs but are found in discrete numbers. As with rudist shells, the poor preservation and the recrystallization degree in PM preclude extraction and a detailed taxonomic determination. But even when a good taxonomic determination is not possible, and biostratigraphic potential is limited, especially in corals, it is important to document the contribution of corals to the carbonate factory and their baffling role within reef ecosystems in Lower Cretaceous outcrops.

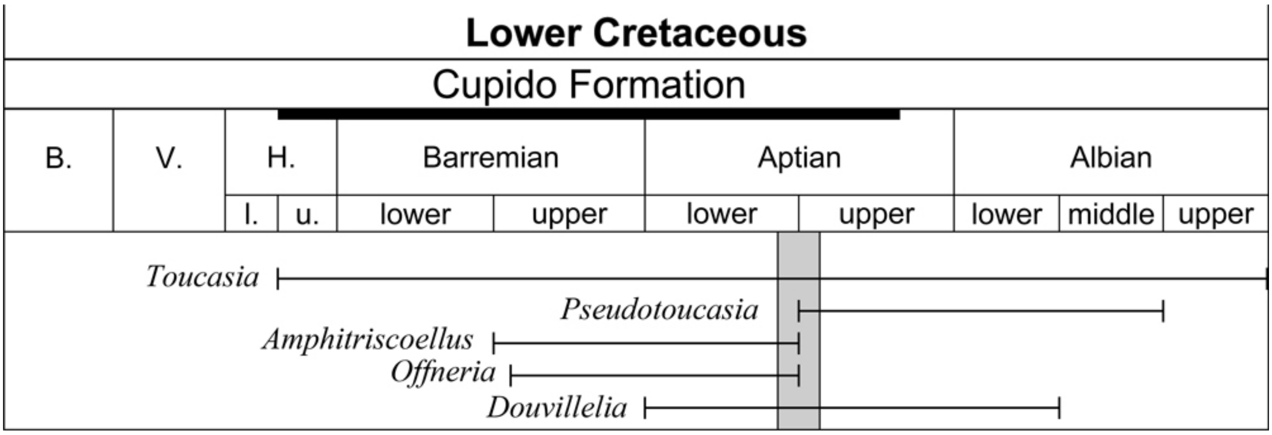


Figure 13: Interpreted stratigraphic range from the Puerto México outcrop according to the fossil documented in this outcrop.

A calcareous green alga referred to the genus *Salpingoporella* is common in Puerto México (work in progress). This alga has been reported in association with *Vercorsella wintereri* in Hauterivian mud mounds exposed at Cañón de Bustamante in Nuevo León State (MURILLO-MUÑETÓN and DOROBEK, 2003). BARRAGAN-MANZO and DÍAZ-OTERO (2004) also identified *S. annulata* in upper Barremian-lower Aptian strata from the Cupido Formation at Sierra del Rosario, in the state of Durango. Using the stratigraphic ranges of the rudist genera *Douvillelia*, *Toucasia*, *Offneria,* and *Amphitriscoelus*, based on the stratigraphic ranges of Jurassic-Cretaceous Hippuritida compiled by STEUBER *et al.* (2016), a lower Aptian age is suggested (Fig. 13). Shells assigned to *Chondrodonta* are common with a reported range from Albian to Campanian (DAMAS *et al.*, 2006). The probable presence of the coral *Cladophyllia* in Puerto México needs further corroboration.

5. Conclusions

Rudist shells are the most common fossils in the Cupido Formation at Puerto México, of which *Amphitriscoelus* sp. is the most abundant shell, *Douvillelia skeltoni* is the largest reported shells from the Cupido Formation and shells of the genus *Toucasia* are relatively diverse in this locality of Cupido.

Although the taxonomic identity of preserved corals remains elusive, it is already clear that the rudists and corals were common in this region and probably provided a main stabilization to the reef community. The observed lateral facies at Puerto México suggest continuous changing environmental conditions, where deposition shows a shallowing up from muddy facies at the base toward coarse facies in zones 3, 4 and 5. This increase of energy level is also correlated with the abundance of benthic foraminifera (miliolids and textularids) together with the relatively high content of dasycladalean green algae (*Terquemella* spp. and *Salpingoporella* spp.) in the lower part. On the other hand, relatively large macro-builders are common in the middle and upper part of the transect.

The Cupido Formation outcrop at Puerto México is a good example of the high variability within reef lateral facies. The lateral facies variation includes a size distribution of fossils from lagoonal facies at the base toward larger fossils in the upper sections, probably corresponding to more exposed facies (closer to the sea margin).

These results suggest that the PM outcrop corresponds to a time frame in the Aptian, just prior to deposition of the La Peña Formation. A tentative prediction would suggest that this outcrop had been the latest development of reef facies, and the evidence of the maximum progradation to the west of the platform edge at the end of a regressive event that ended in sub-aerial platform exposure in those areas nearest to the Coahuila Block.

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