Revista Brasileira de Paleontologia, 22(1):3–14, Janeiro/Abril 2019
A Journal of the Brazilian Society of Paleontology

doi:10.4072/rbp.2019.1.01

ROVEACRINOIDAL ASSEMBLAGES (CRINOIDEA, ROVEACRINIDA, SACCOCOMIDAE) FROM THE ALBIAN CARBONATE MICROFACIES OF SIERRA AZUL (SABINAS BASIN, COAHUILA, MEXICO)

BRUNO FERRÉ
Dame du Lac 213, 3 rue Henri Barbusse, F-76300 Sotteville-lès-Rouen, France.
bruno_ferre@yahoo.fr

ALEJANDRO MONIER-CASTILLO
Léxico Estratigráfico de México, Gerencia Regional Sur, Servicio Geológico Mexicano, Desviación a San Lorenzo Cacaotepec, S/N, Colonia Hacienda Blanca, San Pablo Etla, Oaxaca, CP. 68258, Mexico.
roveacrinus17@yahoo.com

ISABEL LÓPEZ-PALOMINO
Léxico Estratigráfico de México, Oficinas Centrales, Servicio Geológico Mexicano, Boulevard Felipe Ángeles s/n, Carretera Mexico-Pachuca, km 93.50-4, Colonia Venta Prieta, Pachuca de Soto, Hidalgo, CP. 42083, Mexico.
isabellopez@sgm.gob.mx

NOEMI AGUILERA-FRANCO
Soluciones Bioestratigráficas y Sedimentológicas SC, San Patricio 14, Fracc. Misión del Carmen, Cd. del Carmen Campeche, Mexico.
naguiler63@yahoo.com.mx

ARTURO PALMA-RAMÍREZ
Léxico Estratigráfico de México, Oficinas Centrales, Servicio Geológico Mexicano, Boulevard Felipe Ángeles s/n, Carretera México-Pachuca, km 93.50-4, Colonia Venta Prieta, Pachuca de Soto, Hidalgo, CP. 42083, Mexico.
arturopalma@sgm.gob.mx

DIANA CONTRERAS-CRUZ
Posgrado en Ciencias Geológicas, Instituto de Geofísica, Universidad Nacional Autónoma de México, Ciudad Universitaria, CP. 04510, Ciudad de México, Mexico.
diana.dcc19@gmail.com

JULIO REYES ROMO-RAMÍREZ & CARLOS RENE MUÑOZ-JARAMILLO
Gerencia Regional Centro, Servicio Geológico Mexicano, Av. Mariano Jiménez, nº 469 Colonia Alamitos, San Luis Potosí, S.L.P., CP. 78280, Mexico.
julioromo@sgm.gob.mx, carlosmunoz@sgm.gob.mx

ABSTRACT – Plate sections of saccocomid crinoids spotted in the Albian carbonate deposits of the Georgetown Formation from Sierra Azul (Coahuila, NE, Mexico) are reported and described. These microfossil remains consist of discarded proximal plates and partial thecae, *i.e.* primibrachial plates and radial pieces of a partial cup. These roveacrinoids are associated with calcisphere blooms and an abundant diversified planktic foraminiferal assemblage, mostly consisting of favusellids. All these features are evidence of a high primary productivity within an unstable deepening environment. Such pelagic crinoids have been so far regarded as opportunistic organisms that thrived during transgressive eustatic levels and phyto-planktic blooms, in abundance/accumulation events all indicative of hypoxic conditions. The overall microfossil assemblage assigns to this finding an Albian-Early Cenomanian age. Such an event might be well correlated and/or contemporaneous to the bundle of hypoxic events known as OAE1. Such saccocomid plates in Albian deposits revive the debate on the transition between the late Jurassic genera (*Saccocoma* Agassiz and *Crassicoma* Sieverts-Doreck & Hess, *in* Hess) and the late Cretaceous ones (mainly *Applinocrinus* Peck).

Keywords: microfacies, Roveacrinida, Albian, Mexico.

RESUMO – Seções de placas de crinoides saccocomídeos oriundas de depósitos carbonáticos albianos da Formação Georgetown, em Sierra Azul (Coahuila, NE, México) são registradas e descritas. Estes restos fósseis consistem de placas proximais descartadas e parte de teca, *i.e.* placas primibraquiais e peças radiais da taça parcial. Estes roveacrinoides são associados a florações de calcisferas e a uma associação diversificada e abundante de foraminíferos planctônicos, constituída principalmente por favuselídeos. Todos esses aspectos constituem evidência de alta produtividade primária num ambiente instável de batimetria crescente. Tais crinoides pelágicos têm sido considerados como organismos oportunistas que se prosperaram durante fases eustáticas transgressivas e florações fitoplanctônicas, constituindo eventos de acumulação abundante sob condições hipóxicas. O conjunto das associações fossilíferas leva a atribuir idade albiana a eocenomaniana a este registro. O registro pode ser considerado correlato e/ou coevo do evento anóxico conhecido como OAE1. Estas placas de saccocomídeos em depósitos albianos vêm reativar a discussão sobre a existência de formas transicionais entre gêneros neojurássicos (*Saccocoma* Agassiz and *Crassicoma* Sieverts-Doreck & Hess, *in* Hess) e os neocretáceos (principalmente *Applinocrinus* Peck).

Palavras-chave: microfácies, Roveacrinida, Albiano, México.

INTRODUCTION

The north and northeastern parts of Mexico extensively expose Upper Cretaceous marine carbonate deposits that have been long the scope of stratigraphic studies (PEMEX, 1988). There, the Lower Cretaceous (Albian) widely outcropping carbonates record the evolution of a marine shelf environment. Within this tectonic, paleogeographic, and sedimentological framework lies one of the most studied geographic areas in Mexico, the Sabinas Basin, well known for its tremendous geological importance and economic bearings. This basin is restricted by the fold belt and Parras-Popa provinces of the eastern Sierra Madre, and the Coahuila Platform to the south, by the Chihuahua Platform to the west, and by the Burro Platform to the east and north (Eguiluz de Antuñano, 2001).

This basin originated as a rift-type basin bounded by tectonic and paleogeographic blocks: the Coahuila Block in the southeast and the Tamaulipas Block in the northeast (Eguiluz de Antuñano & Aranda-García, 2000). Within this basin were deposited different Mesozoic formations such as the Georgetown Formation, mostly consisting of well stratified, thin to massive, highly fossiliferous limestone beds, with abundant fossil specimens (Hernández, 1977 *in* Hernández-Noriega *et al.*, 1999, 2000). From the fossil content and its stratigraphic position, the middle carbonates of the Georgetown Formation have been assigned to the Albian (Hill, 1901; Echanove-Echanove, 1986; Humphrey & Díaz, 2003; Housh, 2007). The present study arises from the mapping effort of the Mexican Geological Survey (SGM by its Spanish initials) towards the publication of the Geological-mining Map Espinazo G14-A73 (scale 1:50,000), covering the adjacent border area between Nuevo León and Coahuila states.

The exploration efforts have been concentrating on a two-fold approach: 1) issuing a detailed paleontological analysis for the Georgetown Formation stratigraphic sequence by means of microfacies (thin sections); 2) proposing a taxonomic identification of spotted roveacrinoidal remains, towards a subsequent biostratigraphic framework and correlation potentials.

Routine micropaleontological analysis recognized a microfossil association characteristic of a late Albian age and consisting of planktic foraminifers, calcispheres and crinoidal remains (order Roveacrinida; Monier Castillo *et al.*, 2017a). This latter find is worth of mention since the occurrence of roveacrinids in these rocks has never been mentioned ever before in this area, except from grey literature (unpublished internal reports). The present study deals with the morphological description and the tentative systematic identification of these roveacrinoids (*e.g.* Douglas, 1908; Peck, 1943, 1955, 1973; Rasmussen, 1961; Kristan-Tollmann, 1991; Jagt, 1999; Gale, 2016, 2017), sections of which bear interesting stratigraphic promise (*e.g.* Bonet, 1956; Kristan-Tollmann, 1970; Bengtson & Berthou, 1983; Berthou & Bengtson, 1988; Ferré & Berthou, 1994; Ferré, 1995, 1997; Dias-Brito & Ferré, 1997, 2001; Ferré & Granier, 2001). Accordingly, we report their occurrence and subsequent stratigraphic range within the scope of outlining the correlative potentials of these Albian roveacrinoidal plates for Mexico, the adjacent areas and further abroad.

GEOLOGICAL SETTING AND SAMPLE LOCATION

The studied material comes from a carbonate sequence that outcrops in the locality of Sierra Azul, near Castaños town, Coahuila State (26°24’48.9”N - 101°15’11.6”W; Figure 1). Within the scope of the mapping works of the SGM team for the Espinazo map in the area of Sierra Azul, a lithological sequence, *ca*. 42 m in thickness, had been logged. During this geological record special attention has been paid to lithological variations, as well as their stratigraphic relationships pending on the specificities of the study area. Hand samples were precisely localized from sound bulk rocks. Thin sections were processed in the facility of the SGM at Centro Experimental Oaxaca, as a couple of large-sized ones, one parallel, the other perpendicular to the bedding plane. While searching for standard/classical microfossil index species in order to record the petrographic description and the paleoenvironmental interpretation of these microfacies, various oriented sections of roveacrinoidal affinity were detected.

The lithological succession (Figure 2) is composed, from base to top, of: 1) dark grey, fine-grained, medium-to-thick limestone beds with common echinoderm remains (16 m); 2) brown to grey, fine-grained, well-bedded medium carbonate beds with hematitic nodules (10 m); and 3) dark brown, fine-grained, thin-to-medium carbonate beds (17.78 m).

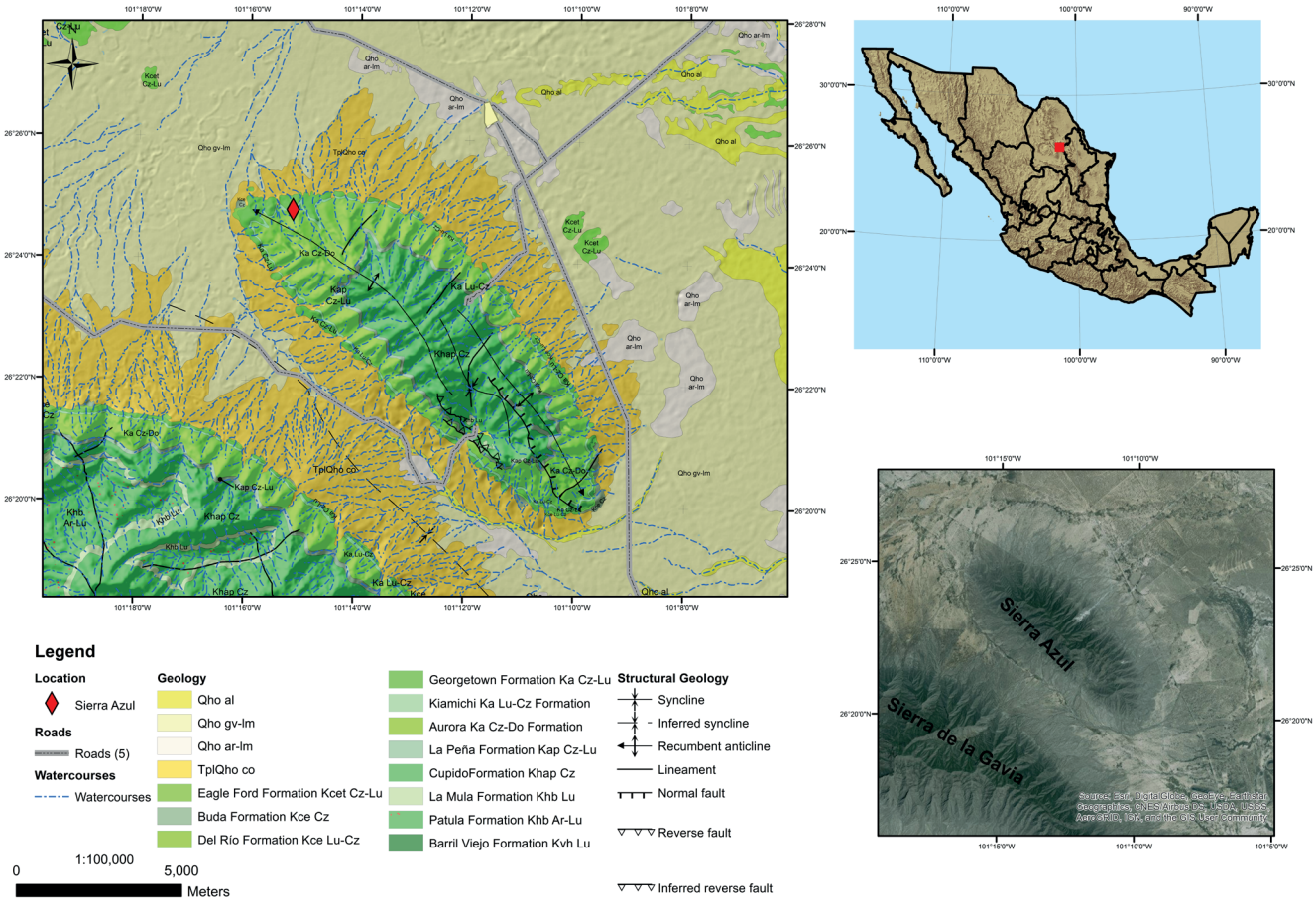

Figure 1. Location of the study area in Sierra Azul locality, at Castaños, eastern Coahuila. Taken from the geological-mining Map Espinazo G14-A73, scale 1:50,000 (Romo-Ramírez *et al.*, 2017).

According to the lithological succession and associated microfaunal association, these carbonate beds are assigned to the Georgetown Formation of mid–to–upper Albian age (Hill, 1901). Lithological samples displaying roveacrinoidal microfacies are indicated in Figure 2.

BIOSTRATIGRAPHY AND ASSUMED AGE OF ROVEACRINOIDAL ASSEMBLAGES

These carbonate deposits were first scrutinized within the scope of the revision of the geological map with the purpose of refining the stratigraphy of this area. To date no macrofaunal evidence has been found during the initial field exploration to provide a precise standard biozonal assignment. Originally Hill (1901) mentioned in this unit the following taxa: *Pachydiscus brazoensis* (Shumard, 1860); *Schloenbachia leonensis* Conrad, 1857; *Epiaster elegans* Adkins, 1920 [now =*Macraster elegans* (Shumard, 1853)]; *Kingena wacoensis* (Roemer, 1852); *Gryphaea washitaensis* Hill, 1884 [now =*Texigryphaea washitaensis* (Hill, 1884)]; *G. corrugata* Say, 1898; *Exogyra americana* Marcou, 1842; *E. plexa* Cragin, 1893; *Alectryonia carinata* (Lamarck, 1806); and *Lima wacoensis* Roemer, 1852. Likewise, Housh (2007) reported additional species, namely: *Idiohamites fremonti* (Marcou, 1842), *Eopachydiscus marcianus* Cobban, 1987; *Mortoniceras trinodosum* Böse, 1910; *M. maximum* Lasswitz, 1904; *M. wintoni* Adkins, 1920; *Prohysteroceras austinense* (Roemer, 1852); *Mariella brazoensis* Roemer, 1852; *Amphidonte walkeri* (White, 1879); and *Texigryphaea washitaensis* (Hill, 1898). Ammonites (especially genera *Mortoniceras*, *Mariella*, *Schloenbachia*, and *Eopachydiscus*) and other macrofossil species, both groups of index fossils of the middle–upper Albian then support the middle-to-late Albian age of these fossiliferous layers.

A general microfacial investigation had been performed to look for some standard microfossil index. During routine examination, echinoderm remains were spotted: given their widespread, repeated occurrence, their relative usefulness and meaning in the historical Mexican stratigraphy (*e.g.* Bonet, 1956), the authors chose to investigate them more thoroughly within the scope of enhanced potentials for stratigraphic precision.

The identified roveacrinoid species from the Albian of the Georgetown Formation display close resemblance to saccocomid taxa described by Sieverts-Doreck & Hess (*in* Hess, 2002) from the Upper Jurassic strata of southern Germany. At that time of full description, their extinction before or at the Jurassic–Cretaceous boundary was still a matter of debate. The material at hand is therefore evidence

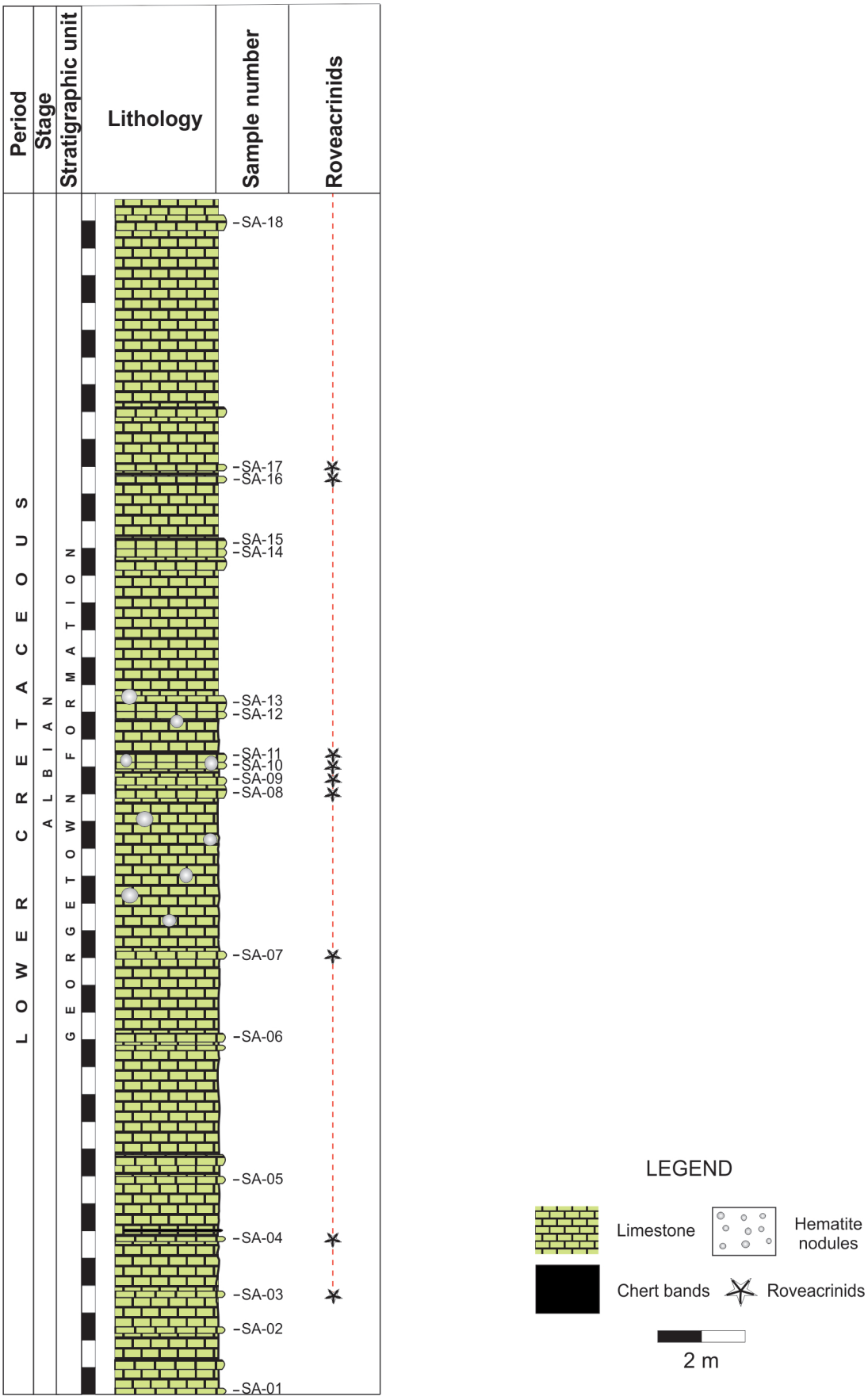

Figure 2. Stratigraphic column of the studied section. Keys SA-01 to SA-17 represent sampled levels while stars indicate the samples displaying roveacrinoidal microfacies.

for earlier forms of saccocomids to cross the J/K boundary into Albian deposits. The questions lying ahead now are how long these genuine saccocomids persisted into the Cretaceous and their relationship to the genus *Applinocrinus* Peck, 1973 and other Cretaceous relatives (Gale, 2016, 2017).

In the Georgetown Formation, these crinoid remains occur in association with planktic foraminifers and calcispheres, indicating a middle–late Albian age (Monier-Castillo *et al.*, 2017b). The microfacies at hand display microfossil evidence such as: planktic foraminifers among which abundant favusellids [*Favusella washitensis* (Carsey, 1926), *F. scitula* Michael, 1973, *F. pessagnoi* Michael, 1973 – all these favusellid species are usually considered conspecific to *F. washitensis*], some ticinellids [*Ticinella roberti* (Gandelfi, 1942), *T. primula* Luterbacher, 1963], bishopellids [*Bishopella ornelasae* Trejo, 1983; *B. alata* Trejo, 1983], calciodinoflagellate cysts [*Calcisphaerula innominata* Bonet, 1956], and some small benthic foraminifers. Such a planktic foraminifer and calcisphere association is characteristic of a middle–late Albian age (Scott, 2009).

SYSTEMATICS

The supra-generic systematics follow the scheme proposed by Hess & Messing (2011), amended by Wright *et al.* (2017). The material herein described (thin sections) is housed in the Paleontological Collection of the SGM, Mexico, under the abbreviation SA (for Sierra Azul) and catalogue numbers from SA-01 to SA-18. Given the lack of complete thecae and/or specific diagnostic thecal plates, we chose to leave these specimens under open nomenclature until further additional material, and compared them to already known species from Upper Jurassic. Worth of mention is that nine roveacrinoidal microfacies levels have been noticed so far, but only four of them (namely samples SA-03, SA-07, SA-08, and SA-09) provided plate sections susceptible to be appropriately identified systematically. The relatively good preservation of sections allowed us to recognize diagnostic features that identify them to family level and compare them to Late Jurassic taxa, on the basis of the seminal works of Lombard (1937, 1945), Brönnimann (1955), Verniory (1954-62), Ferré & Berthou (1993), Ferré & Granier (1997, 2000, 2001), and Hess (2002).

Class CRINOIDEA Miller, 1821
Subclass ARTICULATA Zittel, 1879
Order ROVEACRINIDA Sieverts-Doreck, 1953
Family SACCOCOMIDAE D'Orbigny, 1852

Genus et species indet. 1
(Figures 3A–B)

Material. Thin sections labelled SA-08 (SA-08/01 and SA-08/02).

Description. Figure 3A (SA-08/01) depicts three plate sections assumed to be conspecific. In the upper left corner is a sub-oblique tangential section of a second primibrachial plate (sub-Obl/TgS-IBr2). The gross outline of this plate section is somewhat blunt and resembles a rice grain; the radial 'ridge' is flanked by two large muscular facet areas (the right one is mostly missing on the picture). In the middle lower side lies a tangential longitudinal section of thecal plates (Tg/LgS-Rad/Theca), displaying a deep, elongate ambulacral furrow and suggesting a narrow and long primibrach outline; the articular facet is small. In the lower right corner is a 'massive', high-magnesium calcite (HMC) section, with some butterfly-like outline. This is a paraxial transverse section of a theca (Ax/TS-Rad/Theca). The two interradial processes intersected by the section plane are responsible for the two calcitic 'butterfly wings' on each side of a small radial articular facet. The theca is small, low but wide due to the oval-rounded interradial lobes flanking the tiny articular facet at the rim of the cup. The lateral outline displays some reticulate, crenulate surface. The minute aboral ligament pit is in the section plane. The basals and/or centrale are not visible on the section. Figure 3B (SA-08/02) shows a longitudinal axial section of a first secundibrach (Ax/LgS-IIBr1) of genuine Saccocomidae affinity. The proximal end of this plate is cup-like, suggesting a large slope distal articular facet to the second secundibrach. The main body of the plate is thin and elongate; its outer surface shows neither trace of reticulation, nor ridgelet, nor secondary spinose expansion. The axial canal, as a ventral groove, is faint but distinct.

Discussion. The overall outline of the presumed thecal section resembles much the theca (basals partly fused with centrale) of *Crassicoma feifeli* Sieverts-Doreck & Hess (*in* Hess, 2002; pl. 8, fig. 4). The interradial processes are oval-shaped, instead of sharp and slender, the tiny articular facet is at the rim of the cup, in the central area between the interradial processes. As for the primibrachial plate sections, the first primibrachial plate is slightly elongated, dorso-ventrally flattened, and pin-like; its outline shows a moderate swelling at its end and a relatively 'wide' feeding groove. We cannot distinguish any outer ornamentation. It recalls and matches well with the first primibrachial plate of p. 8, fig. 10 (Hess, 2002), the second primibrachial being thin and really elongated (pl. 8, fig. 11; Hess, 2002). Concerning the theca section, the two blunt radial areas are oval and lappet-like, separated by a tiny articular facet at the upper thecal rim. This set of plates is comparable to the brachials from the Upper Jurassic of Germany (Hess, 2002). We suggest that the material at hand from the Albian of Mexico is close to the original lower Kimmeridgian species *C. feifeli*. However this material is not sufficent to precise their phylogenetic affiliation; they could either be conspecific (with a very large vertical range implying the J/K boundary crossing for genus *Crassicoma*), or being the Lower Cretaceous descendant of genus *Crassicoma*.

Genus et species indet. 2
(Figure 3C)

Material. Thin section labelled SA-08 (SA-08/03).

Description. Figure 3C (SA-08/03) depicts an axial sub-tangential longitudinal section of a first primibrach (Ax/subTg/Lg-IBr1) of a genuine saccocomid. The section plane

is slightly deported 'inwards' on the interior/proximal side. The plate is higher than broad. The proximal part is thicker than the distal one. The proximal articular fossa is of medium size. The inner side has a V-shaped central part with a broad, flat furrow flanked by two exterior trapezoidal 'wings', suggesting a long, broadly 'blocked' cryptosynarthrial surface with a rather large central canal (ambulacral furrow between muscle fields).

Discussion. The ossicle is identified as a first primibrachial plate IBr1 (Figure 3C): slightly elongated and dorso-ventrally flattened, showing a muscular articulation, a non-muscular and sloping distal articulation, and an external surface devoid of ornamentation. It differs from a second primibrachial plate (IBr2) that is strongly wedge-shaped with a triangular profile, lacking both wings and oral processes. The general silhouette of this section (and subsequent identified plate) recalls that of the first primibrachials illustrated by Hess (2002) for *Crassicoma praeschattenbergi* Sieverts-Doreck & Hess (*in* Hess, 2002, pl. 6, figs. 7a–b; 8a–b). Indeed the relative proportions of the primibrachial (Hess, 2002, pl. 6, fig. 7) actually matches with the section at hand. Consequently, it raises once more the issue of the stratigraphical range of Upper Jurassic saccocomids: in the present case, either the range of *C. praeschattenbergi* (upper Kimmeridgian) runs through the J/K boundary up to Albian, or the section at hand might represent a brand new saccocomid taxon.

Genus et species indet. 3
(Figures 3D–E)

Material. Thin sections labelled SA-08 (SA-08/04 and SA-08/05).

Description. Figure **3**D (SA-08/04) shows a transverse section of a brachial plate (TS-NBrn) of a genuine saccocomid. Such a microfacial section is typical and recalls the standard brachial sections of the Jurassic saccocoma microfacies (for details, see Lombard, 1937, 1945; Verniory, 1955-1962). Figure 3E (SA-08/05) consists in a partial oblique/tangential longitudinal section of a first/second primibrach (Obl/Tg/LgS-IBr1-2) of a saccocomid. This kind of 'safety pin' outline evidences a deep ambulacral furrow, a narrow and long primibrach outline, and a small- to medium-sized articular facet.

Remarks. These brachial ossicle sections are distinct from those of any *Saccocoma* brachial plates, they are similar to proximal brachials of *Crassicoma schattenbergi* Sieverts-Doreck & Hess and *Crassicoma subornata* Sieverts-Doreck & Hess (Hess, 2002) but they differ from those ossicles by lacking a reticulate ornament on their surface. This lack of ornamentation could be a mere sign of a new "*Crassicoma*" taxon from Lower Cretaceous.

Saccocomidae indet.
(Figures 3F, 4A–E)

Material. Four thin sections labelled SA-03 (SA-03/01), SA-07 (SA-07/01) SA-08 (SA-08/06), and SA-09 (SA-09/01, SA-09/2 and SA-09/03) respectively.

Description. Assignment to generic and specific positions is difficult; given the lack of specific ornamental features we chose to leave all these morphologically characteristic sections in open nomenclature. Under this family level label are mostly gathered longitudinal paraxial and transverse sections of tertibrachial (median to distal brachial) plates, morphology of which were extensively studied and illustrated by Lombard (1937, 1945) and Verniory (1956-1962) from the Swiss Upper Jurassic carbonate deposits. Transverse sections display an obvious V-shape while longitudinal paraxial sections resemble some safety pin, sometimes with square-to-rounded ends (that is, traces of artcular facets). All these sections are devoid of ornamentation (lack of spines, wings, reticulation and/or corrugations). Figure 3F (SA-03/01) represents a transverse section of a secundibrachial plate (TS-IIBr2). The articular fossa is oval and medium-sized; the inner feeding groove is large, elliptical, and flanked by two alar expansions; the outer rounded side shows some radial ridgelets (crenulation/slight corrugation). Figure 4A (SA-07/01) both feature most likely a tangential section of a thecal or primibrachial plate (TgS-Theca/IBr1-2) of roveacrinoidal affinity ('saccocomid'). Figure 4B (SA-08/06) shows a tangential longitudinal section of a first/second primibrach (Tg/LgS-IBr1-2) that displays a small articular facet, a deep elongate ambulacral furrow, and suggests a narrow and long primibrach outline. Beside this section (right side) lies a 'massive' HMC, butterfly-like section: this is a paraxial transverse section of a theca (Ax/TS-Rad/Theca); unfortunately the basals and/or centrale are not visible. The two interradial processes intersected by the section plane are responsible for the two 'butterfly wings' flanking the small radial articular facet, with a minute aboral ligament (in the section plane). The lateral outline displays some reticulate, crenulate surface. Figure 4C (SA-09/01), slightly below the centre of the picture, is a transverse section of a distal brachial plate (TS-NBrn) of an indeterminate roveacrinoid saccocomid (?), showing a triangular outer shape, a marked inner feeding groove, and a radial ornamental keel.

Figure 4D (SA-09/02) illustrates a small and partial section that could be interpreted either as a tangential section of a primibrach, or a partial transverse section of a broken theca. However it is indeed a tangential longitudinal (paraxial) section of a short and blunt primibrachial plate (Tg/LgS-IBr2) of a saccocomid. Figure 4E (SA-09/03) depicts a transverse section of a distal brachial plate (TS-NBrn), showing a triangular outer shape, a marked inner feeding groove, and a radial ornamental keel, all features recalling a true saccocomid.

Remarks. The brachial ossicles observable in the thin sections at hand are slightly larger than any *Saccocoma* brachial plate ever reported from Upper Jurassic deposits. Furthermore, they show relatively blunt (compared to true *Saccocoma*) oral projections. They are similar to proximal brachials of *Crassicoma schattenbergi* Sieverts-Doreck & Hess and *C. subornata* Sieverts-Doreck & Hess, figured in Hess (2002).

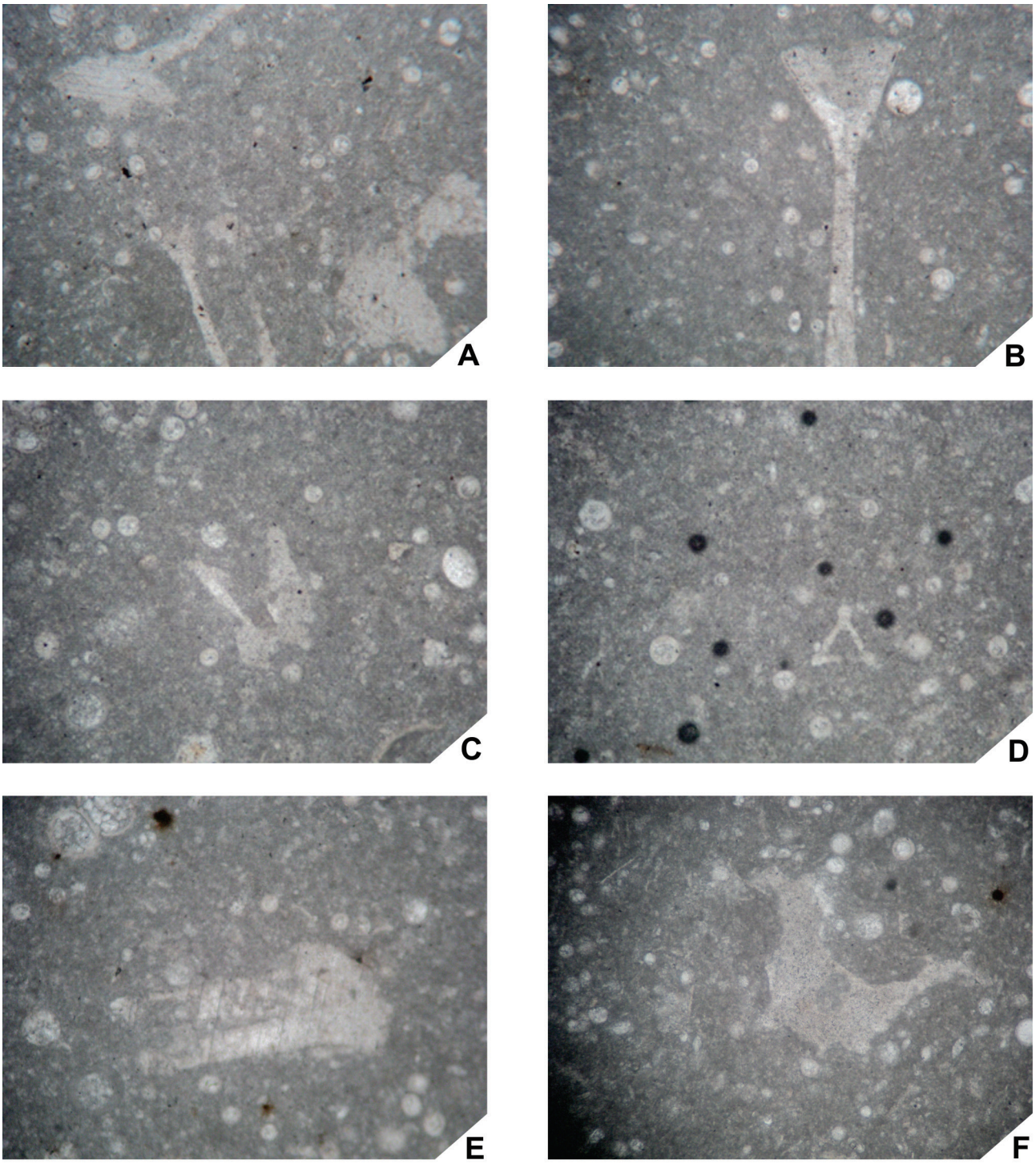

Figure 3. A–B, Genus et species indet. 1. **A**, second primibrachial plate, sub-oblique tangential section (sub-Obl/TgS-IBr2); indeterminable primibrachial plate, tangential longitudinal section (Tg/LgS-IBr1-2); and theca/radial plate, paraxial transverse section (Ax/TS-Rad/Theca) [TS no. SA-08/01]; **B**, first secundibrachial plate, longitudinal axial section (Ax/LgS-IIBr1) [TS no. SA-08/02]. Both magnification: x 6.3. **C**, Genus et species indet. 2, first primibrachial plate, axial sub-tangential longitudinal section (Ax/subTg/Lg-IBr1) [TS no. SA-08/03]. Magnification: x 10. D-E. **D**, Genus et species indet. 3, indeterminable brachial plate, transverse section (TS-NBrn) [TS no. SA-08/04]; **E**, indeterminable primibrachial plate, partial oblique/tangential longitudinal section (Obl/Tg/LgS-IBr1-2) [TS no. SA-08/05]. Magnification: x 10. **F**, Saccocomidae indet., secundibrachial plate, transverse section (TS-IIBr2) [TS no. SA-03/01]. Magnification: x 10.

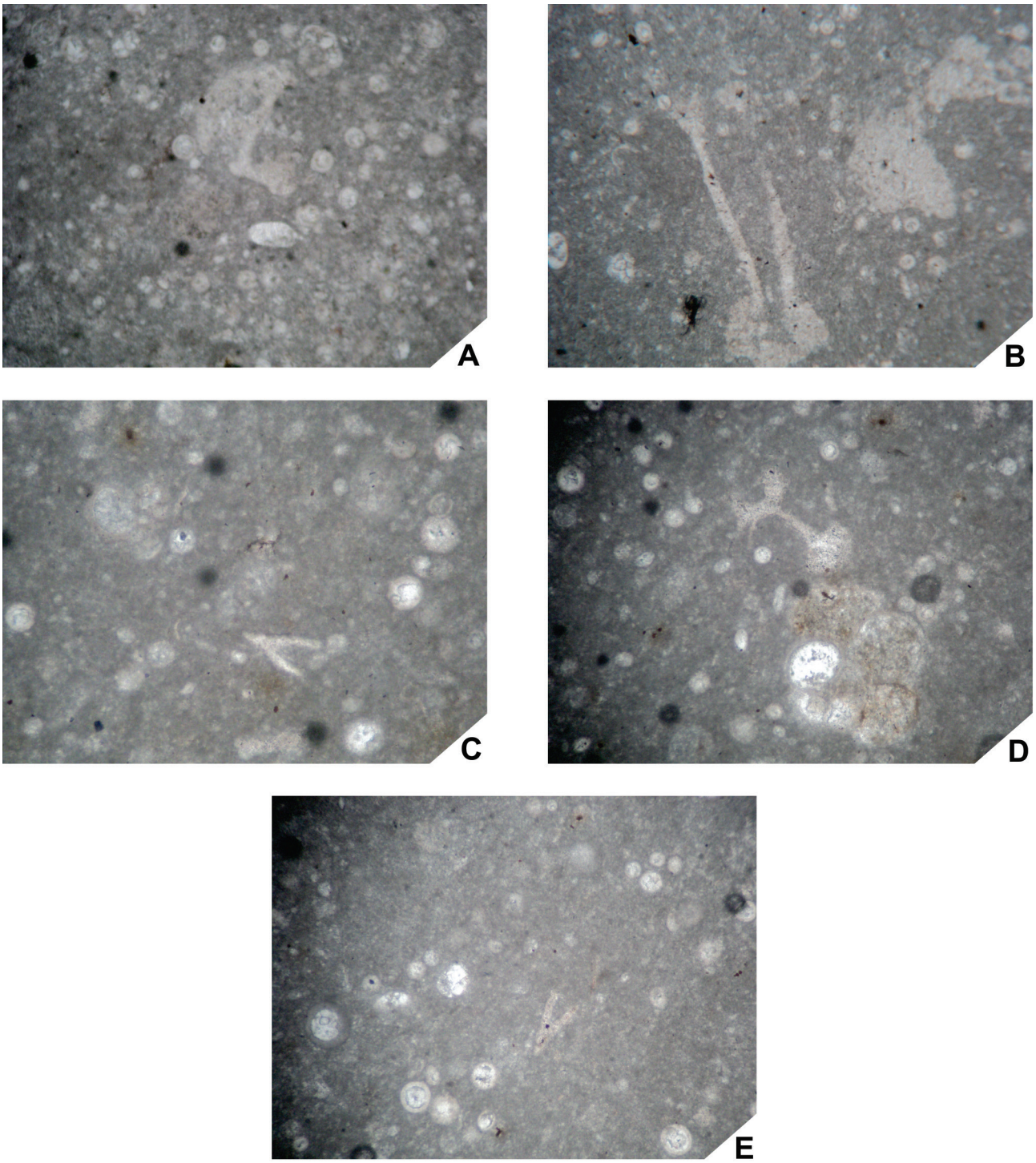

Figure 4. A–E, Saccocomidae indet. **A**, thecal or primibrachial plate, tangential section (TgS-Theca/IBr1-2) [TS no. SA-07/01]; **B**, first-second primibrachial plate, tangential longitudinal section (Tg/LgS-IBr1-2), and theca, paraxial transverse section (Ax/TS-Rad/Theca) [TS no. SA-08/06]; **C**, distal brachial plate, transverse section (TS-NBrn) [TS no. SA-09/01]; **D**, primibrachial plate, partial tangential section, or broken theca, partial transverse section (TgS-IBr1-2 *vel* TS-Theca), and primibrachial plate, tangential longitudinal (paraxial) section (Tg/LgS-IBr2) [SA-09/02]; **E**, distal brachial plate, transverse section (TS-NBrn) [SA-09/03]. All magnification: x 10.

STRATIGRAPHICAL INFERENCE/ PERSPECTIVES AND POTENTIALS/AGE OF THE ASSEMBLAGES

The microfacies and associated roveacrinoidal sections at hand display numerous microfossil evidence such as abundant planktic foraminifers (favusellids, hedbergellids, and ticinellids), bishopellids, calico-dinoflagellate cysts, and some small benthic foraminifers. Such a planktic foraminiferal and calcisphaerulid association is characteristic of the middle–upper Albian (Rosales-Domínguez *et al.*, 2015; Monier-Castillo *et al.*, 2017b).

The presence of *Bishopella ornelasae* in most samples (SA-01 to SA-016) led Rosales-Domínguez *et al.* (2015) to propose a middle–late Albian age. Likewise, the association of *Favusella* cf. *F. pessagnoi*, *F. scitula* (samples SA-016 to SA-017), and *Planomalina* sp. (sample SA-018), in the uppermost part of the section is characteristic of a late Albian age (Rosales-Domínguez *et al.*, 2015). Due to the scarcity of stratigraphical studies on Lower Cretaceous saccocomids, we cannot infer a direct age inference; therefore, we are keen to retain a middle–late Albian age because of the micropaleontological associations aforementioned.

With the exception of the so-called *Microcalamoides* used for slanted ancillary dating of Mexican Cretaceous strata [*Microcalamoides* Bonet, 1956, is the morphological variant thecal sections of *Applinocrinus*, ranging from Aptian to Maastrichtian, thus invalidating any precise datation (for review, see Ferré, 1997; Ferré & Dias-Brito, 1999; Ferré *et al.* 1997, 1999, 2018)], no saccocomid remain has ever been reported so far in Mexican Albian deposits and/or elsewhere (only roveacrinids; for review, see: Rasmussen, 1961; Destombes, 1985; Dias-Brito, 1994, 1995; Dias-Brito & Ferré, 1994, 2001; Ferré & Granier, 2001). This relatively restricted occurrence zone of such saccocomid microfacies, very different from the standard Microcalamoides Zone, is consistent with one of the OAE1 hypoxic events. However, in our current state of knowledge, we cannot precisely conclude which one.

When we do not have planktic foraminifers we use calcisphaerulids as fossil markers; the most important is the fossil assemblage. For example, the total stratigraphic range of *Bishopella ornelasae* is middle–late Albian. The association of *B. ornelasae*, *B. diazi* Trejo, 1983 and roveacrinoids is middle Albian. The association of *B. salinasi* Trejo, 1983, *Bonetocardiella conoidea* Bonet, 1956 and roveacrinoids is late Albian (Ubilla *et al.*, 2013). We also have roveacrinoids in the lower Albian together with *Colomiella mexicana* Bonet, 1956, *C. recta* (Bonet, 1956) and *Favusella washitensis*. In several wells of the Zona Marina de Campeche, the abundance peak of *B. ornelasae* coincides with a maximum flooding surface for the middle Albian and it is a regional stratigraphic marker (Aguilera *et al.*, 2008, 2017a, b).

PALAEOENVIRONMENTAL INTERPRETATION

The fine-grained limestone deposits of the Georgetown Formation were deposited in a transgressive setting, open-marine environment. The high planktic content of the microfossil assemblage is consistent with a high-productivity time interval during which the primary producers had been thriving and triggered the population of filter-feeders. Within such a food chain growing outburst, though elusive within fine-grained bottom dwellers, these pelagic crinoids had been benefitting from this glut of nutrients; they were multiplying and subsequently buried by the high sedimentary rate (Ferré, 1995; Benzaggagh *et al.*, 2015; Mebarki *et al.*, 2016a, b; Benyoucef *et al.*, 2017; Ferré *et al.*, 2016).

The 'last straw' that allowed their finding was the determination of field mappers of the SGM to grasp any bio-stratigraphic chance to better constrain the age of these rocks. Unfortunately, since bed-by-bed sampling was not the core of this primary field survey, only a gross stratigraphic assignment is possible. Since collecting data for this study, additional roveacrinoid material from other Mexican localities and from other time intervals have been found and will be described elsewhere.

STRATIGRAPHICAL INFERENCE/ PERSPECTIVES AND POTENTIALS

This very restricted occurrence zone of such saccocomid microfacies, different from the standard Microcalamoides Zone, is consistent with one of the OAE1 hypoxic events. However, we cannot precisely conclude which one. Besides these isolated finds in multiple, repeated event-beds lead us to think the importance and value of the "*Microcalamoides*" paradigm over, and to forecast a thorough taxonomical revision of the "*Microcalamoides*" mentions their respective datings and correlations.

CONCLUSIONS

During the course of amending exploratory mapping survey and primary sampling, microfacial analysis evidenced the presence of recurrent echinoderm sections. Among these crinoidal remains a few ones can be identified and assigned to saccocomid relatives. With the exception of the so-called *Microcalamoides* used for slanted ancillary dating [*Microcalamoides* Bonet, 1956, is the morphological variant thecal sections of *Applinocrinus* Peck, 1973, ranging from Aptian to Maastrichtian, thus invalidating any precise datation. For review see Ferré *et al.* (1997, 2018)], no saccocomid remain has ever been reported so far in Mexican Albian deposits and/or elsewhere in the Gulf.

The present work highlights the unexploited stratigraphic potential of roveacrinoidal accumulation-event beds and

their interest in improving the taxonomic knowledge of this overlooked crinoid group. This new material, though difficult to assign so far more precisely to a generic and/or specific taxonomic assignment, sheds new light on the roveacrinoidal paradigm and provides additional data between the classical Jurassic *Saccocoma/Crassicoma* (see Hess, 2002), and the Late Cretaceous *Applinocrinus* and Campanian relatives (Gale, 2017). This emphasizes more vividly the inventory work left to be done. These roveacrinoid taxa from the middle part of the Georgetown Formation are corresponding to paleontological forms that were previously identified by Hess (2002) from the Upper Jurassic strata of southern Germany (see also Hess, 1999). In the particular case of this material at hand, we should tackle first the issue of the J/K boundary crossing/transition of Saccocomidae and then the origin of its sister-group Roveacrinidae. This new occurrence zone of such saccocomid microfacies, different from the standard Microcalamoides Zone, is consistent with one of the OAE1 hypoxic events, beyond possibility of precisely concluding which one. Besides these isolated finds in multiple, repeated event-beds lead us to think the importance and value of the "*Microcalamoides*" paradigm over, and to forecast a thorough taxonomical revision of the "*Microcalamoides*" mentions their respective datings and correlations.

ACKNOWLEDGEMENTS

Financial support for this research comes from the SGM through the "Geological-Mining Cartography" Program and the "Mexican Stratigraphic Lexicon" Project. The authors are grateful to the reviewers for their valuable advice and highlighted comments on the preliminary manuscript.

REFERENCES

Aguilera, F.N.; Prado, P.M.A.; Vara, R.L. & Alejandre, B.J.L. 2017a. *Informe Final y Catálogo de Estudio Estratigráfico-Sedimentológico del Cretácico en el Campo Zaap. Región Marina Noreste*. Ciudad de México, Activo de Producción KU-MALOOB-ZAAP. Coordinación del Grupo Multidisciplinario de especialistas Técnicos de Diseño de proyectos, Caracterización de Yacimientos, 106 p.

Aguilera, F.N.; Prado, P.M.A.; Vara, R.L. & Alejandre, B.J.L. 2017b. *Estratigrafía y Sedimentología del Campo Maloob. Subdirección de Producción Bloques Aguas Someras AS01*. Ciudad de México, Coordinación del Grupo Multidisciplinario de Especialistas Técnicos en Diseño de Proyectos, 104 p.

Aguilera, F.N.; Prado, P.M.A.; Zavala, L.E. & López, G.J.C. 2008. *Integración y Actualización de Plays Mesozoicos*. Ciudad de México, PEMEX, Activo de Exploración Plataforma Continental Sur, Coordinación de Plays Establecidos, 61 p.

Bengtson, P. & Berthou, P.-Y. 1983. Microfossiles et échinodermes incertae sedis des dépôts albiens à coniaciens du basin de Sergipe-Alagoas, Brésil. *Cahiers de Micropaléontologie*, **3**:13–22.

Benyoucef, M.; Mebarki, K.; Ferré, B.; Adaci, M.; Bulot, L.G.; Desmares, D.; Villier, L.; Bensalah, M. & Zaoui, D. 2017. Litho- and biostratigraphy, facies patterns and depositional sequences of the Cenomanian-Turonian deposits in the Ksour Mountains (Saharan Atlas, Algeria). *Cretaceous Research*, **78**:34–55. *doi:10.1016/j.cretres.2017.05.013*

Benzaggagh, M.; Homberg, C.; Schnyder, J. & Ben Abdessalem-Mahdaoui, S. 2015. Description et biozonation des sections de crinoïdes saccocomidés du Jurassique supérieur (Oxfordien-Tithonien) du domaine téthysien occidental. *Annales de Paléontologie*, **101**:95–117. *doi:10.1016/j.annpal.2015.02.002*

Berthou, P.-Y. & Bengtson, P. 1988. Stratigraphic correlation by microfacies of the Cenomanian-Coniacian of the Sergipe Basin, Brazil. *Fossils and Strata*, **21**:1–38.

Bonet, F. 1956. Zonification microfaunística de las calizas del Este de Mexico. *Boletín de la Asociación Mexicana de Geólogos Petroleos*, **8**:3–102.

Brönnimann, P. 1955. Microfossils incertae sedis from the Upper Jurassic and Lower Cretaceous of Cuba. *Micropaleontology*, **1**:28–51.

Destombes, J.-P. 1985. Roveacrinidae nouveaux de l'albien du Bassin de Paris. *Bulletin trimestriel de la Soiété Géologique de Normandie et des Amis du Muséum du Havre*, **71**:9–16.

Dias-Brito, D. 1994. Comparação dos carbonatos pelágicos do Cretáceo médio da Margem Atlântica Brasileira com os do Golfo do México: novas evidências do Tétis Sul-Atlantiano. *In*: SIMPÓSIO SOBRE O CRETÁCEO DO BRASIL, 3, 1994. *Boletim*, Rio Claro, p. 11–18.

Dias-Brito, D. 1995. *Calcisferas e microfácies em rochas carbonáticas pelágicas mesocretáceas*. Programa de Pós-Graduação em Geociências, Universidade Federal do Rio Grande do Sul, PhD Thesis, 688 p.

Dias-Brito, D. & Ferré, B. 1997. Albian roveacrinids (stemless crinoids) in fine-grained carbonates from the Santos Basin in southeastern Brazil, western South Atlantic. *In*: REGIONAL EUROPEAN MEETING OF SEDIMENTOLOGY, 28, 1997. *Abstracts*, Heidelberg, IAS, p. 118–119.

Dias-Brito, D. & Ferré, B. 2001. Rovearinids (stemless crinoids) in the Albian carbonates of the offshore Santos Basin, southeastern Brazil: stratigraphic, palaeobiogeographic and palaeoceanographic significance. *Journal of South American Earth Sciences*, **14**:203–218. *doi:10.1016/S0895-9811(01)00013-X*

Douglas, J.A. 1908. A note on some new Chalk crinoids. *Geological Magazine*, **5**:357–359. *doi:10.1017/S0016756800138907*

Echanove-Echanove, M. 1986. *Geología petrolera de la Cuenca de Burgos (parte I), consideraciones geológico petroleras*. Ciudad de México, Asociación Mexicana de Geólogos Petroleros, p. 3–39 (Boletín 38).

Eguiluz de Antuñano, S. 2001. Geologic evolution and gas resources of the Sabinas Basin in Northeastern Mexico. *In*: C. Bartolini; R.T. Buffler & A. Cantu-Chapa (eds.) *The western Gulf of Mexico Basin: tectonics, sedimentary basins, and petroleum system*, Tulsa, American Association of Petroleum Geologists, p. 241–270 (Memoir 75).

Eguiluz de Antuñano, S. & Aranda-García, M. 2000. Tectónica de la Sierra Madre Oriental, México. *Boletín de la Sociedad Geológica Mexicana*, **53**:1–26.

Ferré, B. 1995. *Incidences des événements anoxiques océaniques sur les microfaunes cénomano-turoniennes du bassin anglo-parisien*. Université Paris VI - Pierre et Marie Curie, Thèse de Doctorat, 394 p.

Ferré, B. 1997. *Lombardia*-facies and saccocomid-like sections in Cretaceous sediments: whose pieces? *Mineralia Slovaca*, **29**:336–337.

Ferré, B.; Benyoucef, M.; Zaoui, D.; Adaci, M.; Tchenar, S.; Meister, C.; Mebarki, K.; Piuz, A. & Bensalah, M. 2016. Cenomanian-Turonian roveacrinid microfacies assemblages (Crinoidea, Roveacrinida) from the Tinrhert area (SE Algeria). *Annales de Paléontologie*, **102**:225–235. *doi:10.1016/j.annpal.2016.09.001*

Ferré, B. & Berthou, P.Y. 1993. Roveacrinidal remains from the Cotinguiba formation (Cenomanian-Turonian) of the Sergipe Basin (NE-Brazil). *In*: CONGRESSO BRASILEIRO DE PALEONTOLOGIA, 13, 1993. *Boletim de Resumos*, São Leopoldo, SBP, p. 119.

Ferré, B. & Berthou, P.Y. 1994. Roveacrinidal remains from the Cotinguiba formation (Cenomanien-Turonien) of the Sergipe Basin (NE-Brazil). *Acta Geologica Leopoldensia*, **18**:299–313.

Ferré, B. & Dias-Brito, D. 1999. Microfacies recognition of Roveacrinid families *Lombardia*, *Eothrix*, *Globochaete* and other strains. *In*: SIMPÓSIO SOBRE O CRETÁCEO DO BRASIL, 5, 1999. *Boletim*, Rio Claro, p. 651–659.

Ferré, B.; Fernandez-Gonzalez, M. & Dias-Brito, D. 1999. New insight into *Microcalamoides* Bonet, 1956 - Revised systematics and subsequent bearings. *In*: SIMPÓSIO SOBRE O CRETÁCEO DO BRASIL, 5, 1999. *Boletim*, Rio Claro, p. 661–668.

Ferré, B. & Granier, B. 1997. The Albian stemless microcrinoids (Roveacrinidae, Crinoidea) of the Congo Basin (Angola). *In*: REGIONAL EUROPEAN MEETING OF SEDIMENTOLOGY, 28, 1997. *Abstracts*, Heidelberg, IAS, p. 129–130.

Ferré, B. & Granier, B. 2000. *Roveacrinus berthoui* nov. sp., Early Hauterivian representative of Roveacrinidae (Roveacrinida, Crinoidea) of Busot (Alicante, Spain). *Geologica Carpathica*, **51**:101–107.

Ferré, B. & Granier, B. 2001. Albian roveacrinids from the southern Congo Basin, off Angola. *Journal of South American Earth Sciences*, **14**:219–235. *doi:10.1016/S0895-9811(01)00023-2*

Ferré, B.; Granier, B.; Gorzelak, P. & Salamon, M.A. 2018. Cretaceous roveacrinids from Mexico revisited: overcoming the taxonomic misidentifications and subsequent biostratigraphic abuse. *Boletín de la Sociedad Geológica Mexicana*, **70**:499–530. *doi:10.18268/BSGM2018v70n2a12*

Gale, A.S. 2016. Roveacrinida (Crinoidea, Articulata) from the Santonian–Maastrichtian (Upper Cretaceous) of England, the US Gulf Coast (Texas, Mississippi) and southern Sweden. *Papers in Palaeontology*, **2**:489–532. *doi:10.1002/spp2.1050*

Gale, A.S. 2017. An integrated microcrinoid zonation for the lower Campanian chalks of southern England, and its implications for correlation. *Cretaceous Research*, **87**:312–357. *doi:10.1016/j.cretres.2017.02.002*

Hernández-Noriega L.; Carrizales-Aguilar, A.; Ávila-Lugo, F. & Ramírez Tello, E. 2000. *Carta Geológico-Minera Ciudad Delicias H13-11, escala 1:250 000*. Pachuca, Consejo de Recursos Minerales, 85 p.

Hernández-Noriega, L.; Hernández, V.M.; Pérez-Vargas, M.A.; Ramírez-Tello, E.; Rivera-Ruiz, T.; Jiménez-Carrillo, G. & Zubiate-Ruiz, J.L. 1999. *Carta Geológico-Minera Ciudad Camargo G13-12, escala 1:250 000*. Pachuca, Consejo de Recursos Minerales, 52 p.

Hess, H. 1999. Upper Jurassic Solnhofen Plattenkalk of Bavaria, Germany. *In*: H.H. Hess; W.I. Ausich; C.E. Brett & M.J. Simms (eds.) *Fossil Crinoids*, Cambridge University Press, p. 216–224.

Hess, H. 2002. Remains of Saccocomids (Crinoidea: Echinodermata) from the Upper Jurassic of southern Germany. *Stuttgarter Beiträge zur Naturkunde B*, **329**:1–55.

Hess, H. & Messing, C.G. 2011. *Treatise on Invertebrate Paleontology, Part T, Echinodermata 2 Revised, Crinoidea 3*. Lawrence, University of Kansas Press, 261p.

Hill, R.T. 1901. *Geography and Geology of the Black and Grand Prairies, Texas with detailed descriptions of the Cretaceous formations and special reference to artesian waters*. Reston, The United States Geological Survey to the Secretary of the Interior, 666 p. (Report 21)

Housh, T.B. 2007. *Bedrock geology of round rock and surrounding areas, Williamson and Travis counties, Texas*. Geological Sciences, The University of Texas, Doctoral thesis, 65 p.

Humphrey, W.E. & Díaz, T. 1956. Tectonic framework of northeast Mexico. *Gulf Coast Association of Geologist Society Transactions*, **6**:25–35.

Jagt, J.W.M. 1999. Late Cretaceous – Early Paleogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium. Part 2: Crinoids. *Scripta Geologica*, **116**:59–162.

Kristan-Tollmann, E. 1970. Die Osteocrinusfazies, ein Leithorizont von Schwebcrinoiden im Oberladin-Unterkarn der Tethys. *Erdöl und Kohle, Erdgas, Petrochemie*, **23**:781–789.

Kristan-Tollmann, E. 1991. Echinoderms from the Middle Triassic Sina Formation (Aghdarband Group) in NE Iran. *Abhandlungen Geologischen Bundesanstalt*, **38**:175–194.

Lombard, A. 1937. Microfossiles d'attribution incertaine du Jurassique supérieur alpin. *Eclogae Geologicae Helvetiae*, **30**:320–331.

Lombard, A. 1945. Attribution de microfossiles du Jurassique supérieur alpin à des Chlorophycées. *Eclogae Geologicae Helvetiae*, **38**:163–173.

Mebarki, K.; Adaci, M.; Meister, C.; Benyoucef, M.; Ferré, B.; Läng, E.; Cavin, L.; Zaoui, D.; Desmares, D.; Villier, L.; Malti, F.Z. & Bensalah, M. 2016a. Lithostratigraphy, paleoenvironments and sequence evolution of the Cenomanian-Turonian deposits from the Guir area (SW-Algeria). *In*: N. Morel; D. Desmares & D. **Néraudeau (**eds.) *Colloque Cénomanien*, Groupe Français du Crétacé, p. 64–65.

Mebarki, K.; Sauvagnat, J.; Benyoucef, M.; Zaoui, D.; Benachour, H.B.; Mahboubi, M. & Bensalah, M. 2016b. Ostracodes cénomano-turoniens dans l'Atlas saharien occidental et le Bassin du Guir (sud-ouest de l'Algérie): systématique, biostratigraphie et paléobiogéographie. *Revue de Paléobiologie*, **35**:249–277.

Monier-Castillo, A.; Ferré, B.; López-Palomino, I.; Aguilera-Franco, N. & Palma-Ramírez, A.; Contreras-Cruz, D.; Reyes-Ramírez, J.R. & Muñoz-Jarillo, C.R. 2017a. Asociación de Roveacrínidos del Albiano de Sierra Azul, Cuenca de Sabinas, Coahuila, México. *In*: CONGRESO NACIONAL DE PALEONTOLOGÍA, 15, 2017. *Posters*, San Luis Potosí, LEM.

Monier-Castillo, A.; López-Palomino, I.; Contreras-Cruz, D.; Palma-Ramírez, A. & Reyes-Ramírez, J.R. 2017b. Evidencias micropaleontológicas del Cretácico Temprano (Albiano) en la localidad de Sierra Azul, Coahuila, Región Norte de México. *In*: CONGRESO DE GEOLOGÍA, 12, 2017. *Posters*, Habana.

Peck, R.E. 1943. Lower Cretaceous crinoids from Texas. *Journal of Paleontology*, **17**:451–475.

Peck, R.E. 1955. Cretaceous microcrinoids from England. *Journal of Paleontology*, **29**:1019–1029.

Peck, R.E. 1973. *Applinocrinus*, a new genus of Cretaceous microcrinoids and its distribution in North America. *Journal of Paleontology*, **47**:94–100.

Petróleos Mexicanos (PEMEX). 1988. *Estratigrafía de la República Mexicana, Mesozoico*. Ciudad de México, Subdirección de Producción Primaria, Coordinación Ejecutiva de Exploración, 216 p.

Rasmussen, H.W. 1961. A Monograph on the Cretaceous Crinoidea. *Biologiske Skrifter udgivet af Det Kongelige Danske Videnskabernes Selskab*, **12**:1–428.

Romo-Ramírez, J.R. & Muñoz-Jarillo, C.R. 2017. *Informe de la carta geológico-Minera Espinazo, G14-A73, escala 1:50,000, estados de Nuevo Léon y Coahuila*. Pachuca, Consejo de Recursos Minerales, 80 p.

Rosales-Domínguez, M.-C.; Contreras-Cruz, D. & López-Palomino, I. 2015. *Informe sobre el studio micropaleontológico de muestras (Láminas delgadasà) de la localidad Sierra Azul, correspondiantes a la carta geológico-minera Espinazo (G14-A73), escala 1:50,000, OT. 12625*. Pachuca, Servicio Geológico Mexicano, Departamento de Estratigrafía, 22 p.

Scott, R.W. 2009. Uppermost Albian biostratigraphy and chronostratigraphy. *Carnets de Géologie*, CG2009_A03. *doi:10.4267/2042/24969*

Ubilla, O.A.; Hernández, M.J.; Salguero, O.D.; Castillo, G.G.; Olvera, C.A.; Guzmán, L.A.; Vázquez, M.M.E. & Aguilera, F.N. 2013. *Proyectos de análogos de geología superficia*l. Estado de Nuevo León, Pemex, Gerencia de Estudios Regionales, Activo de Exploración Cuencas del Sureste Terrestre, Instituto Politécnico Nacional, Ciencias de la Tierra, 59 p.

Verniory, R. 1954. *Eothrix alpina* Lombard, Algue ou Crinoïde? *Archives des Sciences*, **7**:327.

Verniory, R. 1955. Extension géographique et stratigraphique du genre *Saccocoma* Agassiz dans le Dauphiné méridional et en Provence. *Archives des Sciences*, **8**:225–226.

Verniory, R. 1956. La création du genre *Lombardia* Brönnimann est-elle justifiée? *Archives des Sciences*, **9**:86.

Verniory, R. 1960. Présence (et variétés) de *Saccocoma tenella* Goldfuss à Talloires (Haute-Savoie). *Archives des Sciences*, **13**:250–257.

Verniory, R. 1961. Présence de *Saccocoma quenstedti* Doreck (in coll.) dans les gorges de la Méouge (Sisteron Provence). *Archives des Sciences*, **14**:315–320.

Verniory, R. 1962. Une nouvelle forme de *Saccocoma* (Montbrand, Hautes-Alpes, France). *Archives des Sciences*, **15**:391–397.

Wright, D.F.; Ausich, W.I.; Cole, S.R.; Peter, M.E. & Rhenberg, E.C. 2017. Phylogenetic taxonomy and classification of the Crinoidea (Echinodermata). *Journal of Paleontology*, **91**:829–846. *doi:10.1017/jpa.2016.141*

Received in 11 December, 2018; accepted in 17 March, 2019.