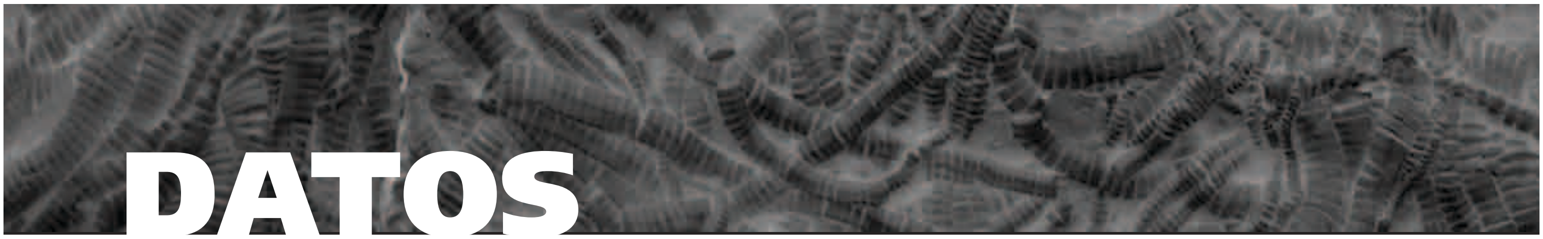

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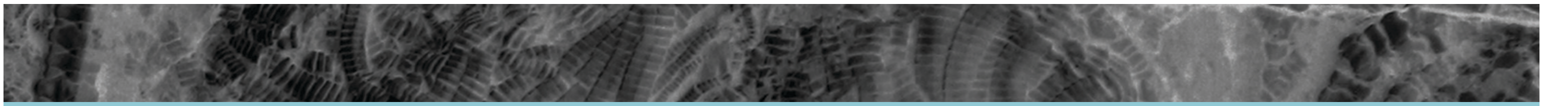

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CRINOIDES DEL MISISÍPICO DE LA REGIÓN DE EL BÍSANI, NOROESTE DEL ESTADO DE SONORA, MÉXICO

Blanca E. Buitrón-Sánchez[1,*], Daniel Vachard[2], Sebastién Clausen[2],
Juan José Palafox[3], Catalina Gómez-Espinosa[4]

RESUMEN

En el Estado de Sonora existen varias localidades con rocas sedimentarias del Misisípico. Particularmente, en el área de El Bísani que se localiza en la región de Caborca al noroeste del Estado de Sonora, afloran rocas de la formaciones Represo y Venada, cuya edad misisípica (Osageano inferior), se datό, inicialmente, por la presencia del coral colonial *Lithostrotionela confluens* Easton y por los conodontes de las especies *Gnathodus cuneiformis* (Mehl y Thomas) y *Gnathodus typicus* Cooper

La composición litológica de la Formación Represo corresponde principalmente a calizas dolomíticas con un alto contenido de fragmentos del tallo y placas articulares de crinoides muy pequeños que por su abundancia forman encrinita.

Los afloramientos contienen abundantes y diversos fósiles de invertebrados marinos entre ellos, se encuentran foraminíferos, ostrácodos, conodontos, corales, briozoarios, braquiópodos, crinoides y con menor presencia moluscos pelecípodos y gasterópodos.

Procedentes de la Formación Represo, se identificaron cuatro especies de crinoides que fueron descritas anteriormente de Estados Unidos de Norteamérica y corresponden a *Goniocion turgidus* Moore y Jeffords 1968, del Misisípico temprano de Iowa, *Flucticharax undatus* Moore y Jeffords 1968 y *Euloncherostigma impunitum* Moore y Jeffords, 1968 del Misisípico temprano de Kentucky y *Pentagonomischus plebeius* Moore y Jeffords 1968 del Misisípico Tardío de Illinois.

Con base en la composición de la comunidad biótica, se infiere que el ambiente de depósito tuvo lugar en plataformas carbonatadas de mares tropicales, someros, bien oxigenados que prevalecieron durante el Misisípico en la región de Bísani-Caborca, Sonora.

El análisis de la distribución de las especies de crinoides y de la fauna asociada del noroeste de Sonora, permitió establecer relaciones paleogeográficas con faunas del Misisípico (Osageano) de Iowa, Illinois y Kentucky, EUA, pertenecientes a la Provincia del Cratón Norteamericano.

Palabras clave: Crinoides, Misisípico, Bísani, Sonora, México.

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ABSTRACT

In the Sonora State, there are several regions with sedimentary rocks from the Mississippian age. Particularly in the Bisani area, located in the Caborca region, northwestern Sonora State, crops out rocks from the Represo and Venada Formation, Mississippian age (lower Osagean). The age of these rocks were dated previously by the presence of colonial coral *Lithostrotionella confluens* Easton and conodonts of the species *Gnathodus cuneiformis* (Meth and Thomas) and *Gnathodus typicus* Cooper.

Lithologically the Represo Formation consists of mainly dolomitic limestone with a high content of fragments from stem and articulate plates of crinoids of very small size that conformed encrinites. The four species of crinoids from Sonora were previously described in the United States of America and correspond to *Goniocion turgidus* Moore and Jeffords 1968, of the early Mississippian Iowa, *Flucticharax undatus* Moore and Jeffords 1968, *Euloncherostigma impunitum* Moore and Jeffords 1968 identified of early Kentucky and *Pentagonomischus plebeius* Moore and Jeffords 1968 late Mississippian Illinois.

The outcrops contain abundant and diverse marine invertebrate fossils among them, foraminifers, ostracods, conodonts, corals bryozoans, brachiopods, crinoids, pelecypods and gastropods.

In this study were identified four species of crinoids that correspond to *Goniocion turgidus* Moore and Jeffords 1968, *Flucticharax undatus* Moore and Jeffords 1968, *Euloncherostigma inpuditum* Moore and Jeffords 1968 referred to the late Mississippian of Iowa, USA, and *Pentagonomischus plebeius* Moore and Jeffords 1968 referred to the late Mississippian of Kentucky, USA.

Based on the composition of the biotic community, it is inferred that the depositional environment was in a carbonate platform of shallow, well oxygenated tropical seas, this kind of environments prevailing during the Mississippian in the Caborca-Bisani region.

Distribution analysis of the crinoids species and associated fauna of northwestern Sonora region, allowed to relationships it with Mississippian fauna (Osagean) of Iowa, Illinoids and Kentucky, USA, localities that belong to the North American Craton Province.

Key words: Crinoids, Mississippian, El Bisani, Sonora, Mexico.

INTRODUCCIÓN

Los afloramientos del Paleozoico marino de México se consideran escasos en relación a la extensión territorial del país, esto debido a que fueron cubiertos en gran parte por una gruesa secuencia de sedimentos mesozoicos y cenozoicos. No obstante, en la región norte de México donde se localizan los estados de Baja California, Sonora, Chihuahua y Tamaulipas se encuentran rocas sedimentarias con una abundante y variada biota de la era paleozoica (Maldonado-Koerdell, 1954; López-Ramos, 1971, 1982; Téllez y Malpica (1972); Malpica y De la Torre (1980); Buitrón, 1992; Buitrón *et al.*, 2008).

En Sonora se hallan afloramientos de todos los periodos del Paleozoico. Los depósitos del Paleozoico Superior representan una secuencia de rocas carbonatadas de plataforma (Sistema Cordillerano) que son cabalgadas por rocas siliciclásticas y carbonatadas de cuencas oceánicas (Orozco-Grajeda, 2005). Las rocas del Sistema Cordillerano corresponden a depósitos de plataformas continentales en mares someros, que se desarrollaron en el borde oeste de Laurentia (Cratón Norteamericano), (Poole *et al.*, 2005).

Particularmente para el Misisípico del Estado de Sonora en este trabajo se documenta varias localidades en la región noroccidental del estado, como son la Sierra El Tule, el Cerro La Morita, la Sierra de Los Ajos, los Cerros Las Mesteñas, el Cerro Cabullona y la Sierra El Tigre. En la región centro oriente se localizan afloramientos misisípicos en la Sierra Santa Teresa, el Cerro Las Trincheras, la región del Rancho Las Norias, la Sierra de Mazatán, la Sierra Agua Verde y en el extremo oriental del estado, en la región de Arivechi (Figura 1).

Los crinoides formaron parte de las faunas bentónicas ampliamente distribuidas en el mundo, que en muchos casos únicamente se conservaron partes de la columna (tallo) y de sus placas articulares disociadas. Las placas articulares presentan características morfológicas que permiten su estudio sistemático.

Los crinoides fueron muy abundantes en los mares del Paleozoico del mundo, evolucionaron rápidamente de tal manera que son utilizados, tanto los cálices como las placas articulares de los tallos como indicadores de la edad de las rocas que los contienen, y constituyen un recurso invaluable en la datación de las mismas (Gluchowski, 1981, 1986, 2001, 2002).

ESTUDIOS PREVIOS

Existen varias investigaciones sobre el Paleozoico Superior de Sonora, entre ellas se mencionan la de Cooper y Arellano (1946), Weller *et al.* (1948), Cooper *et al.* (1953), Arellano (1956), Easton (1958), Easton *et al.* (1958), Sanders (1958), Brookes (1958); Miller (1958), Fries (1962), López-Ramos (1971, 1982), Téllez y Malpica (1972), Brunner (1976; 1984), Armstrong *et al.* (1981), González-León (1982, 1989),

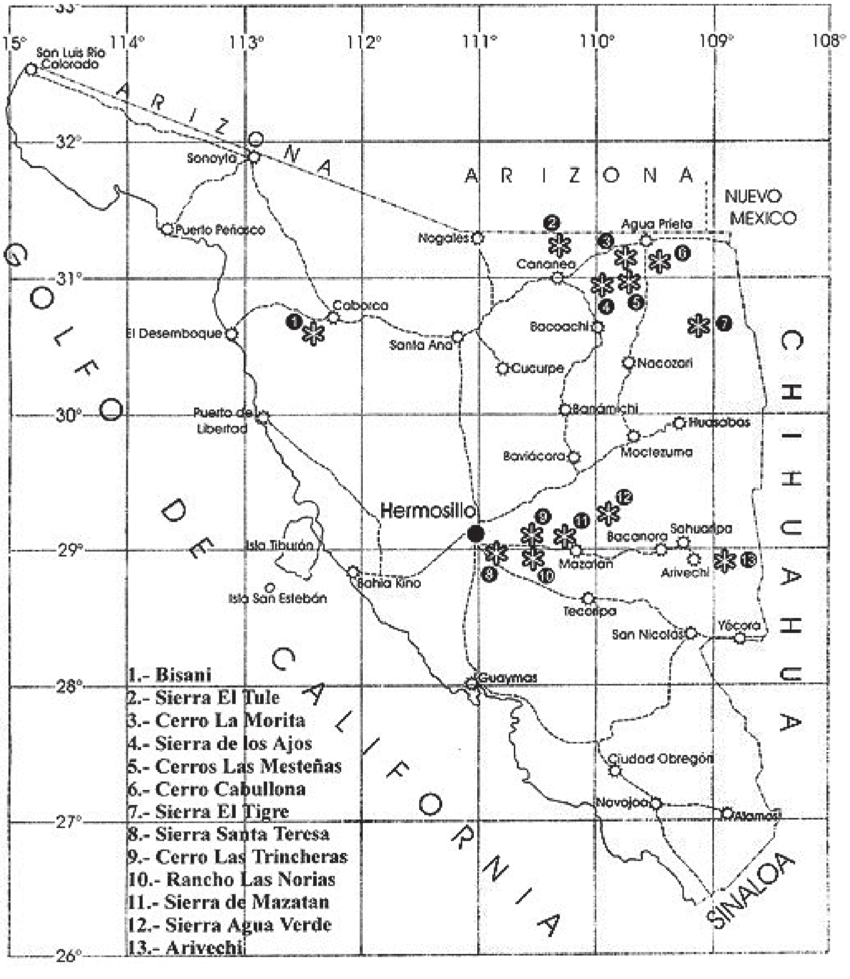

Figura 1. Localidades del Misisípico de Sonora

Stewart, *et al.*, 1999, Poole y Amaya-Martínez, (2000), Stewart y Poole (2002) y Poole *et al.* (2008) en las cuales se abordan principalmente aspectos geológicos y solamente en algunas publicaciones aspectos paleontológicos que incluyen las descripciones de los fósiles.

Una compilación muy completa con datos geográficos y geológicos sobre localidades del Paleozoico de Sonora se encuentra en el trabajo realizado por Stewart y Poole en el 2002.

El primer estudio sobre la estratigrafía de la región de Caborca, fue publicado por Cooper y Arellano en 1946, quienes hicieron recolectas de invertebrados fósiles, durante los años de 1943 y 1946 en la región de El Bísani, el material fue donado por el Dr. G. Arthur Cooper, Curador del Departamento de Geología del Museo Nacional de Estados Unidos al Dr. W.H. Easton, quien con varios especialistas de diferentes instituciones de los Estados Unidos de Norteamérica realizaron las descripciones de los invertebrados de El Bísani con excepción de los crinoides.

Brunner publicó en 1976, el estudio sobre la litología y estratigrafía del Misisípico del área de El Bísani y anota que durante la prospección geológico-paleontológica observó que las rocas contienen una rica y variada biota que ha sido escasamente estudiada, con excepción del trabajo de Easton (1958). Brunner (*op. cit.*) realizó el estudio sistemático de los microfósiles como foraminíferos-endotíridos, calciesferúlidos, conodontes, ostrácodos y mencionó la presencia de macrofósiles entre ellos esponjas, corales solitarios y coloniales, briozoarios-fenestélidos, braquiópodos, moluscos, trilobites, crinoides, algas y restos de peces. Brunner en 1989, estudió los conodontes de varias localidades del Paleozoico de México y anotó sobre la presencia de fragmentos de crinoides en rocas del Misisípico Inferior y Superior de El Bísani, que por su abundancia forman encrinita.

Posteriormente, autores como Buitrón y Almazán (2002) y Buitrón *et al.* (2008) publicaron sobre los fragmentos de columnas y placas articulares de crinoides del Carbonífero de México y citaron la presencia de *Rhysocamax cristata* Moore y Jeffords 1968 y *Gilbertocrinus aequalis* Moore y Jeffords 1968 en el Misisípico del cerro Las Trincheras localizado en la región centro-sur del Estado de Sonora.

En trabajo de campo realizado por los autores en 2010 y 2011, en la región de Caborca, y particularmente en el área de El Bísani se recolectaron entre otros fósiles, fragmentos de columnas y placas articulares de crinoides que son motivo de esta investigación.

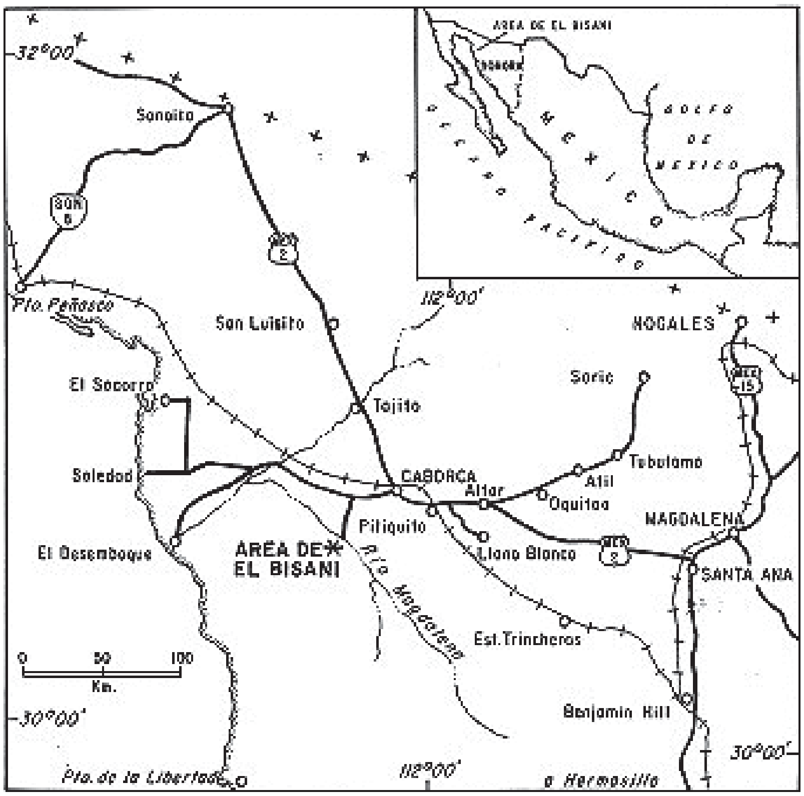

Figura 2. Localización del Área de El Bísani, Caborca, Sonora.

LOCALIZACIÓN DEL ÁREA DE ESTUDIO

El área de Caborca se localiza en la región noroeste del Estado de Sonora, en las coordenadas 31° 45´ de latitud norte y 111° 55´ de longitud oeste. Los afloramientos del Misisípico se encuentran expuestos en dos pequeños cerros, uno situado aproximadamente a 2.5 km al oeste-noroeste de el Rancho El Bísani y el otro a 800 m al oeste del primer cerro, en ambos afloran rocas de la formaciones Represo y Venada del Osageano inferior (Misisípico). En afloramientos correspondientes a la Formación Represo se recolectaron los crinoides estudiados (Figura 2).

La composición litológica de la Formación Represo corresponde principalmente a calizas dolomíticas con un alto contenido de fragmentos del tallo y placas articulares de crinoides muy pequeños que por su abundancia forman encrinita (Figura 3).

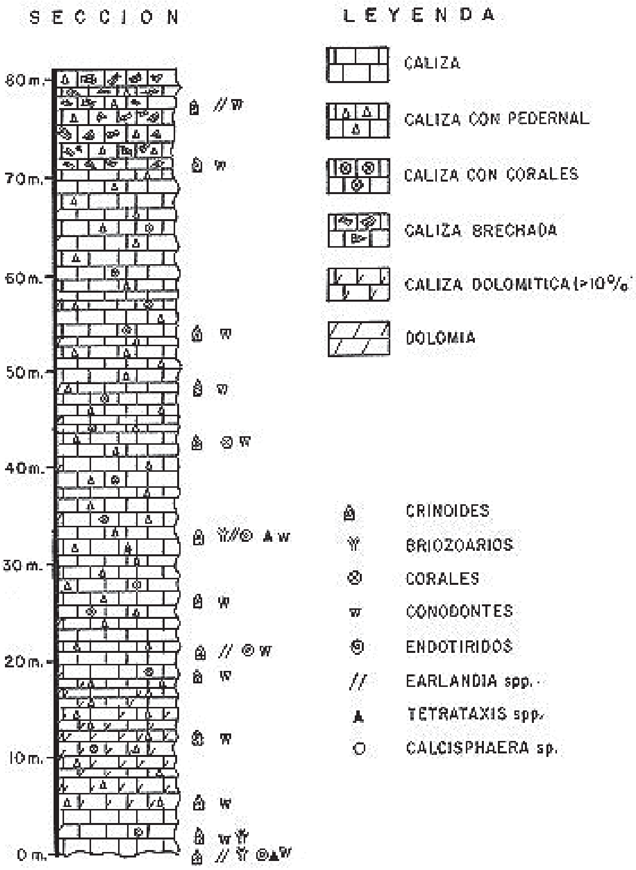

Figura 3. Columna Estratigráfica de la Fm Represo, Caborca, Sonora.

ASOCIACIÓN FAUNISTICA

Los afloramientos misisípicos expuestos en los dos cerros próximos al Rancho El Bísani contiene abundantes invertebrados marinos entre los que se encuentran foraminíferos, ostrácodos, conodontos, corales solitarios y coloniales, briozoarios fenestélidos, braquiópodos, crinoides y con menor presencia moluscos (pelecípodos, gasterópodos, cefalópodos) y trilobites, (Brunner, 1976).

Las especies de corales descritas para esta área son *Cyathaxonia cordillerensis* Easton, *Rotiphyllum occidentale*, Easton, *R. vesiculosum* Easton, *Triplophyllites circularis* Easton, *Caninophyllum sonorense* Easton, *Lithostrotionella confluens* Easton, *Cystelasma invaginatum* Easton, *Pleurodictyum subramosum* Easton y *Syringopora tubifera* Easton; también se reporta la presencia de las especies *Syringopora Trochophylum* sp., *Triplophyllites* sp., *Neozaphrentis tenella* (Millar), *Caninia corniculum* (Miller), *Caninia* sp. y *Koninckophyllum* sp.

Los braquiópodos están representados por las especies *Rhipidomella* cf. *R. missouriensis* (Swallow), *Perditocardinia* cf. *P. dubia* (Hall), *Schizophoria sulfata* Sanders, *Leptaena cooperi* Sanders, *Schuchertella* sp., *Schellwienella umbonata* Sanders, *Pliocochonetes geniculatus* (White) *Girtyella* sp., *Dielasmoides* sp., *Beecheria* sp., *Camarotoechia* sp., *Dorsisinus louisianensis* (Wellar), *Cyrtospirifer*? *latiot* (Swallow), *Tylothyris*? sp., *Reticularia cooperensis* (Swalow), *Crurithyris levicula* (Rowlwy), *Composita obesa* Sanders, "*Cleiothyridina*" *glenparkensis* Weller, *Cyrtina burlingtonensis* Rowler, *Punctospirifer sulcifer* Sanders, *P. globosa* Sanders, *Hustedia circularis* (Miller) y los pelecípodos por *Parallelodon sulcatus* Weller y *Conocardium* sp. (Sanders, 1958).

Las especies de gasterópodos reportadas son *Bellerophon* sp., *Baylea* sp., *Boretus* sp., *Rhineoderma* cf. *R. nystii de* Koninck, *Platyschisma* sp., *Straparolus* sp., *Phanerotinus* cf. *P. paradoxus* Winchell y *Platyceras* sp., se encontró que tienen afinidades con faunas del Carbonífero Temprano de Inglaterra, Irlanda y con el noroeste de Europa y poco significativas con las faunas del Misisípico de Nueva Escocia, EUA (Knight, 1958).

El cefalópodo *Triboloceras digonum* (Meek y Worthen) formó parte de la asociación faunística (Miller, 1958), anota que la especie ha sido anteriormente citada para el mar del Kinderhookiano que se extendió desde el suroeste de Indiana e Illinois a Missouri, Nuevo Mexico, Arizona, EUA y Sonora, México.

PALEONTOLOGÍA SISTEMÁTICA

El material estudiado se encuentra depositado en la Colección Paleontológica del Departamento de Geología de la División de Ciencias Exactas y Naturales, Universidad de Sonora, con los números de catálogo USONDG-320 - USONDG-323.

Phylum Echinodermata
Clase Crinoidea Miller, 1821
Subclase Incierta Moore y Jeffords, 1968
Orden Incierto Moore y Jeffords, 1968
Grupo Cyclici Moore y Jeffords, 1968
Familia Cyclopagodidae Moore y Jeffords, 1968

Diagnosis. La columna es distintivamente heteromórfica con nodales que sobresalen comúnmente de los límites de los internodales y son bastante más altos. La faceta articular tiene un crenulario ancho rodeado por un lúmen ancho pentalobado o circular y no presenta areola ni perilúmen (Moore y Jeffords, 1968).

Género *Euloncherostigma* Moore y Jeffords, 1968.

Diagnosis. Los nodales se extienden lateralmente hacia la periferia como un reborde delgado de contorno circular, los internodales son mucho más estrechos y bajos que los nodales. La faceta articular tiene el crenulario y el lúmen circular de la misma anchura, los cúlmenes son rectos y gruesos (Moore y Jeffords, 1968).

Euloncherostigma impunitum Moore y Jeffords 1968 (Fig. 4).
Euloncherostigma impunitum Moore y Jeffords 1968, p. 58, lám. 11, figs. 6a, b

Descripción. Únicamente se cuenta con una placa incompleta de forma circular, ancha que mide 3 mm de diámetro en la que se observa la superficie articular formada por un crenulario de 0.7 mm de ancho con cúlmenes gruesos, que escasamente se bifurcan en el borde de la placa, separados por crenelas un poco más estrechas que ellos. El lúmen tiene aproximadamente 1.6 mm de ancho.

Ejemplar No.USONDG-320.

Localidad y posición estratigráfica. Cerro localizado aproximadamente a 2.5 km W-NW del Rancho El Bísani, noroeste de Sonora. Formación Represo (Misisípico-Osageano inferior).

Discusión. La especie *Euloncherostigma impunitum* Moore y Jeffords (1968, p. 58, lám. 11, figs. 6a, b) fue descrita anteriormente de la Shale New Providence, Grupo Borden del Misisípico Inferior (Osageano) de Kentucky, EUA.

La diferencia con la especie procedente de El Bísani radica en el menor tamaño de la placa articular y en la presencia de escasos cúlmenes bifurcados en la proximidad del borde la placa.

Familia Flucticharacidae Moore y Jeffords, 1968.

Diagnosis. Columna homeomórfica o heteromórfica, muy delgada pero algunas columnas de tamaño medio, suturas crenuladas entre ellas. La faceta articular presenta cúlmenes anchos, rectos separados por crenelas estrechas y rectas, el perilumen es prominente (Moore y Jeffords, 1968, p. 70).

Género Flucticharax Moore y Jeffords, 1968.

Diagnosis. Columna homeomórfica, de tamaño medio a moderadamente ancha, las placas columnares gruesas con lados convexos y unidas por suturas onduladas. Faceta articular con cúlmenes gruesos, rectos rodeados por una areola estrecha, perilumen prominente el cual es relativamente ancho y marcado por costillas y surcos finos vermiculados, lumen circular, muy pequeño (Moore y Jeffords, 1968, p. 70).


Figura 4. *Euloncherostigma impunitum* Moore y Jeffords, 1968.


Figura 5. *Flucticharax undatus* Moore y Jeffords, 1968.

Flucticharax undatus, Moore y Jeffords, 1968 (Figura 5).
Flucticharax undatus, Moore y Jeffords, 1968, p. 71, lám. 20, figs. 7-8.

Descripción. La placa articular es circular, pequeña con diámetro de 1.4 mm, el crenularium es estrecho, mide 0.25 mm y está formado por cúlmenes gruesos, rectos que ocupan la tercera parte de la superficie articular, las crenelas son más estrechas que los cúlmenes, la areola es estrecha y lisa, el perilumen es ancho y mide 0.6 mm, el lúmen es estrecho y mide 0.1 mm.

Ejemplar No USONDG-321.

Localidad y posición estratigráfica. Cerro localizado aproximadamente a 2.5 km W-NW del Rancho El Bísani, noroeste de Sonora. Formación Represo (Misisípico-Osageano inferior).

Discusión. *Flucticharax undatus* fue descrita por Moore y Jeffords (1968, p. 71, lám. 20, figs 7a, b, 8) como una especie muy abundante y buen índice estratigráfico de la Shale New Providence, Grupo Borden, Kentucky, EUA (Misisípico Inferior-Osageano). Se diferencia de la especie de El Bísani, Sonora porque ésta es de dimensiones más pequeñas y está escasamente presente.

Familia Exaesiodiscidae Moore y Jeffords, 1968.

Diagnosis. La columna es conspicuamente heteromórfica con nodales anchos más que los internodales. La superficie articular de las placas presenta crenulario muy estrecho con perilumen ausente o quinquelobado, pentaestelar o circular, de tamaño medio a pequeño (Moore y Jeffords, 1968, p. 73).

Género *Goniocion* Moore y Jeffords, 1968.

Diagnosis. Columna conspicuamente heteromófica, en algunas especies hay nodales yuxtapuestos, visibles externamente que dan la apariencia de columna homeomórfica; nodales con amplio perfil anguloso, mucho más alto que en los internodales, carece de cirros. La placa presenta la superficie articular con el crenulario estrecho, la areola ancha, plana y con lúmen pequeño y circular (Moore y Jeffords, 1968, p. 73).

Goniocion turgidus Moore y Jeffords,
1968 (Figura 6).
Goniocion turgidus Moore y Jeffords, 1968, p. 75,
lám. 23, figs. 4a, b.

Figura 6. *Goniocion turgidus* Moore y Jeffords, 1968.

Figura 7. *Pentagonomischus plebeius* Moore y Jeffords, 1968

Descripción. Columna heteromórfica, la placa articular es pequeña con diámetro de 2.4 mm donde se observa en la periferia parte de un internodal estrecho de contorno circular y epifaceta redonda, estrecha con diámetro de 0.35 mm. En la superficie articular hay un crenularium estrecho con cúlmenes cortos y gruesos separados por crenelas estrechas, presentan areola ancha y plana y mide 0.15 mm, el lumen es circular y muy pequeño que mide 0.3 mm.

Ejemplar USONDG-322.

Localidad y posición estratigráfica. Cerro localizado aproximadamente a 2.5 km W-NW del Rancho El Bísani, noroeste de Sonora. Formación Represo (Misisípico-Osageano inferior).

Discusión. El ejemplar procedente de El Bísani, Sonora es más pequeño que el reportado por Moore y Jeffords, (1968, p. 75, lám. 23, figs. 4a, b) de la Caliza Burlington del Misisípico Inferior (Osageano) de Iowa, EUA. La especie de Sonora es semejante a *Goniocion gonimus* (Moore y Jeffords, (1968, p. 75, lám. 23, figs. 6a, b) también procedente de la Caliza Burlington del Misisípico Inferior (Osageano) de Iowa, EUA, pero se diferencia con la especie de El Bísani, porque el crenulario tiene los cúlmenes y las crenelas menos aparentes, sin embargo son casi iguales en las dos especies. La diferencia principal radica en la morfología de la columna. Al no contar con columnas en el material de El Bísani, se identificó la placa articular con *Goniocion turgidus* Moore y Jeffords

Familia Pentacauliscidae Moore y Jeffords, 1968

Diagnosis. Tallo heteromórfico, en sección pentagonal con o sin cirros (Moore y Jeffords, 1968, p. 51).

Género *Pentagonomischus* Moore y Jeffords, 1968.

Diagnosis. La columna es pentagonal, distintivamente heteromórfica, los nodales con o sin cirros o, moderadamente anchos y mas altos que los priminternodales, noditaxis de cuatro columnas, superficie articular con pequeñas crenulaciones, areola pentagonal ancha y lisa, ligeramente cóncava, lumen circular. Canal axial conteniendo el claustro es estrecho con pequeñas yugula estelares (Moore y Jeffords, 1968).

Pentagonomischus plebeius Moore y Jeffords, 1968 (Figura 7).
Pentagonomischus plebeius Moore y Jeffords, 1968, p. 53, lám. 8, figs 1-7, 8.

Descripción. Placa articular pequeña de contorno pentagonal, que mide 2.2 mm el crenularium mide 0.2 mm y está formado por cúlmenes gruesos cortos separados por crenelas mas estrechas que ellos. La areola es pentagonal amplia y lisa ligeramente hundida, el lumen es de contorno circular y mide 0.2 mm.

Ejemplar No USONDG-323.

Localidad y posición estratigráfica. Cerro localizado aproximadamente a 2.5 km W-NW del Rancho El Bísani, noroeste de Sonora. Formación Represo (Misisípico-Osageano superior).

Discusión. *Pentagonomischus plebeius* fue descrito por Moore y Jeffords (1968, p. 53, lám. 8, figs 1-7, 8) de la Formación Saint Creek del Misisípico Superior (Chesteriano) de Illinois, EUA. Tanto los ejemplares de El Bísani, Sonora como los de Illinois, EUA son de pequeñas dimensiones.

RESULTADOS

Se identificaron cuatro especies de crinoides que corresponden a *Goniocion turgidus* Moore y Jeffords 1968, del Misisípico temprano de Iowa, *Flucticharax undatus* Moore y Jeffords 1968 y *Euloncherostigma impunitum* Moore y Jeffords 1968 del Misisípico temprano de Kentucky y *Pentagonomischus plebeius* Moore y Jeffords 1968 del Misisípico Tardío de Illinois, EUA.

Con base en la composición de la comunidad biótica, se infiere que el ambiente de depósito tuvo lugar en plataformas carbonatadas de mares tropicales, someros, bien oxigenados que prevalecieron durante el Misisípico en la región de El Bísani-Caborca, Sonora.

El análisis de la distribución de las especies de crinoides y de la fauna asociada del noroeste de Sonora, permitió establecer relaciones paleogeográficas con faunas del Misisípico (Osageano) de Iowa, Illinois y Kentucky, EUA, pertenecientes a la Provincia del Cratón Norteamericano.

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NEW EARLY EOCENE ECHINOIDS FROM BAJA CALIFORNIA SUR, MEXICO

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ABSTRACT

Four genera of spatangoid echinoids (*Agassizia*, *Pericosmus*?, *Asterostoma* and *Eupatagus*) are reported and a new form of spine (Order Cidaroida?) that were found in Tepetate and Bateque Formations in Baja California Sur, Mexico. These formations are important in the geological record, especially in the North American Pacific region, as they may represent one of the fossil records and paleoceanographic most complete Paleogene period. The Tepetate Formation is between 70 and 150 km east-northeast of the city of La Paz, while the Bateque Formation is located on the eastern and western of Cuenca Laguna San Ignacio to Arroyo Mezquital (between San Juanico and La Purísima). Previous studies, prove that the marine invertebrates found in the middle part of the Tepetate Formation match those present in the middle part of the Bateque Formation, this proves that both formations are equivalent in time and correspond to the "Capay Stage" (Early Eocene: Ypresian). The specimens found in this study are representative of the "Capay Stage" and are typical internal to external platform environments. These echinoderms have their origin in the warm waters of the Indo-Pacific region, and are believed to have been carried by the Tethys circumglobal current to the American continent.

Key words: Baja California Sur, Bateque, echinoderms, Eocene, spatangoid, Tepetate.

RESUMEN

Se reportan cuatro nuevos géneros de equinoideos espatangoideos (*Agassizia*, *Pericosmus*?, *Asterostoma* y *Eupatagus*) y una nueva forma de radiola (Orden Cidaroida?) hallados en las formaciones Tepetate y Bateque, Baja California Sur, México. Estas formaciones son importantes en el registro geológico, especialmente en la región de América del Norte del Pacífico, ya que pueden representar uno de los registros fósiles y paleoceanográfica período Paleógeno más completa. La Formación Tepetate se encuentra entre los 70 y 150 km al este-noroeste de la ciudad de

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La Paz; mientras que la Fm. Bateque se ubica en la ribera oriental y occidental de la Cuenca de la Laguna San Ignacio hasta el Arroyo El Mezquital (entre San Juanico y La Purísima). Estudios previos demuestran que los invertebrados marinos que se encuentran en la parte media de la Formación Tepetate coinciden con los presentes en la parte media de la Formación Bateque, esto demuestra que ambas formaciones son equivalentes en tiempo y corresponden al "Piso Capay" (Eoceno Temprano: Ypresiano). Los ejemplares encontrados en este estudio son representativos del "Piso Capay" y son típicos de ambientes de plataforma interna y externa. Estos equinodermos tienen su origen en las cálidas aguas de la región del Indo-Pacífico, y se cree que se han llevado por la corriente circumglobal Tetis al continente americano.

Palabras clave: Baja California Sur, Bateque, Eoceno, equinoideos, espatangoideos, Tepetate.

INTRODUCTION

The echinoderms have a rich and ancient fossil record; this group appears in the Early Cambrian and was most abundant at the end of the Paleozoic Era, where some kinds of fossils records indicate that some specimens peaked in evolutionary development (Ruppert and Barnes, 1996). Paleontological information for this group during the Cenozoic is abundant, mainly from the Eocene epoch, where records of the same genera are numerous (seven genera are common) and are found on the coast of the Atlantic as well as the Pacific (Alvarado *et al*., 2006).

The Eocene is one of the most studied periods and most important in the state of Baja California Sur, since for this period several new species of invertebrates have been found and identified, mainly mollusks (Squires and Demetrion, 1992; González-Barba, 2003). However, also important findings have been reported for echinoderms, although there have been only "irregular urchins" (Squires and Demetrion, 1992, 1994b, 1995; Morales-Ortega, 2012).

Irregular urchins have been found in Tepetate and Bateque Formations, which are important in the Earth's geological record, especially in the North American Pacific region, as they may represent one of the fossil records and paleoceanographic most complete Paleogene period in Mexico (Figure 1) (Squires and Demetrion, 1992; Morales-Ortega, 2012).

Before this study, Squires and Demetrion (1992) reported for the Bateque Formation, three types of spines of Order Cidaroida (spine A, B and C) and two spatangoid echinoids (*Schizaster* (*Paraster*) sp. aff. *S. lecontei* y *Eupatagus batequensis*). Subsequently, Squires and Demetrion (1994b) recorded as a new species *Haimea bajasurensis* for Tepetate and Bateque Formations.

In 1995, the same authors report two species of the Order Cassiduloida (*Cassidulus ellipticus* y *Calilampas californiensis*) found in Llajas Formation, northern California, United States of America and Bateque Formation, Baja California Sur, Mexico.

In recent years, different locations have been revised from those reported by Squires and Demetrion (1992, 1994b, 1995) in both formations, however, there is a large amount of fossil content that is still unknown; of these new collections, we obtained four new records of spatangoid echinoids and a new type of spine (Order Cidaroida?), all present in layers of the "Capay Stage" (Figure 2). These new reports represent the acquisition of new data, whose interpretations provide knowledge in regards to paleoclimatic, paleobiogeographic, stratigraphic correlation and evolutionary history of the species.

Previous studies, based on lithostratigraphic and biostratigraphic data show that the fossils found in the middle part of the Tepetate Formation match those

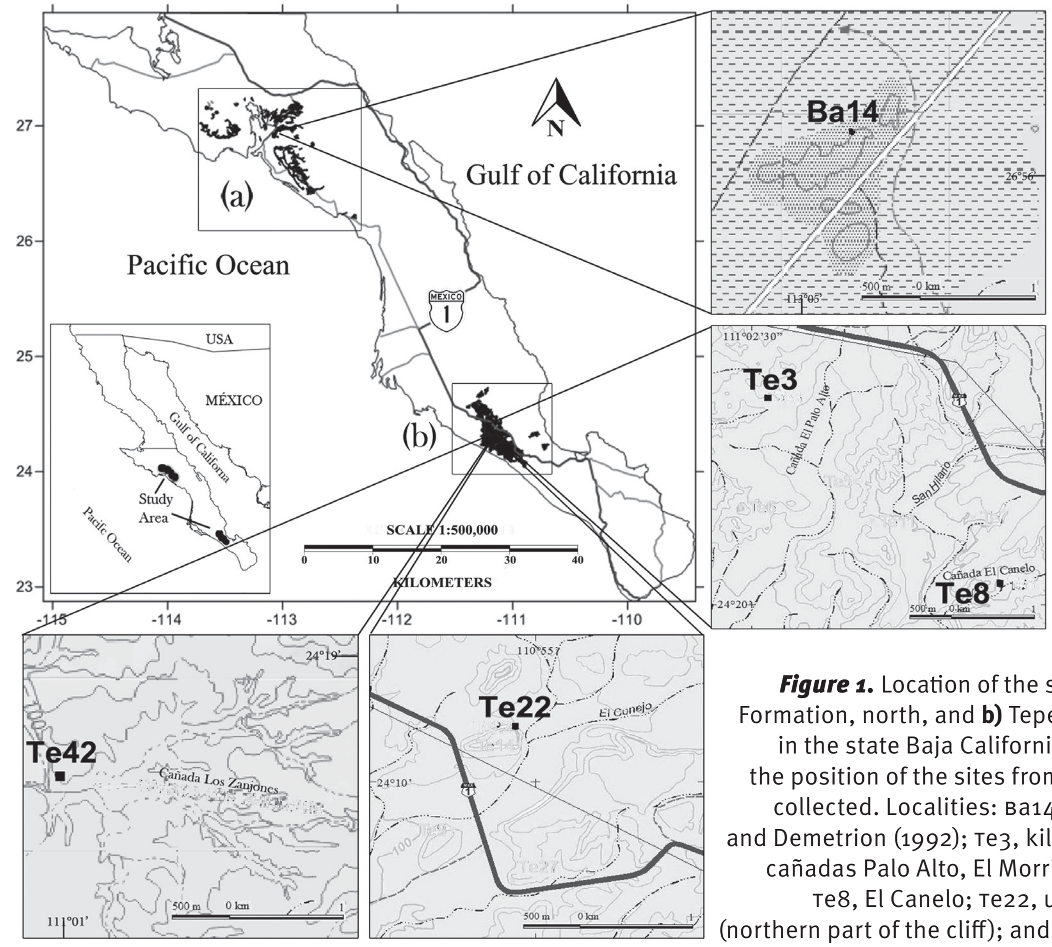

Figure 1. Location of the study areas: **a)** Bateque Formation, north, and **b)** Tepetate Formation, south, in the state Baja California Sur, México, showing the position of the sites from which echinoids were collected. Localities: Ba14, locality 1219, Squires and Demetrion (1992); Te3, kilometer 103.5 (between cañadas Palo Alto, El Morrito Alto and El Mangle); Te8, El Canelo; Te22, upstream Mesa Yesenia (northern part of the cliff); and Te42, Cañada El Llano.

present in the middle part of the Bateque Formation, this proves that both formations are equivalent in time and correspond to the "Capay Stage" (Early Eocene: Ypresian). Also, the type of sediment deposited along both formations is yellow sandstone, characteristic of the Eocene layers of Baja California Sur. The platform depositional environments are internal to external, so the faunal associations found in both formations correspond to this type of environments (Squires, 1992; Squires and Demetrion, 1992; González-Barba *et al.*, 2002; Schwennicke, *et al.*, 2004; Morales-Ortega, 2012).

PALEOCLIMATE AND PALEOBIOGEOGRAPHY

The Tepetate Formation is between 70 and 150 km east-northeast of the city of La Paz; while the Bateque Formation is located on the eastern and western of Cuenca Laguna San Ignacio to Arroyo El Mezquital (between San Juanico and La Purísima) (González-Barba, 2003; Morales-Ortega, 2012). The macroinvertebrates found in these formations strongly support the presence of tropical waters (mainly during the Early and Middle Eocene). This was an equatorial current, called the Tethys circumglobal current (it existed 270 Ma ago, during the Permian and lasted until 15 Ma, Miocene). This current flowed in the direction from east to west, which led to subtropical climate and high bioproductivity, which coincided with an increase in sea level (Squires, 1992; González-Barba, 2003). The richness of this current is manifested by the high diversity and abundance of marine invertebrates found in both formations (Squires and Demetrion, 1992; Morales-Ortega, 2010, 2012).

The presence of echinoderms such as *Agassizia*, *Pericosmus*? and *Eupatagus*, originate in the warm waters of the Indo-Pacific region and were transported by currents of Tethys to the Americas. *Agassizia, Pericosmus*? y *Asterostoma* have been reported in Eocene

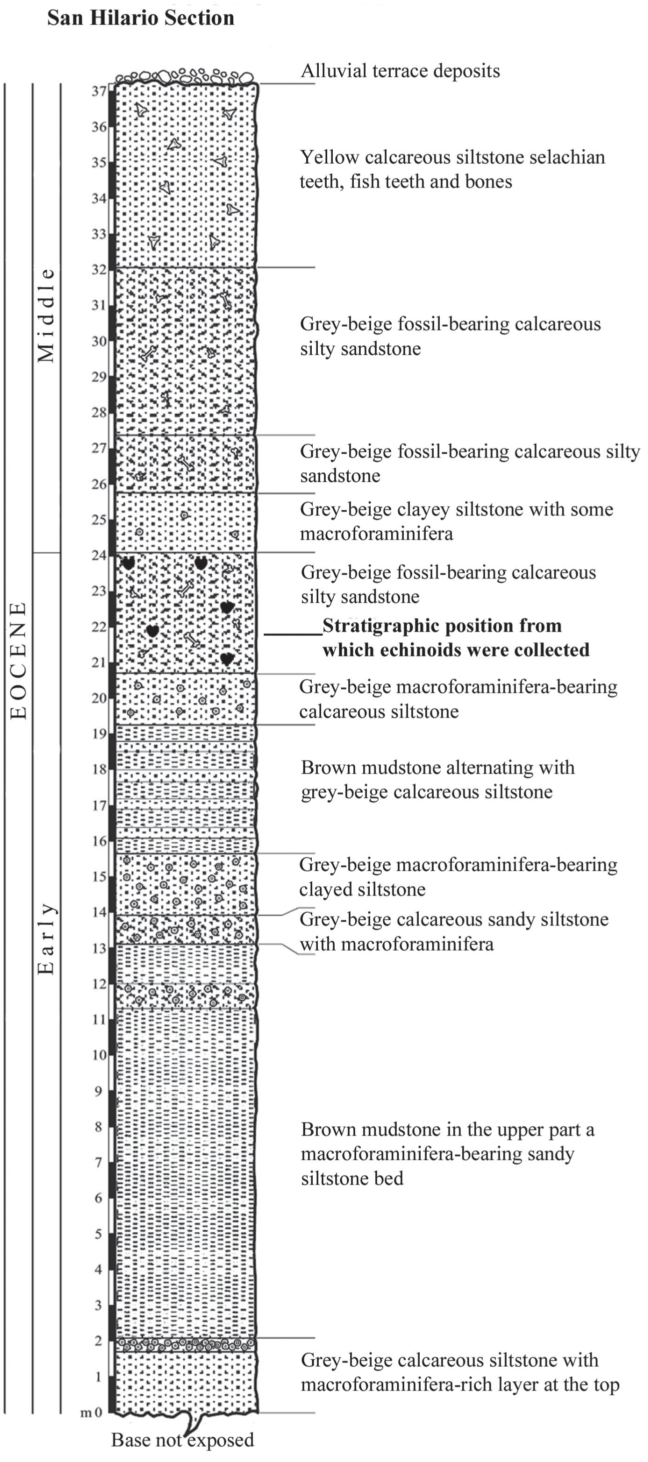

Figure 2. Composite stratigraphic section of the San Hilario locality (modified section of Schweitzer *et al.*, 2002) of the Tepetate Formation showing the stratigraphic position from which echinoids were collected.

strata of Cuba, Jamaica and the eastern United States of America, it is noteworthy that both genera are new records for the Pacific coast of North America, proving the broad biotic exchange during the Eocene (Cooke, 1959; Kier, 1972, 1980, 1984; Kier and Lawson, 1978; Donovan, 1988; Kroh, 2010). In addition, these genera are typically found in tropical paleoenvironments, although varied in depth, since *Agassizia* lived from the coast to 900 m, while *Pericosmus* probably lived in depths less than 100 m (typically between 18-70 m), but also reported depths of 200 to 500 m (Kier, 1984). Moreover, currently only five species of *Eupatagus* are recognized and they are all west of the Indo-Pacific (Buitrón and Silva-Sánchez, 1979; Squires and Demetrion, 1992).

The warm water conditions that prevailed during the Eocene were, in part, because of the latitudinal gradients. But, paleolatitude determination for Baja California Peninsula during deposition of the Tepetate and Bateque Formations is difficult to interpret (Morales-Ortega, 2012).

Nowadays, the most accepted tectonic models are those which propose that the Baja California Peninsula is separated by only 450 to 500 km, in the north-northwest direction from the Mexican continental massif (Jalisco, Nayarit, Sinaloa and Sonora). New geological and geochronological data show that sediments are derived mainly from volcanic rocks of the Sierra Madre Occidental. Also, numerous lithological and geochemical correlations support the idea that the batholiths that are found on both land masses, that is to say, on the peninsula and on the continental massif; these are areas that continue through the Gulf of California rift, indicating that from the Late Cretaceous to Middle Miocene, the Baja California Peninsula was connected to the mainland (Gastil *et al.*, 1981; Flynn, 1989; Squires and Demetrion, 1992; Fletcher *et al.*, 2007; Plattner *et al.*, 2009).

Although it is unknown exactly where is the paleolatitude of the peninsula, it is believed that the latitude was not very different from what is currently known, and that the current flow tropical Tethys had a greater influence on the climate of the Eocene, and in distribution and dispersal marine fauna worldwide (Morales-Ortega, 2012).

SISTEMATIC PALEONTOLOGY

The classification system used was that by Kroh and Smith (2010) for identifying the family level, in the case of genus and species the Kroh (2010) classification system was used. All specimens are deposited at Colección de Referencia Paleontológica de Invertebrados, Museo de Historia Natural de la Universidad Autónoma de Baja California Sur (MHN-UABCS), with their respective identification key (location/number of collect/number of specimens).

Class Echinoidea Leske, 1778
Subclass Cidaroidea Smith, 1984
Order Cidaroida Claus, 1880
Cidaroida?, indet. spine D
(**Figure 3.1**)

Description. A single spine is divisible into three parts, a tip, a long shaft, a short neck and a base; however, the pair of spines found in Bateque Formation is incomplete. The specimen MHN-UABCS Ba14/33/46 preserves the base and part of the shaft. This spine is small, thin, smooth and flat (crescent shaped). The acetabulum has a circular shape with a diameter of 1.2 mm and a height of 0.3 mm (to the base). The base is smooth, and is not observed ornamentations measured 1.5 mm (from the acetabulum to the milled ring). Milled ring with grooves, measure 0.3 mm in height. The neck is slightly narrower, measures 1.7 mm and shows fine striations ranging from the milled ring to the base of the shaft. The shape of the shaft is truly unique, is completely smooth and crescent (on one side has an entirely flat face and on the other side a convex face). The shaft portion closer to the base is narrow but widens towards the middle of the shaft; not possible to infer whether there is continuous widening to tip (wide tip) or only covers the middle and perhaps becomes narrower towards to end.

Material examined. MHN-UABCS Ba14/33/46, 12.8 mm total length (from the base and part of the shaft). MHN-UABCS Ba14/33/47, 9.7 mm total length (shaft only).

Ocurrence. All specimens were collected near the locality 1219, Squires and Demetrion (1992), Bateque Formation; at Lat. N 26°55.9', Long. W 113°04.8'.

Discussion. Squires and Demetrion (1992) reported three different forms of irregular urchin spines the Order Cidaroida (Cidaroida, indet. spine A, B and C); however, the shape and structure of these spines are nothing like the kind of spine that is reported in this paper.

It is permissible that the new spine "flat" corresponds to the same order, as there are some genus of Order Cidaroida (*Prionocidaris, Stylocidaris*?), which have similar characteristics to the base, however the structure of the shaft is different. Most spines are cylindrical and have different ornaments, for example, longitudinal rows with granules (genus *Eucidaris*), longitudinal ridges, which have tiny spines (genus *Stylocidaris*? and *Prionocidaris*) or flat but strongly serrated on the sides (Subfamily: Cidarinae, indet.) (Kroh, 2005). However, the specimens found are completely smooth and flat with no trace of any ornamentation. Until now, there is no report of such a spine in any other part of the world.

Order Spatangoida L. Agassiz, 1840a
Suborder Paleopneustina Markov and Solovjev, 2001
Family Schizasteridae Lambert, 1905
Genus *Agassizia* Valenciennes, in L. Agassiz and Desor, 1847

Agassisia Valenciennes, in Du Petit-Thouars, 1846 (original incorrect spelling).
Eoagassizia Grant and Hertlein, 1938, p. 115.

Type species. *Agassizia scrobiculata* Valencinnes in Agassiz and Desor, 1847, p. 20; by original designation. Recient, west coast of Central America.

Ocurrence. Cuba, Jamaica, Middle East, eastern Pacific and United States of America (East Coast).

Diagnosis. Test ovate, of small to medium sized, with no anterior sulcus at ambitus; rounded in profile. Apical disc ethmolytic, with four central gonopores. Anterior ambulacrum and petals are flush to slightly depressed, pores in anterior poriferous zones of petals are smaller than in posterior; both peripetalous and latero-anal fascioles. Periproct on vertical, truncate face. Two or three subanal penicillate tube-feet. Peristome large and D-shaped; labral plate not projecting strongly and peristome facing downwards.

***Agassizia* sp.**
(Figures 3.3, 3.6)

Description. Specimens are common at locality Cañada El Llano, have complete or partially complete exoskeleton, although most are eroded. Urchin spherical or oval. Apical disc ethmolytic, with four gonopores central approximately the same size. Anterior pair of petals (II and IV) longer than the others and flexed forward; anterior column rudimentary pores pairs,

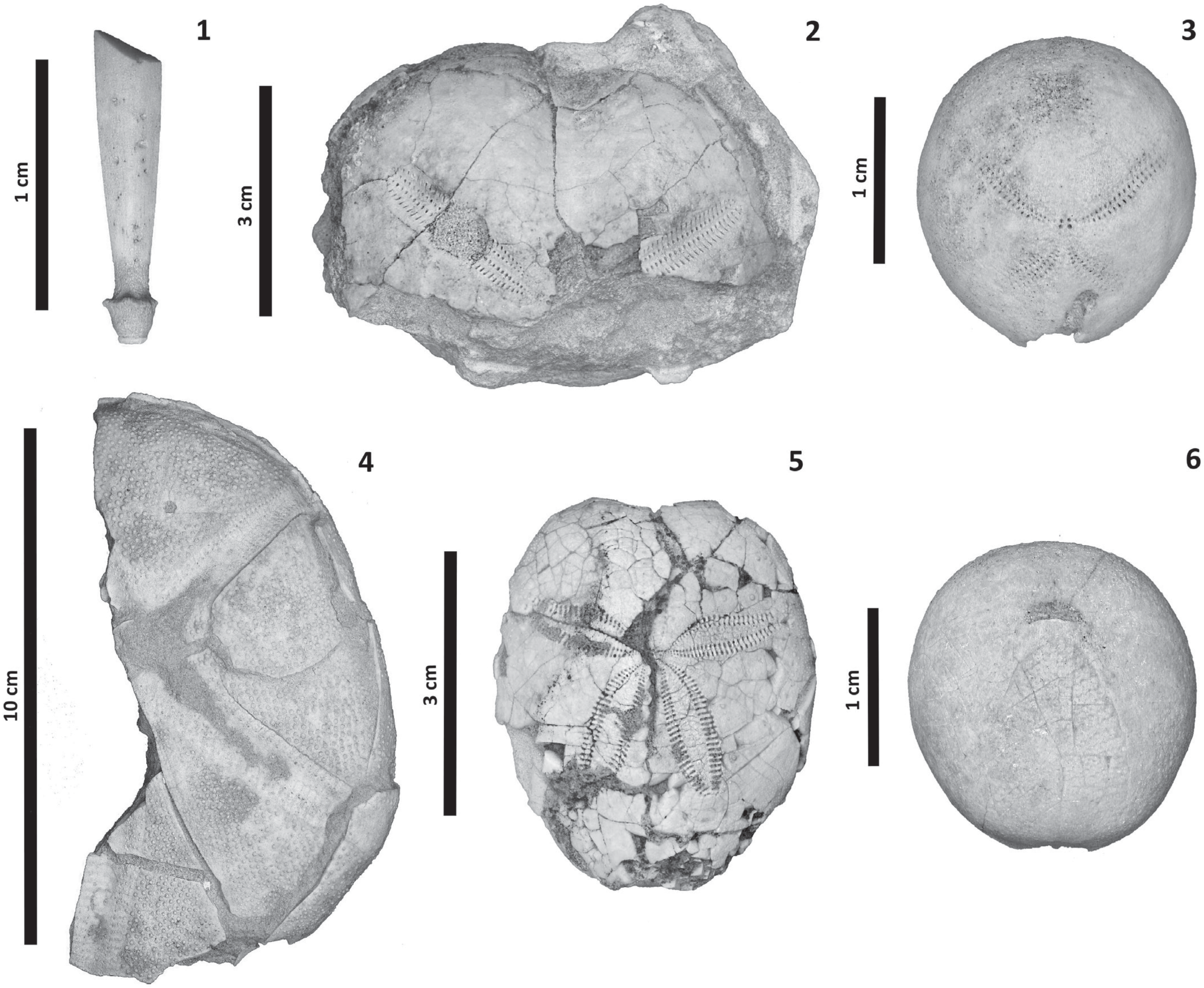

Figure 3. **1)** Cidaroida?, indet. spine D, MHN-UABCS Ba14/33/46, frontal view; **2)** *Pericosmus?* sp., MHN-UABCS Te8/74/921, aboral view; **3** and **6**, *Agassizia* sp., MHN-UABCS Te42/95/330: **3)** aboral view; **6)** oral view; **4)** *Asterostoma* sp., MHN-UABCS Te8/9b/257, oral view; **5)** *Eupatagus stevensi*, MHN-UABCS Te8/74/920, aboral view.

posterior and anterior columns with the same number of plates. Posterior pair of petals (I and V) short, weakly depressed and with two equally developed pore columns. Ambulacrum III straight, narrow but wide at its apical end; composed of two keyhole-shaped plates, each plate with a single pore in the center. Periproct on vertical, truncate face. Adorally interambulacrum with five long plates shield-shaped forming the plastron. Interambulacral areas, two and three on contact peristome but only one of each side plate, one and four did not extend to the peristome. Peristome large and D-shaped. Aboral tuberculation fine, uniform and dense. Oral tubercles also dense and uniform.

Material examined. The 24 specimens from the same locality, MHN-UABCS Te42/95/330-354. Maximum diameter 25 mm.

Ocurrence. All specimens were collected at Cañada El Llano (from cliffs in a broad cañada), Tepetate Formation; at Lat. N. 24°19.7', Long. W 111°01.0'.

Discussion. There are several species of *Agassizia* reported in the Eocene: *A.* (*Anisaster*) *arabica* Kier (1972), from Eocene-Oligocene? of Saudi Arabia; *A. caribbeana* Weisbord (1934) and *A. flexuosa* Sánchez Roig (1949), Upper Eocene and *A. caobaensis* Sánchez-Roig (1953), Middle Eocene of Cuba; *A. lamberti*, Upper Eocene? according to Palmer (in Sánchez-Roig, 1949) but, Brodermann (1949) as reported in the Oligocene? of Cuba (Provincia Las Villas); *A. inflata* Jackson (1922) from Middle Eocene, reported in Jamaica, Cuba, North and South Carolina, United States of America; *A.* (*An.*) *wilmingtonica wilmingtonica* Cooke (1942), Middle Eocene of North Carolina; *A.* (*An.*) *wilmingtonica inflata* Kier (1980), Middle Eocene of South Carolina; *A. floridana* de Loriol (1887) Upper Eocene of Florida, these latter reported in United States of America (Cooke, 1959; Kier, 1972, 1980, 1984; Kier and Lawson, 1978; Donovan, 1988; Kroh, 2010).

Undoubtedly the specimens belong to the genus *Agassizia*, however, the specific determination is complicated by the preservation and the similarity of these aspects with other species. The species most similar *Agassizia* sp. is *A. inflata*, however it has a number of synonyms: *A. caobaensis*, *A. egozcuei* and *A. wilmingtonica* (Kier, 1984).

Kier (1980) reported *A.* (*An.*) *wilmingtonica wilmingtonica* of Castle Hayne Limestone, North Carolina: Maple Hill, and *A.* (*An.*) *wilmingtonica inflata* of Santee Limestone, South Carolina: Georgetown. In the same study mentioned that the only differences between a subspecies and another is that the specimens have a slightly inflated Georgetown and for that reason the apical system is located more anteriorly, out of those two slight differences, the rest of the characters between both species are completely identical.

The work "Fossil Spatangoid Echinoids of Cuba", by Kier (1984) reported finding *A. inflata*, and compared this species with that found in Jamaica and mentions that they are indistinguishable. Also he could not find differences between Cuban specimens with specimens of *A. wilmingtonica of the* Middle Eocene of North and South Carolina, United States of America. In this work, Kier, made scatter diagrams of the main characters of *A. inflata* and *A. wilmingtonica* and the results did not reveal any separation between the two species.

Moreover, the allocation remains complicated several authors consider that the species name *A. inflata*, *A.* (*W*) *wilmingtonica inflata* and *A. wilmingtonica* as synonyms, while others regard them as three different species although the range of variation from one species to another is very small or even null.

The specimens found in Tepetate Formation represent the first record of the genus *Agassizia* on the Pacific coast of North America, however designated it as new species is bold, and especially when considering that the differentiation between species is very small.

Superfamily Paleopneustidea A. Agassiz, 1904
Family Pericosmidae Lambert, 1905
Genus *Pericosmus* L. Agassiz, in L. Agassiz and Desor, 1847

Megalaster Duncan, 1877, p. 61.
Platyspatus Pomel, 1883, p. 29.

Type species. *Hemiaster* (*Pericosmus*) *latus* Desor, *in* Agassiz and Desor, 1847, p. 19; by subsequent designation of de Loriol, 1875, p. 115. Early Eocene to Recent.

Ocurrence. Cuba, Madagascar, New Zealand, Somalia and Spain.

Diagnosis. Test generally moderately large, broad, with flattened ventral surface, domed dorsal surface. Apical disc ethmolytic, with three gonopores (no gonopore in genital plate two). Anterior ambulacrum narrow and sunken adapically. Pore-pairs uniserial and enlarged adapically. Petals depressed, of approximately equal length, with occluded plates at ends, plates beyond petals with single pores. Periproct towards top of short vertically-truncate posterior face. Peristome ovate to kidney-shaped with labral plate projecting to a greater or lesser extent.

Pericosmus? sp.

(Figure 3.2)

Description. Only a fragment of exoskeleton preserved, embedded in sandstone. This genus has an elongated shape with ventral surface flattened and a dorsal surface domed. The anterior pair of petals are visible on the fragment (II and IV) of equal length (24 mm), that are slightly depressed. Ambulacrum III is narrow and sunk; this extends from the apical system to the peristome; it usually, has small pores in the anterior part but at the most distal part these may be occluded, characters present in the species *Pericosmus*; however, this feature is not observed in the specimen of *Pericosmus*? sp. and it seems that all the pores are closed or simply not present. Peripetalous and marginal fascioles are indistinguishable. The specimen has a pair of gonopores approximately the same size, although it is known that the apical system of this genus only presents three gonopores.

Material examined. Only specimen, MHN-UABCS Te8/74/921; maximum height 38 mm, maximum length 52 mm (anterior part fragment).

Ocurrence. The specimen was collected in the locality El Canelo, Tepetate Formation; at Lat. N 24°20.2', Long. W 111°00.6'.

Discussion. Morales-Ortega (2010) assigns *Metalia*? sp. the specimen MHN-UABCS Te8/74/921, years later this same specimen was again discussed and compared with other genres, and came to the conclusion that the issue should be reassigned to the genus *Pericosmus*? (although only comparable the anterior pair of petals (II and IV) and Ambulacrum III). Metalia has the anterior pair of petals (II and IV) narrower and depressed, and have a separation of about 180 degrees; also the perradial space that separates the two columns of pairs pores of the petals narrower in *Pericosmus*? sp. that several species of *Metalia* (*M. scutiformis*, *M. sowerbyi* y *M. agariciformis* from Eocene, India) (Coppard 2008; Morales-Ortega, 2010; NHM, 2013)

Moreover, there are several species of *Pericosmus* reported from the Eocene epoch in various parts of the world, for example: *P. annosus* Herderson (1975), New Zealand (Upper Eocene); *P. farresi* Carrasco (2003), Spain; *P. atolladosae* (Sánchez-Roig, 1953c) (synonyms; *P. rojasi* y *P. zanolettii*) and *P. cubanus* Palmer in Sánchéz-Roig (1949), Cuba (Upper Eocene); *P. clarki* Lambert (1933), Madagascar (Middle Eocene: Lutetiano); and *P. gregoryi* Currie (1927), Somalia (Eocene) (Kier, 1984; Kier and Lawson, 1978; Kroh, 2010). Despite the existence of several species from the Eocene, the specific assignment was not possible as it is necessary to observe other particular structures, such as the shape and size, the apical system, the ambulacral, the peristome and periprocto, the facioles and arrangement oral plates (Kier, 1984).

Therefore, the main characteristics suggest that the specimen can be classified in this genus and is *Pericosmus*? sp., This is suggested by the shape and likeness of the characters present in the ambulacrum III, the shape of the anterior pair of petals, the presence of marginal faciole and maybe also the perradial space is the same as in some species of *Pericosmus* since it is narrow. The genus assignment can be discussed, but not until more and better specimens are found.

Suborder Brissidina Stockley, Smith, Littlewood,
Lessions and MacKenzie-Dodds, 2005
Family Asterostomatidae Pictet, 1857
Genus *Asterostoma* L. Agassiz, in Agassiz and
Desor,1847

Type species. *Asterostoma excentricum* Agassiz, in Agassiz and Desor, 1847, p. 168; by monotypy. Eoceno, Caribe.

Ocurrence. Cuba and Jamaica.

Diagnosis. Test large and ovate without anterior sulcus at ambitus; base flat; upper surface domed. Apical system ethmolytic, with four genital pores. Petals long, open, anterior petals transverse, no occluded plates at ends of petals; anterior ambulacrum narrow and flush aborally; pore-pairs simple; ventrally ambulacra in deep grooves, with phyllodal pores not concentrated around peristome. Peristome subcentral; pentagonal in outline, wider than long. periproct marginal to inframarginal, opening higher than wide. No fascioles.

Asterostoma sp.

(Figure 3.4)

Description. Only a single, body broken in half and slightly flattened. Diameter approximately 115 mm (measured from the anterior to posterior part). The oral hemisphere remains of exoskeleton, while the aboral hemisphere only preserves a fragment in the back. Paired ambulacra petaloid; long and flush; extending to ambitus; open distally, without occluded end plates. Part of the exoskeleton is preserved on the ventral part, in which is observed deep grooves, important feature of the genus; also, observed are small pores along the plates. The peristome is slightly shifted to the anterior part (45 mm from the anterior part). *Asterostoma* has four gonopores, although these are not preserved in the sample. The specimens have small tubers of approximately the same size, and on the ventral part they are uniformly distributed.

Material examined. Only specimen, MHN-UABCS Te8/9b/257. Diameter approximately 115 mm (measured from the anterior to posterior part).

Ocurrence. Locality El Canelo, Tepetate Formation; at Lat. N 24°20.2', Long. W 111°00.6'.

Discussion. This is the first report of the genus *Asterostoma* on the Pacific coast of North America. Previously, this genus had only been reported in the regions of Pinar del Río Province, Cuba and St. James, Jamaica, in the Atlantic. The species reported in these regions are: *A. excentricum* (synonyms: *A. dickersoni* and *A. irregularis*), *A. pawsoni* and *A. subcircularis* (Arnold and Clark, 1927; Kier, 1984).

The specimen found in the Tepetate Formation resembles *A. excentricum* and *A. subcircularis*, nevertheless due to the nature of the sample, certain characters cannot be compared; however, both are very similar species as the petals of both species that are indistinguishable, as in *Asterostroma* sp. A character that could not be compared and which is a small difference between the two species is the apical system, since this is located near the anterior margin and is 26% of the total length of *A. excentricum*, while that in *A. subcircularis* it is 36%. Although, the differences between both species is minimal and within the range of variation of the species, it has not yet been determined whether these species are the same or not, as only few specimens in the regions of Cuba and Jamaica have been found (Kier, 1984).

The specimen found in the Tepetate Formation contribute little to differentiate *A. excentricum* from *A. subcircularis*, although according Kier (1984) these should be considered two different species. It is expected, that in future that new specimens will be collected in the Tepetate Formation with better preservation and perhaps facilitate differentiation of one from the other.

Family Brissidae Gray, 1855

Genus *Eupatagus* L. Agassiz, in Agassiz and Desor, 1847

Eupatagus de Groot, 1863, p. 515 (error).
Pseudopatagus Pomel, 1885, p. 18.
Melitia Fourtau, 1913, p. 68.
Heterospatangus Fourtau, 1905, p. 606.
Euspatangus Cotteau, 1869, p. 257 (indeterminate name).
Perispatangus Fourtau, 1905, p. 605.
Koilospatangus Lamber, 1906, p. 185 (objective).
Herreraster Sánchez Roig, 1951, p. 52.
Zanolettiaster Sánchez Roig, 1952c, p. 14.
Megapatagus Sanchez Roig, 1953, p. 58.
Neopatagus Sánchez Roig, 1953b, p. 258.

Type species. *Eupatagus valenciennesi* L, Agassiz in Agassiz and Desor, 1847, by subsequent designation, of Pomel, 1883, p. 28. Recent, Australia.

Ocurrence. Cuba, Haiti, Libya, Mexico, Panama, United Kingdom and United States of America (East and West Coast).

Diagnosis. Test ovate without anterior sulcus. Anterior ambulacrum narrow and flush; pore-pairs small, simple isopores. Other ambulacra petaloid and flush. Petals distinctly bowed and tapering adapically. Apical system ethmolytic with four genital pores usually close together. Periproct large; on short vertical truncate face. Peristome large and kidney-shaped. Plastron short and triangular.Well-developed peripetalous and subanal fascioles. Subanal fasciole bilobed.

Eupatagus stevensi Grant and Hertlein, 1938

(Figure 3.5)

Type species. *Eupatagus stevensi* Grant and Hertlein, 1938: 134-135, text fig. 12.

Description. Specimens are uncommon in the formation but have poor preservation, some preserve part of the exoskeleton. These urchins are generally oval, but truncated in the posterior part. The specimen MHN-UABCS Te8/74/920, preserves much of the exoskeleton; aboral view allows for the anterior pair of petals to be seen (II and IV) of equal length (14 mm), posterior pair of petals (I and V) slightly longer (17 mm) and closer together. Ambulacrum III non-petaloid, narrow and flush; pore-pairs small. Due to poor preservation only two gonopores are seen, however the literature mentions that the species of *Eupatagus* presents four. The oral view it can be seen that some plates are welded together.

Material examined. Specimens are poorly preserved, MHN-UABCS Te3/52/85, MHN-UABCS Te8/9b/256, MHN-UABCS Te8/74/920 and MHN-UABCS Te22/51/11-14. Specimens with diameters 50 mm.

Ocurrence. All specimens were collected at Tepetate Formation. A single specimen MHN-UABCS Te3/52/85, kilometer 103.5 (between cañadas Palo Alto, El Morrito Alto and El Mangle), at Lat. N 24°21.5', Long. W 111°02.6'. Two specimens, MHN-UABCS Te8/9b/256 and MHN-UABCS Te8/74/920, El Canelo, at Lat. N 24°20.2', Long. W 111°00.6'. Four specimens, MHN-UABCS Te22/51/11-14, upstream Mesa Yesenia (northern part of the cliff), at Lat. N 24°10.3', Long. W 110°55.1'.

Geographic distribution. Simi Valley and upper Cuyama River, Ventura County, California, United States of America, lower middle Eocene ("Domengine Stage"); and Tepetate Formation, Baja California Sur, México, lower Eoceno ("Capay Stage").

Discussion. *E. stevensi* represents the first record of this species in Baja California Sur, Mexico. This species was reported by Squires (2001) in Ventura County, California, United States. The specimens reported by Squires and those found in the Tepetate Formation are poorly preserved, but they have the main characteristics of the genus *Eupatagus* and specifically the species *E. stevensi*.

The specimens found in this formation could extend the age range, as these were found in yellow sandstone layers representing the "Capay Stage"; while the specimen reported by Squires (2001) have an age range of "Domengine Stage", this should be considered for future publications and extends the geographic range of the species.

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CATALOGUE OF LATE JURASSIC VERTEBRATE (PISCES, REPTILIAN) SPECIMENS FROM WESTERN CUBA

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ABSTRACT

Vertebrate remains are relatively well known in Late Jurassic deposits of western Cuba. The fossil specimens that have been collected so far are dispersed in museum collections around the world and some have been lost throughout the years. A reassessment of the fossil material stored in some of these museums' collections has generated new data about the fossil-bearing localities and greatly increased the number of formally identified specimens. The identified bone elements and taxa suggest a high vertebrate diversity dominated by actinopterygians and reptiles, including: long-necked plesiosaurs, pliosaurs, metriorhynchid crocodilians, pleurodiran turtles, ichthyosaurs, pterosaurs, and sauropod dinosaurs. This assemblage is commonly associated with unidentified remains of terrestrial plants and rare microorganisms, as well as numerous marine invertebrates such as ammonites, belemnites, pelecypods, brachiopods, and ostracods. This fossil assemblage is particularly valuable because it includes the most complete marine reptile record of a chronostratigraphic interval, which is poor in vertebrate remains elsewhere. In this contribution, the current status of the available vertebrate fossil specimens from the Late Jurassic of western Cuba is provided, along with a brief description of the fossil materials.

Key words: Late Jurassic, Oxfordian, dinosaur, marine reptiles, fish, western Cuba.

INTRODUCTION

Since the early 20th century, different groups of collectors have discovered a relatively rich and diverse vertebrate assemblage in the Late Jurassic strata of western Cuba, which has been only partially investigated (Brown and O'Connell, 1922; De la Torre y Callejas, 1949; De la Torre y Madrazo and Cuervo, 1939; De la Torre y Madrazo and Rojas, 1949; Gasparini and Iturralde-Vinent, 2006, and references therein; Gregory, 1923; Iturralde-Vinent and Norell, 1996; Judoley and Furrazola-Bermúdez, 1965).

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The fossil material was recovered from lenticular calcareous concretions within the Oxfordian Jagua and Francisco Formations, and to a lesser extent from well-bedded limestones of the Tithonian Guasasa and Artemisa Formations. These stratigraphic units crop out at several localities in the Guaniguanico mountains of the Pinar del Rio province of western Cuba.

In the Oxfordian fossil-bearing strata more than seventy rather well-preserved reptile specimens have been collected, and more than five hundred fish remains, some of which have been assigned to family, genus, or species. Reptiles within this fossil assemblage include two rhamphorhynchid pterosaur taxa (*Nesodactylus hesperius*, *Cacibupteryx caribensis*), a cryptoclidid plesiosauroid taxon (*Vinialesaurus caroli*), a medium-sized pliosauroid (*Gallardosaurus iturraldei*), indeterminate rhacheosaurin crocodilians, a fragmentary specimen of pleurodiran turtle (*Caribemys oxfordiensis*), several unidentified ichthyosaurs including ophthalmosaurian elements, and at least one camarasaurid sauropod bone (Gasparini and Iturralde-Vinent, 2006; Young, 2013).

Identifiable remains of bony fish (actinopterygians) are also common including the following taxa: *Lepidotes gloriae*, *Gyrodus macrophthalmus cubensis*, *Caturus deani*, *Sauropsis woodwardi*, *Eugnathides browni*, *Leptolepis euspondylus*, *Luisichthys vinalesensis*, *Aspidorhynchus arawaki*, *Pholidophorus* sp., *Hypsocormus leedsi*, which are sometimes fossilized in three dimensions (Arratia and Schultze, 1985; Gregory, 1923; White, 1942; and others). Disarticulated bones of fish (provisionally identified as *Hypsocormus* sp.), and unidentified plesiosaur remains have been unearthed from Tithonian strata (Furrazola-Bermúdez in Gasparini and Iturralde-Vinent, 2006; Judoley and Furrazola-Bermúdez, 1965; Sánchez-Roig, 1920). Fragments of tree trunks, branches, and detrital vegetal material, and an assortment of marine invertebrates including ammonites, belemnites, pelecypods, brachiopods, and ostracods, are associated with fish and reptiles in the mid-to early-Late Oxfordian strata (Gasparini and Iturralde-Vinent, 2006; Iturralde-Vinent and Norell, 1996; Pszczólkowski, 1978; Wierzbowski, 1976).

The Cuban Late Jurassic vertebrate assemblage is important not only for its high taxonomic diversity and relative abundance, but it also includes the most complete marine reptile record for the mid-to early-Late Oxfordian as yet discovered (Gasparini and Iturralde-Vinent, 2006). This chronostratigraphic interval is poor in marine reptiles in other parts of the planet, and those which have been collected are often fragmentary (Gasparini and Iturralde-Vinent, 2006; Young, 2013). Furthermore, the presence of marine forms that are closely related phylogenetically in Late Jurassic-Early Cretaceous American and European deposits, underline the outstanding position of the Oxfordian early Caribbean taxa of western Cuba. However, only in the last decade, taxonomic, biogeographic and paleogeographic studies have been accomplished (Gasparini and Iturralde-Vinent, 2006; Iturralde-Vinent, 2004; Iturralde-Vinent and Norell, 1996; Pszczólkowski, 1978, 1999; Wierzbowski, 1976).

Late Jurassic vertebrate specimens of Cuba are dispersed in museum collections in Cuba, Puerto Rico, the United States of America and Great Britain, but unfortunately, some are known to have been lost (Table I). Most of the Late Jurassic fish and reptile fossil-bearing localities in Cuba were poorly known prior to the work of Iturralde-Vinent and Norell (1996), but since the publication of this synoptic catalog, new localities and fossil materials have been discovered, and new taxa named and/or revisited. In Cuba, the Late Jurassic fish-bearing localities were not catalogued before and the majority of existing specimens are awaiting a formal identification.

The main objective of this paper is to provide an assessment of the current status of the available fossil vertebrate specimens of the Late Jurassic of western Cuba, and present an updated catalog including previously unpublished specimens and localities.

PREVIOUS WORK

Alexander von Humboldt inferred the existence of Jurassic rocks in the western part of the island at the beginning of the 19th century, but he did not provide paleontological evidence. Actually, the first to prove the occurrence of Jurassic strata was the Spanish mining engineer Manuel Fernández de Castro, who reported Jurassic ammonites in the Pinar del Río province in 1881. However, these fossils were neither illustrated nor identified. The first author to properly identify rocks of the Jurassic period was the outstanding Cuban naturalist Don Carlos de la Torre y Huerta (De la Torre y Huerta, 1909, 1910*a*, 1910*b*), who reported the occurrence of Jurassic fossils in Pinar del Río. Between 1911 and 1919, Barnum Brown (American Museum of Natural History) visited Cuba to collect fossils guided by Carlos de la Torre y Huerta and was impressed by the Jurassic fauna of the Viñales region. The occurrence

Table 1. Repositories and abbreviations for material investigated in this paper.

	Repository	Abbrev.	Location	Fish	Reptile
01	Museo Nacional de Historia Natural de Cuba	MNHNCu	Habana, CUBA	*	*
02	Instituto de Geología y Paleontología de Cuba	IGP	Habana, CUBA	*	*
03	Antonio Núñez-Jiménez Foundation for Nature and Humanity	FANJ	Habana, CUBA	*	*
04	Museo "Campismo Dos Hermanas"	MDH	Pinar del Río, CUBA	*	*
05	Museo de Viñales	MV	Pinar del Río, CUBA	*	
06	Gallardo's collection	GC	Pinar del Río, CUBA	*	
07	American Museum of Natural History	AMNH	New York, USA	*	*
08	British Museum of Natural History	NMH	London, UK	*	
09	Museum of Comparative Zoology	MCZ	Cambridge, USA	*	
10	National Museum of Natural History	USNM	Washington, D.C, USA	*	*
11	Museum of Paleontology of University of California	UCMP	Berkeley, USA	*	*
12	Texas Memorial Museum of University of Texas	TMM	Austin, Texas, USA	*	
13	University of Puerto Rico, Paleontology Collection	UPRMP	Mayagüez, PUERTO RICO	*	

of Oxfordian beds in western Cuba bearing ammonites, fish, and marine reptiles was consequently reported by Brown and O'Connell (1919, 1922).

Perhaps the earliest paper describing the Cuban Jurassic fish fauna was by Sánchez-Roig (1920), who collected fossils with his father and Juan Gallardo concurrently with the Brown expeditions. He illustrated some rare Tithonian fish remains, which have been stored in the British Museum of Natural History since 1924 (Z. Johanson, *personal commun.*, 2009) and Gregory (1923) described several new fish taxa treasured at the American Museum of Natural History. Since then, few new taxa have been published from museum collections in the United States of America (Arratia and Schultze, 1985; Brito, 1997, 1999; Thies, 1989; White, 1942).

Others collectors, active during the first half of the 20th century, includes: América Ana Cuervo, Ricardo De la Torre y Madrazo, Julio de Quesada, Theodore E. White, Thomas Barbour, David H. Dunkle, Julian Millo, Carl Parsons, and Charles W. Hatten. Most of these early collecting works were accompanied by the late Juan Gallardo, an experienced Cuban fossil hunter, whose later findings, including well-preserved actinopterygians, plesiosauroids, pliosauroids, pterosauroids and the pleurodiran turtle, have strongly contributed to the present knowledge of the Cuban Jurassic fauna. These vertebrate fossil specimens were stored in private Cuban collections, at the Museo Felipe Poey of the University of Havana, and at several North American institutions including the Smithsonian Museum of Natural History in Washington D.C., the American Museum of Natural History in New York City, the Museum of Paleontology at Berkeley, and the Museum of Comparative Zoology at Harvard. During the second half of the 20th century additional samples were collected by Antonio Núñez-Jiménez (housed at the Antonio Núñez-Jiménez Foundation for Nature and Humanity), A. Pszczólkowski, R. Myczyński, C. Judoley, G. Furrazola-Bermúdez and R. Gutiérrez-Domech (stored at the Instituto de Geología y Paleontología de Cuba).

With the exception of a rhamphorhynchid pterosaur in the collection of the American Museum of Natural History (Colbert, 1969), most of the Cuban Late Jurassic reptile specimens were poorly prepared, inadequately studied, and improperly allocated taxonomically before 1996. These specimens were usually identified as ichthyosaurs (De la Torre y Madrazo and Cuervo, 1939; De la Torre y Madrazo and Rojas, 1949) or sauropod dinosaurs (De la Torre y Callejas, 1949).

In the late eighties, M. Iturralde-Vinent started a new stage of research relocating the historic Jurassic vertebrate-bearing localities with the late Juan Gallardo and his oldest son. Also in the early nineties, M. Iturralde-Vinent visited every paleontological collection in Cuban museums, the Cuban collections in museums in the United States of America, and the British Museum of Natural History. Consequently, a detailed catalog of Cuban Late Jurassic reptile specimens and localities, with a preliminary discussion of the taxonomic position of the known reptile taxa was

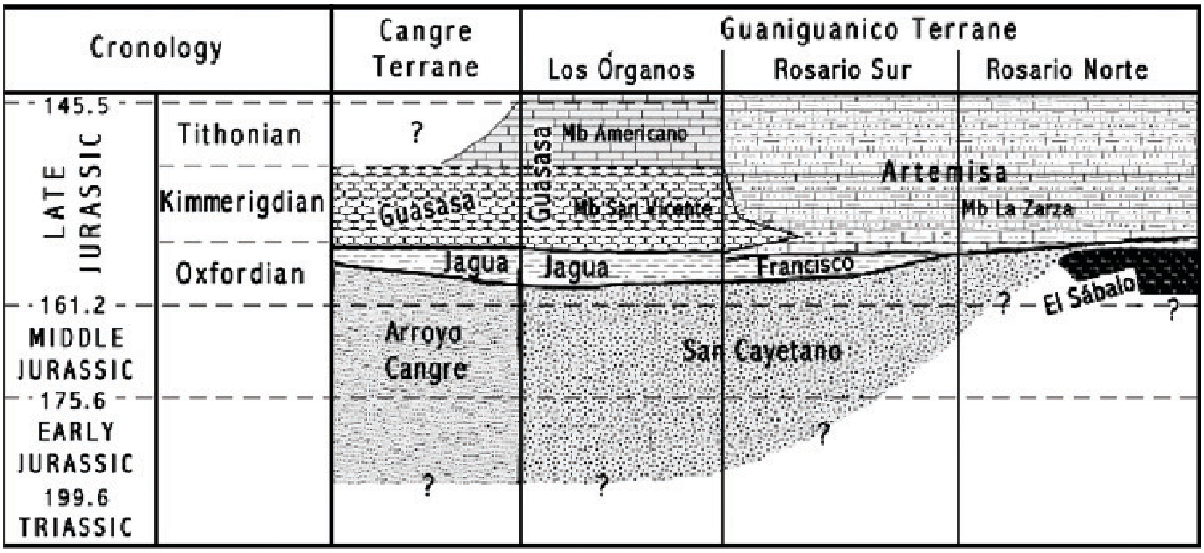

Figure 1. Jurassic stratigraphic scheme of the Cangre and Guaniguanico terranes, simplified from Iturralde-Vinent and Pszczólkowski (2012).

completed (Iturralde-Vinent and Norell, 1996). During this process a Jurassic vertebrate collection was created in the Museo Nacional de Historia Natural de Cuba, with materials obtained by means of collection, donation, and exchange.

In 1999, an important cooperation between the Museo Nacional de Historia Natural de Cuba and the Museo de Historia Natural de La Plata in Argentina began. The Cuban collections were revisited and part of the fossil material was sent to the Museo de Historia Natural de La Plata to be prepared and examined. In the meantime, taxonomic, biogeographic and paleogeographic investigations of the fossil-bearing localities were continued (De la Fuente and Iturralde-Vinent, 2001; Fernández and Iturralde-Vinent, 2000; Gasparini, 2009; Gasparini and Iturralde-Vinent, 2001; Gasparini *et al.*, 2002, 2004; Iturralde-Vinent, 2004). The Cuban-Argentinean cooperation resulted in the discovery and redefining of several new taxa of marine crocodile, ichthyosaurs, plesiosauroids and pterosauroids.

The results of these investigations, including taxonomy, stratigraphy, taphonomic interpretations, and paleobiogeography were summarized by Gasparini and Iturralde-Vinent (2006) and in a popular book for the general public (Iturralde-Vinent and Gasparini, 2014).

GEOLOGICAL SETTING

The Jurassic section exposed in the Pinar del Río Province in western Cuba (Sierra de los Órganos and Sierra del Rosario) includes vertebrate-bearing units of Oxfordian and Tithonian age (Figure 1). Detailed geological descriptions of the Mesozoic formations in western Cuba include those of Herrera (1961), Iturralde-Vinent and Pszczólkowski (2012), Pszczólkowski (1978, 1999), Wierzbowski (1976), as well as a synthesis of the most important fossil-bearing formations by Gasparini and Iturralde-Vinent (2006), and Iturralde-Vinent and Norell (1996). The Guaniguanico cordillera, from both a stratigraphic and tectonic standpoint, has been subdivided into several units (Figure 1): Cangre and Guaniguanico Terrane, which include the Los Órganos, Rosario Sur, Rosario Norte, and Guajaibón belts; described lately by Iturralde-Vinent and Pszczólkowski (2012).

Data collected for this study was insufficient to solve some ambiguous localities such as "Near Viñales" and "Near Viñales town", which could be anywhere between Puerta del Ancón, Laguna de Piedra, and Hoyos de San Antonio (Iturralde-Vinent and Norell, 1996). However, during the course of our research, new localities containing fish and unidentified reptiles were added to those already known (Figure 2). Generally, a palaeontological site represents about one square kilometer, although their limits are poorly defined. Fossil-bearing terrains include the slopes, creek, and farmlands near the karstified limestone hills (locally named "mogotes"). Laminated calcareous concretions of lenticular shape commonly occur at the surface, many with external casts of ammonites or bones extruding from their surfaces.

The majority of the fossil vertebrates material found in Pinar del Río, comes from a mid-to early-Late Oxfordian horizon named the Jagua Vieja Member of the Jagua Formation of Sierra de los Órganos. Palaeoenvironmentally, these marine deposits represent a low-energy, near shore, lower shelf, with water depths less than 100 meters (Wierzbowski, 1976). They were deposited during a transition from a siliciclastic deltaic continental plain (Early Oxfordian and older), into a marine carbonate shelf that was shallow and muddy (Late Oxfordian-Kimmeridgian) (Gasparini and Iturralde-Vinent, 2006; Iturralde-Vinent 2004; 2006).

The mid-to early-Late Oxfordian Jagua Formation outcrops in the Sierra de los Órganos belt, and consists of approximately 160 meters of shale and limestones overlying the San Cayetano Formation (Pszczólkowski, 1978). The Jagua Vieja Member of the Jagua Formation, a reach fossil-bearing horizon, consists of black, laminated, bituminous shales with thin intercalations of argillaceous, micritic to biomicritic limestones up to 60 meters thick, containing lenticular diagenetic calcareous concretions with fairly abundant fossils (Pszczólkowski, 1978). Fossils found in this member include: abundant unidentified terrestrial plant remains, trace fossils (*Teredolites clavatus*), sepioids (*Voltzia palmeri*), bivalves (*Liostrea* sp., *Ostrea* sp., *Plicatula* sp., *Exogira* sp., *Gryphaea* sp., ?*Posidonomya* sp.), small-sized gastropods, fora-

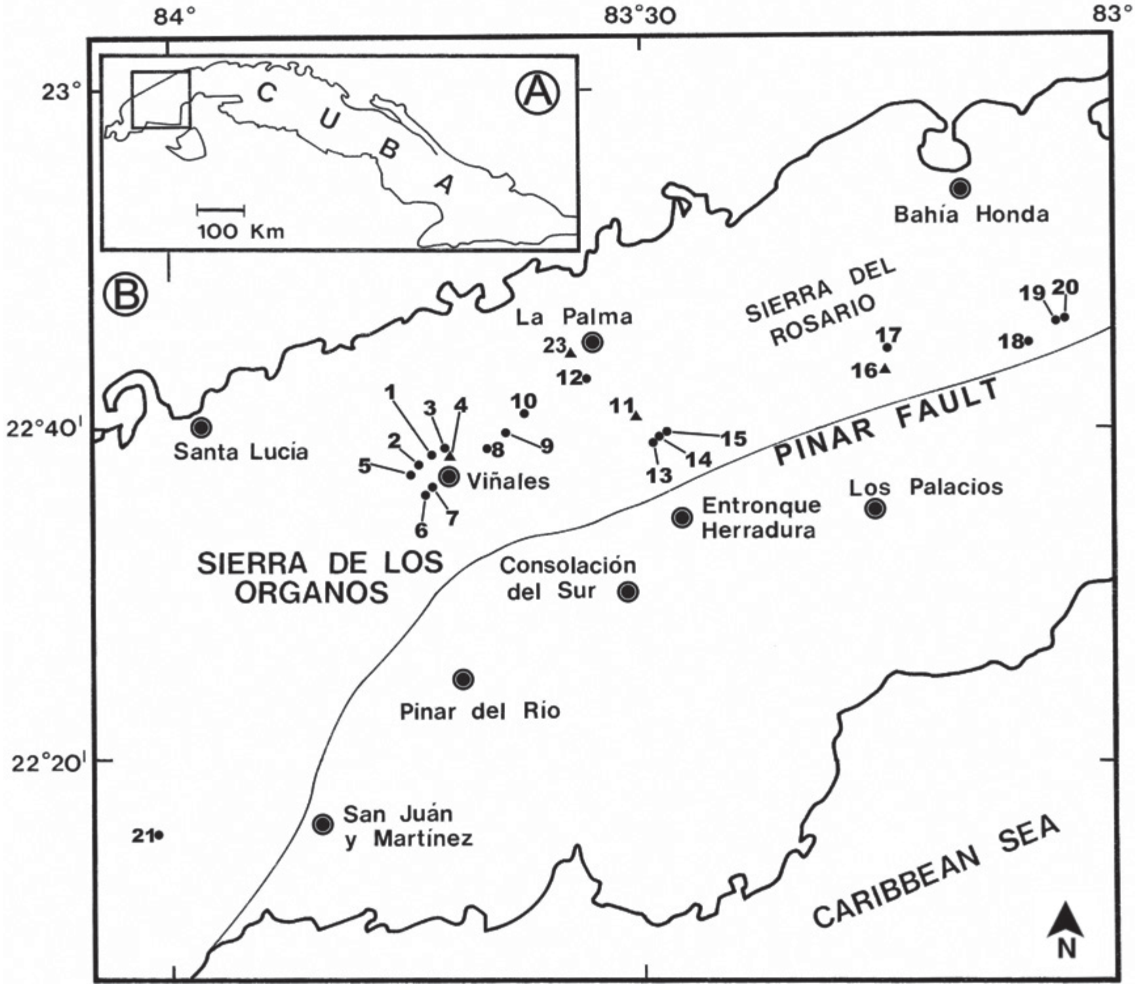

Figure 2. Location of the Cuban Late Jurassic vertebrate-bearing localities (Updated from Iturralde-Vinent and Norell (1996) and Gasparini and Iturralde-Vinent (2006). **A)** Position of the area investigated; ***B)*** Simplified map of Pinar del Rio Province. Black circles represent Oxfordian localities: **(1)** Puerta de Ancón, **(2)** Near Viñales, **(3)** Laguna de Piedra (Norte), **(5)** Mogote la Penitencia, **(6)** Valle los Jazmines, **(7)** Viñales Town, **(8)** Hoyos de San Antonio, **(9)** Mogote La Mina, **(10)** Jagua Vieja, **(12)** Mogote Pico Chico, **(13)** Hoyo del Palmar, **(14)** Hoyo de la Sierra, **(15)** Caiguanabo, (17) Rangel Arriba, **(18)** Puerta de la Muralla, **(19)** Near Cinco Pesos, (20) 1km N of Cinco Pesos, **(21)** Punta de la Sierra. Black triangles represent Tithonian localities: **(4)** Laguna de Piedra (Sur), **(11)** Hacienda El Americano, **(16)** Rancho Mundito, **(23)** Vega Nueva.

minifera (*Conicospirillina basiliensis*), belemnites and ammonites (typically belong to Perisphinctidae, less numerous amounts of Glochiceratidae, and Aspidoceratidae, among others). According to Wierzbowski (1976), the ammonite assemblage from the Jagua Vieja Member represents the *Gregoryceras transversarium* and *Perisphinctes bifurcatus* Chrons of the Middle Oxfordian age, but later, Myczyński *et al.* (1998) correlated this ammonite assemblage with the *Perisphinctes bifurcatus* Chron of Late Oxfordian age. Vertebrates fossils embrace actinopterygian fishes and reptiles that include rhamphorhynchid pterosaurs (*Nesodactylus hesperius*, *Cacibupteryx caribensis*), ophthalmosaurian ichthyosaurs and an unidentified ichthyosaur skull, a cryptoclidid plesiosaur (*Vinialesaurus caroli*), a medium-sized pliosaurid (*Gallardosaurus iturraldei*), indeterminate thalattosuchian, rhacheosaurin crocodylomorphs, a marine pleurodiran turtle (*Caribemys oxfordiensis*), and at least one camarasaurid sauropod (Gasparini and Iturralde-Vinent, 2006; Gregory, 1923; Iturralde-Vinent and Norell, 1996; Pszczólkowski, 1978; Wierzbowski, 1976; Young, 2013). In the Sierra del Rosario, an equivalent unit of the Jagua Formation is the Francisco Formation, which consists of black shales, micritic limestones, and thin sandstone intercalations, about 25 meters thick, containing a few small to medium calcareous concretions with rare bivalves, ammonites, fish and plant remains (for details see Kutek *et al.*, 1976; Pszczólkowski, 1999). According to Kutek *et al.* (1976, see fig. 4, fig. 5), unidentified fish material was found in two localities from exposures near the Cinco Pesos area, located about 10 km NW of San Cristóbal.

The fossil-bearing concretions are highly variable in size, from a few centimeters to nearly one meter in diameter, and are composed of laminated micritic limestone or dolostone and calcareous siltstone. It have been suggested an early diagenetic origin for the fossiliferous concretions (Wierzbowski, 1976). In the local vernacular these concretions are known as "quesos" (cheese), "jicoteas" (tortoise), or "jocoteas" (colloquial misspelling of jicotea). For this reason, some fish specimens housed in the Museum of Comparative Zoology have been improperly labeled as originating in the "horizon Camada de Quesso" [*sic*] which is not a valid stratigraphic unit, but it is most probably the Jagua Vieja Member of the Jagua Formation.

In the concretions, saurian bones are usually found as disarticulated or isolated elements, but also fragmentary skulls and two or more articulated vertebrae are often preserved. The bones are three-dimensional, fossilized as a dark black microcrystalline limestone which is difficult to separate from the concretions. Some examples suggest that the preservation of the fossils was restricted to the concretions and parts of the carcass may have been dissolved by rain water after fossilization (Gasparini and Iturralde-Vinent, 2006). Skulls can be fairly complete or fragmentary, due to the partial loss of the braincase or the tip of the rostrum. However, in many of the skulls the mandible is articulated although slightly twisted, *e.g. Vinialesaurus caroli*, *Gallardosaurus iturraldei*, and the rhacheosaurin crocodylomorphs (MNHNCU P3009 and USNM PAL 419640). This suggests that the missing part of those bones may have been originally preserved in the embedding shales, but were later lost due to weathering or a secondary erosion of the concretion by down slope movements or by farmers during land preparation (Gasparini and Iturralde-Vinent, 2006). Both saurian and fish elements can be found in association with ammonites encrustations and perforated by invertebrates (De la Torre y Callejas, 1949; Iturralde-Vinent and Norell, 1996; and author's observations) suggesting that some specimens suffered decay providing that the bones were eventually exposed and dispersed on the sea bottom prior to burial. Fish remains can be flattened, probably due to desiccation, but three-dimensional specimens also occur. They usually are not dismembered and retain their scales, suggesting that the bodies were not scavenged. The taphonomic analysis of reptilian bones suggests that there was no active predation on the sea floor prior to fossilization. (Gasparini and Iturralde-Vinent, 2006; Wierzbowski, 1976).

Tithonian strata are generally poor in vertebrate remains, although the well-stratified limestones of the Late Oxfordian (?) to Valanginian Guasasa and Artemisa Formations have yielded pectoral and caudal fins of *Hypsocormus*–like fish (Sánchez-Roig, 1920), a few fragmentary and undiagnostic marine reptile bones (Judoley and Furrazola-Bermúdez, 1965) and unidentified plesiosaurian remains (Furrazola-Bermúdez in Gasparini and Iturralde-Vinent, 2006). In latest Jurassic strata of the Artemisa Formation at Vega Nueva Quarry (Loc. 23, Fig. 2), a well preserved nearly complete fish specimen was found recently (E. Linares, *personal commun.*, 2013). Both Guasasa and Artemisa formations rest, respectively, on the Jagua and Francisco Oxfordian formations and represent two facies: carbonate shelf and slope deposits.

RESULTS AND DISCUSSION

To date, the fossil vertebrates found in the Late Jurassic rocks of western Cuba comprise more than five hundred fish and more than seventy reptilian specimens. The specimens are preserved in several collections (Table I). In Cuba, the Museo Nacional de Historia Natural has the largest and best documented collection, including some of the earliest specimens to be collected. Other materials in paleontological collections of this country have suffered from inadequate or no curation and in the course of our study we found some specimens that were only partly labeled or in unsatisfactory condition.

The following table lists the vertebrate taxa identified from Jurassic strata of Cordillera de Guaniguanico (Table II).

We re-examined and photographed the fossils in our Cuban collections and tentatively identified several fish specimens of Late Oxfordian age including *Gyrodus* sp. cf. *Gyrodus macrophthalmus cubensis* Gregory, 1923 (MNHNCu P0822, 2003, 2091, 2093, 2094, 2104, 2107, 2110, 2112, 3852, 3857, 3887, 3892, 5068, 5070, 5071, 5079, 5081); *Lepidotes* sp. (MNHNCu P2122, 3829, 5074); cf. *Luisichthys vinalesensis* White, 1942 (MNHNCu P0821, 2102, 2116, 3821, 3831, 5298); cf. *Caturidae* indet. (MNHNCu P2002); cf. *Pachycormidae* indet. (MNHNCu P3922); and *Pycnodontiformes* indet. (MNHNCu P5078). These species all came from the Jagua Formation. There are also fish material of Oxfordian age (also from the Jagua Formation) of *Lepidotes* Agassiz, 1832 (identified by D. Thies, *personal commun.*, 2010), *Gyrodus* sp. and *Caturus* sp. in the paleontological collection of the Museo "Dos Hermanas" that have not been cataloged. Only a small specimen (IGP-V-273) stored at Instituto de Geología y Paleontología de Cuba, which we tentatively identified as leptolepid fish, probably came from the limestones of the Artemisa Formation (as it is labeled as collected in that unit). Thus, the diversity of actinopterygians appears to be higher in rocks of the Late Oxfordian Jagua Formation.

Unfortunately, the preserved fish material in the Cuban collections is mostly unprepared and therefore, some specimens could not be identified. *Gyrodus*–like is by far the most abundant element of the Cuban Jurassic fish assemblage demonstrating that these pycnodonts were abundant in the Caribbean Seaway's ecosystem.

A notable number of fish specimens housed in paleontological collections are pending identification. We have also found that some of the preliminary information shown on the labels in the collections is probably incorrect. For example, two unpublished fish taxa (*Gyrodus vinalensis* and *Lepidotes vinalensis* named by D.H. Dunkle in 1950) , based on specimens housed in the vertebrate paleontological collections of the Museum of Paleontology of University of California, are *nomen nudum* because have never been described. The specimen AMNH 8031 labeled as "*Colobodus*?, Jurassic, Constancia (?), Cuba, Acc. 260 from Dr. Carlos De la Torre", is the Turonian ptychodontid shark *Ptychodus cyclodontis* (Mutter *et al.*, 2005). Likewise, some materials could not be located in the museums' collections (*e.g.* specimen MCZ 6500, J. Cundiff, *personal commun.*, 2009; and specimen AMNH 2258, J. Maisey, *personal commun.*, 2010).

Furthermore, as suggested by Schaeffer and Patterson (1984) and G. Arratia, *personal commun.* (2011), the validity of some published fish taxa is questionable, for example: *Caturus*, *Sauropsis* (?), *Eugnathides* and *Leptolepis sensu* Gregory (1923). White's (1942) monotypic "leptolepid" genus *Luisichthys* was placed within the family Varasichthyidae acoording to Arratia and Schultze (1985). Therefore, the Late Jurassic fish fauna of Cuba includes at least three valid species of Oxfordian age (*Lepidotes gloriae*, *Luisichthys vinalesensis*, and *Aspidorhynchus arawaki*).

Concerning reptilian taxa, various isolated saurian bones (MNHNCu P3002, P3003) stored at the Museo Nacional de Historia Natural de Cuba were named as *Cryptocleidus*? [*sic*] *vignalensis* by Ricardo de la Torre y Madrazo, another *nomen nudum* as it was never described (see Iturralde-Vinent and Norell, 1996: p. 11-12 for general comments), and the material is not adequate to be positively assigned to any taxa (Gasparini and Iturralde-Vinent, 2006). Many other elements recovered from the same stratigraphic horizon such as vertebrae, fragmentary mandibles, and pectoral girdles, are also present in the MNHNCu collection (Iturralde-Vinent and Norell, 1996). Such specimens were labeled by Z. Gasparini as Plesiosauroidea indet. (MNHNCu P3066, P3805, P3832) and Cryptoclididae indet. (MNHNCu P3005, P3006, P3804). Additional disarticulated bones, ribs, phalange, and vertebrae of marine reptiles housed at the Instituto de Geología y Paleontología de Cuba were catalogued as Plesiosauria (cf. *Cryptoclidus*? sp.), but the fragmentary nature of these specimens prevents a more precise identification than Plesiosauroidea indet. A three-dimensional plesiosaurian paddle (stored at the Fundación Antonio Núñez-Jiménez para la Naturaleza y el Hombre, unnumbered), although perhaps not taxonomically

Table II. Jurassic vertebrate taxa identified from Cordillera de Guaniguanico, western Cuba.

REPTILES

Taxa	Specimen number	References	Locality in figure 1	Annotation
Camarasaurid sauropod	Lost	Salgado in Gasparini and Iturralde-Vinent (2006)	(10) Jagua Vieja	Originally identified as *Diplodocus* or *Brontosaurus* by De la Torre (1949)
Nesodactylus hesperius Colbert	AMNH 2000	Colbert (1969)	(13) Hoyo del Palmar	
Cacibupteryx caribensis Gasparini, Fernández and De la Fuente	IGP-V-208	Gasparini, Fernández and De la Fuente (2004)	(10) Jagua Vieja	
Gallardosaurus iturraldei Gasparini	MNHNCu P3005	Gasparini (2009)	(15) Caiguanabo	Previously identified as *Peloneustes* sp. *sensu* Gasparini and Iturralde-Vinent (2006)
Vinialesaurus caroli Gasparini, Bardet and Iturralde-Vinent	MNHNCu P3008	Gasparini, Bardet and Iturralde-Vinent (2002)	(2) Near Viñales	Previously identified as *Cryptocleidus cuervoi caroli* by De la Torre y Madrazo and Rojas (1949)
Ophthalmosaurid gen. and sp. indet.	MNHNCu P3068	Fernández and Iturralde-Vinent (2000), Gasparini and Iturralde-Vinent (2006)	(2) Near Viñales	
Ichthyosaur	MNHNCu P3001	De la Torre y Madrazo and Cuervo (1939), Gasparini and Iturralde-Vinent (2006)	(3) Laguna de Piedra (Norte)	Named as *Ichthyosaurus torrey* De la Torre y Madrazo and Cuervo, later Gasparini and Iturralde-Vinent referred to Ichthyosaur.
Caribemys oxfordiensis De la Fuente and Iturralde-Vinent	MNHNCu P3125	De la Fuente and Iturralde-Vinent (2000)	(2) Near Viñales	
Cricosaurus sp.	MNHNCu P3009	Gasparini and Iturralde-Vinent (2001)	(1 to 3) Southern slope of Sierra de Guasasa	This taxa is in need of revision
Cricosaurus sp.	USNM PAL 419640	Gasparini and Iturralde-Vinent (2001)	(1) Puerta de Ancón	Previously assigned to Cryptocleidoid by O'Keefe and Wahl (2003). This taxa is in need of revision
Thalattosuchia indet.	USNM PAL 451942	Gasparini and Iturralde-Vinent (2006)	(14) Hoyo de la Sierra	

FISH

Taxa	Specimen number	References	Locality in figure 1	Annotation
Aspidorhynchus arawaki Brito	USNM PAL 018648	Brito (1997, 1999)	Specific locality of this specimen unknown	
Caturus deani Gregory	AMNH 7930	Gregory (1923)	(2) Near Viñales	This taxa is in need of revision
Eugnathides browni Gregory	AMNH 7937	Gregory (1923)	(9) Mogote La Mina	This taxa is in need of revision
Gyrodus macrophthalmus cubensis Gregory	AMNH 7928	Gregory (1923)	(9) Mogote La Mina	
Hypsocormus leedsi	NMH P.13090		(4) Laguna de Piedra (Sur)	This taxa is in need of revision
Lepidotes gloriae Thies	USNM PAL 279856	Thies (1989)	Specific locality of this specimen unknown, but probably (14) Hoyo de la Sierra	
Leptolepis euspondylus Gregory	AMNH 7939	Gregory (1923)	(9) Mogote La Mina	This taxa is in need of revision
Luisichthys vinalesensis White	MCZ 8345	White (1942), Arratia and Schultze (1985)	Specific locality of this specimen unknown	
Sauropsis woodwardi Gregory	AMNH PAL 7934	Gregory (1923)	(2) Near Viñales	This taxa is in need of revision

important, it is the only occurrence of a well-preserved paddle for Cuban Late Jurassic marine reptiles.

The only marine turtle specimen found in the Cuban Oxfordian was named *Caribemys oxfordiensis* by De la Fuente and Iturralde-Vinent (2001), who recognized its relationships to other pleurodiran turtles from the Late Jurassic. More recently, Cadena-Rueda and Gaffney (2005) recombined the Cuban turtle to *Notoemys oxfordiensis*. De Lapparent de Broin *et al*. (2007), however, keeps *Caribemys oxfordiensis* within the family Notoemydidae.

Marine crocodilians are represented by three specimens (MNHNCu P3009, USNM PAL 451942, 419640). The MNHNCu P3009 specimen was assigned to *Geosaurus* sp. by Gasparini and Iturralde-Vinent (2001), but later transferred to its early synonym *Cricosaurus* (Young and Andrade, 2009). The USNM PAL 419640 specimen was preliminarily identified as plesiosaur (Iturralde-Vinent and Norell, 1996: p. 11), later referred to *Geosaurus* sp. (Gasparini and Iturralde-Vinent, 2001), but can also be related to *Cricosaurus*. Neither of these papers provided a detailed description for the specimen, which is acid prepared and partially melted in the process, loosing important bone features (note that in both papers USNM PAL 419640 was referred to as USNM 18699). On the other hand, O'Keefe and Wahl (2003, fig. 6) provided a brief description but incorrectly interpreted USNM PAL 419640 as an aberrant cryptocleidoid plesiosaur. More recently, Gasparini and Iturralde-Vinent (2006) and Young and Andrade (2009) identified the specimen as an indeterminate metriorhynchine.

Gasparini and Iturralde-Vinent (2001) included a fragmentary skull (MNHNCu P3001) in Metriorhynchidae, but it has subsequently been re-assessed to be an ichthyosaur (Gasparini and Iturralde-Vinent, 2006). This specimen is quite remarkable since not many three-dimensional Late Jurassic ichthyosaurian skulls are known (Z. Gasparini, *personal commun*., 2010). Only MNHNCu P3068 was properly identified as ichthyosaur (Fernández and Iturralde-Vinent 2000), probably an Ophthalmosauridae.

Another fossil misidentified as Ichthyosauridae (*Sphaerodontes caroli* De la Torre y Madrazo and Cuervo, 1939), was a negative spheroidal cast which was later tentatively identified by Iturralde-Vinent and Norell (1996: p. 12) as a ganoid fish tooth. Iturralde-Vinent and Norell (1996: p. 12) also listed a set of four plesiosaurian elements collected by Charles W. Hatten in 1956 from a locality about one kilometer southwest of the town of Viñales, and stored in the Berkeley's Museum of Paleontology, but these specimens are now lost (M. Goodwin, *personal commun*., 2009). According to Furrazola-Bermúdez (*fide* Iturralde-Vinent and Norell 1996), a large carcass of a *Plesiosaur*–like marine reptile was found in Tithonian limestones of the El Americano Member (Guasasa Formation) in the locality named "Hacienda del Americano", but apparently was lost due to quarry exploitation. In 1972, a Tithonian reptilian bone fragment collected in the Niceto Pérez area (Rancho Mundito) was given to Dr. Alfredo de la Torre y Callejas for identification (A. Pszczólkowski, *personal commun*., 2009), but it whereabouts is currently unknown. Furthermore, during the geological mapping carried out in the Pinar del Rio province in the mid-seventies, vertebrate remains were observed in the Tithonian limestones of La Zarza Member of Artemisa Formation, however, because they were incomplete, none of these materials ended in museum's collections (A. Pszczólkowski, *personal commun*., 2009). These findings indicate that the Tithonian strata may also be an important source of fossil marine reptiles that have yet to be properly collected and identified.

Within the collections, flying reptiles (pterosaurs) are represented by two remarkable rhamphorhynchoid specimens: *Nesodactylus hesperius* (AMNH 2000) and *Cacibupteryx caribensis* (IGP-V-208), which is the best preserved Middle-Late Oxfordian pterosaur skull reported so far (Gasparini *et al*., 2004). A third probable pterosaur specimen (MNHNCu P3806) preserved on the surface of a partially eroded concretion was discovered (during a paleontological survey directed by the senior author) at the beginning of 2002. An extremely fragmented pterosaur remains (MNHNCu P3817) was collected from a poorly identified locality in Sierra de los Órganos. A fragment of mandible with long pointed, recurved teeth (MNHNCu P3794) can provisionally be referred to as pterosaur. These fossils collectively indicate a high potential of finding more pterosaur remains in the Oxfordian sediments of the Jagua Formation.

Dinosaur material was not found in any Cuban vertebrate collection, neither discovered during field work performed since 1998. Only Gutiérrez (1981) reported the discovery of two dinosaurian bones from Punta de la Sierra, Pinar del Rio province, but they are lost. Unpublished photographs provided by R. Gutiérrez (*personal commun*., 2010) add no clue, as the suspected bones are not identifiable.

Early in the 20th century a 45-centimeter long bone of a sauropod dinosaur was collected by Carlos de la Torre y Huerta from the Jagua Vieja Member of Jagua Formation. De la Torre y Callejas (1949) described and identified the element as a femur or humerus of '*Diplodocus*' or '*Brontosaurus*' with their "extremes missing". This historical specimen unfortunately got lost, but based on De la Torre y Callejas' description and illustration, L. Salgado (in Gasparini and Iturralde-Vinent, 2006) identified the element as a fairly complete metacarpal bone of a camarasauromorph dinosaur, common in the Late Jurassic of North America.

Oxfordian vertebrate fossils in western Cuba are fairly common in the Jagua Vieja Member of Jagua Formation. While many specimens have been collected from these rocks, some of the fossil-bearing concretions in the museums remain unprepared, so more fossil evidence is sure to be recovered in the future. The Tithonian beds also represent a challenge for further collecting.

CONCLUSIONS

The Late Jurassic rocks in Cuba have produced a reach vertebrate assemblage dominated by actinopterygians and long-necked plesiosaurs. There are also pliosaurs, metriorhynchid crocodilians, pleurodiran turtles, ichthyosaurs, pterosaurs, and sauropod dinosaurs. Fish assemblages include pycnodontiforms, semionotiforms, amiiforms, pachycormiforms, aspidorhynchiforms, pholidophoriforms, and smaller leptolepids. Abundant terrestrial plant remains, yet unidentified, as well as marine invertebrates have been recovered from the same beds. Although the richest reptile-bearing horizons are found within the Oxfordian Jagua Formation, which has produced more than six hundred vertebrate specimens, the unidentified fossil vertebrates encountered in Tithonian strata demonstrate that more collecting is needed within this stratigraphic horizon. Up to the present, the western territory of Cuba is the only place in the Caribbean islands which yields mid-to early-Late Oxfordian and Tithonian vertebrates. Fish are fairly well preserved, but reptilian specimens usually suffered decay and the bones were eventually exposed and dispersed in the sea bottom prior to burial.

The Cuban Late Jurassic vertebrate material is dispersed in paleontological collections of Cuba, Puerto Rico, the United States of America, and England. Many specimens are fossil fragments that were collected in the early 20th century and have only been formally described in the last decade. Today, Cuban Late Jurassic vertebrates are best known, but research must continue, especially in the Tithonian strata.

Advances in our understanding of Late Jurassic fossil-bearing localities in Cuba and the recent improvement of taxa identification are summarized, and a list of specimens is included as Appendix 2.

In summary, the review of the historical collections confirms that: (1) the western Cuban Oxfordian material is of worldwide importance; (2) actinopterygians and marine reptiles prevail in the vertebrate faunal composition; (3) some fossils are preserved in great detail, especially fish and pterosaurs; (4) some fish taxa remain obscure and must be investigated in the future; (4) this assemblage of vertebrate fossils has shed light in understanding the marine fauna circulating across the Late Jurassic Caribbean Seaway; (5) future research is necessary because there is abundant unprepared material in the museums and in the field, pending to be prepared and investigated.

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APPENDIX 1

Annotated list of the known Cuban Late Jurassic collecting sites arranged in the same order that they are numbered in Figure 2. Data included with the list were the location, stratigraphic level and a synopsis of the scientific potential of each site, ranging from sites with multiple findings to those with a single one.

1 **Loc. Puerta del Ancón** (Iturralde-Vinent and Norell, 1996: p. 11).

Location. Sheet Consolación del Sur, coordinates: x 221,100 y 316,000. Jagua Formation. The fossils are from the southern and southwestern slope of the hills.

Vertebrate fauna. This locality has yielded *Luisichthys vinalesensis* (MCZ 8344), indeterminate fish (IGP-V-278), and rhacheosaurin metriorhynchid (USNM PAL 419640).

2 **Loc. "Near Viñales"** (Iturralde-Vinent and Norell, 1996: p. 7).

Location. Ambiguous locality probably referred to the southern slope of Sierra de Guasasa, on the northern flank of the Viñales valley, northeast of the town of Viñales. Jagua Formation.

Vertebrate fauna. Type locality for plesiosaur *Vinialesaurus caroli* (MNHNCu P3008). Other remains include the type material of *Cryptocleidus*? [*sic*] *cuervoi* (De la Torre y Madrazo and Rojas, 1949) which is *nomen dubium*; rhacheosaurin metriorhynchid (MNHNCu P3009), ophthalmosaurian ichthyosaur (MNHNCu P3068) and few plesiosauroids (MNHNCu P3007, 3065, 3066, 3070).

3 **Loc. Laguna de Piedra (Norte)** (Iturralde-Vinent and Norell, 1996: p. 11).

Location. Sheet Consolación del Sur, coordinates: x 222,900 y 316,300. Jagua Formation. This locality corresponds to the southern slope of the Sierra de Guasasa, a few kilometers east of Puerta del Ancón.

Vertebrate fauna. Fossil vertebrates collected here since early 20th century include the unpublished taxa *Cryptocleidus?* [*sic*] *vignalensis* (MNHNCu P3002, 3003), an unidentified ichthyosaur (MNHNCu P3001) designated as the holotype of *Ichthyosaurus torrey* (De la Torre and Cuervo, 1939), and the material designated as the holotype of *Sphaerodontes caroli* (De la Torre and Cuervo, 1939), all of them are *nomen dubium*. Fish remains collected more recently include a tail of probable caturid fish (MNHNCu P2002).

4 **Loc. Laguna de Piedra (Sur)** (Judoley and Furrazola-Bermúdez, 1965; Sánchez-Roig, 1920).

Location. Although this locality is reported as Tithonian in age from the literature, according to J. Gallardo, Jr. (*personal commun.*, 2010) it is probably the unpublished Oxfordian locality known as "La Chorrera", which contains fossil-bearing concretions.

Vertebrate fauna. Caudal fins and disarticulated bones of fish (NMH P.13089, 13090, 13091, 13092) provisionally identified as *Hypsocormus* and labeled as Tithonian in age.

5 **Loc. Mogote la Penitencia**

Location. Sheet Consolación del Sur, coordinates: x 217,500 y 314,000. Described as Jurassic. Jagua Formation (?).

Vertebrate fauna. According to J. Gallardo, Jr. (*personal commun.*, 2010) this locality contains vertebrate fossils, however, only a single record appears in the collections (MCZ 12490).

6 **Loc. Valle los Jazmines**

Location. This is an ambiguous locality. Sheet Consolación del Sur. Described as Oxfordian. Jagua Formation (?).

Vertebrate fauna. It has yielded fish *Caturus* sp. (MCZ 10484, 10485).

7 **Loc. Viñales Town** (Iturralde-Vinent and Norell, 1996: p. 12).

Location. Sheet Consolación del Sur, coordinates: x 220,800 y 310,900. About 1 km SW of the town of Viñales. Jagua Formation.

Vertebrate fauna. Very fragmentary bones of indeterminate plesiosaurs (UCMP 105703, 105704, 105720, 105725). We recently visited this locality and no fossils are currently exposed at this site.

8 **Loc. Hoyo de San Antonio** (Iturralde-Vinent and Norell, 1996: p. 12).

Location. Sheet La Palma, coordinates: x 226,300 y 320,800. The Jagua Formation outcrops in low hills and in the valley.

Vertebrate fauna. Indeterminate pterosauroid (MNHNCu P3806), pliosauroid (MNHNCu P0828) and plesiosaurian bones (MNHNCu P3805, USNM PAL 18688, 18721), cryptoclidid mandible (MNHNCu P3806), and Ichthyosauria indet. (MNHNCu P3808). Source of abundant and diverse fish fauna: *Gyrodus macrophthalmus cubensis* (MCZ 6639, 6640), *Gyrodus* sp. (MCZ 10377, 10389, 10390, 10416), *Caturus deani* (MCZ 6641, 8352), *Caturus* sp. (MCZ 10394, and other 16 MCZ specimens), *Hypsocormus* sp. (MCZ 10247, 10248, 10250, 10238), *Lepidotes* sp. (MCZ 10300, 10301, 10302, 10303), cf. *Pachycormidae* indet. (MNHNCu P3922), and several unidentified fish specimens (e.g. MNHNCu P0796, 0810, 0814, 0828, 0838, 1971, 3125, 3794, 3796, 3798, 3799, 3800, 3801, 3804, 3805, 3806, 3819, 3820, 3824, 3825, 3826, 3829, 3831, 3833, 3834, 3839, 3840, 3842, 3843, 3844, 3845, 3846, 3847, 3848, 3850, 3852, 3853, 3855, 3870, 3904, 3921, 3922, 5082, 5103, 5297, 5108, 5162). Type locality for turtle *Caribemys oxfordiensis* (MNHNCu P3125). We recently visited this locality with Juan Gallardo, Jr., and still is rich in fossil-bearing concretions.

9 **Loc. Mogote La Mina** (Iturralde-Vinent and Norell, 1996: p. 14).

Location. Represented by the south slope of Mogote La Mina, located just south of the old copper mine. The mine itself is not a fossil-bearing site as no Oxfordian sediments are present. Sheet La Palma, coordinates: x 226,300 y 320,800. Jagua Formation.

Vertebrate fauna. This locality has yielded *Gyrodus macrophthalmus* (AMNH 7927), *Leptolepis? euspondylus* (AMNH 7939), *Eugnathides browni* (IGP-V-291) and marine reptiles (Brown and O'Connell, 1922).

10 **Loc. Jagua Vieja** (Iturralde-Vinent and Norell, 1996: p. 12). This is the Cuban richest Late Jurassic vertebrate locality.

Location. Sheet La Palma, coordinates: x 228,800 y 320,900. Jagua Formation. Slopes of mogote Jagua Vieja.

Vertebrate fauna. Type locality for pterosaur *Cacibupteryx caribensis* (IGP-V-208). One of few pterosaur localities in western Cuba. Also, historically important site as it has yielded a sauropod bone (De la Torre y Callejas, 1949). Some plesiosaurian remains (IGP-V-209, 210, 211, 258, 259) and other indeterminate reptilian bones (IGP-V-212, 213). Diverse fish fauna including *Gyrodus macrophthalmus cubensis* (MCZ 6638, 6646, 6647, 6648), *Gyrodus* sp. (MCZ 10380, and other MCZ specimens), *Gyrodus* cf. *macrophthalmus cubensis* (MNHNCu P2111, 2112, 3857, IGP-V-280), *Eugnathides browni* (MCZ 6649), *Caturus deani* (MCZ 6637, 6642, 6643, 6644, 6645, 6500), *Caturus* sp. (MCZ 10492, and other MCZ specimens), *Hypsocormus leedsi* (MCZ 7023, 7024, 7024), *Hypsocormus* sp. (MCZ 10229, and other MCZ specimens), *Lepidotes* sp. (MNHNCu P5074, MCZ 10290, and other MCZ specimens), *Luisichthys vinalesensis* (MCZ 8345, 8346, 8347, 8348), cf. *Luisichthys vinalesensis* (MNHNCu P0821, 2116), leptolepid (IGP-V-283) and Pycnodontiformes indet. (MNHNCu P5078). Numerous unidentified fish specimens (*e.g.* MNHNCu P0834, 2123, 3807, 3818, 3823, 3838, 3856, 3863, 3864, 3877, 3878, 3886, 3892, 5069, 5080, 5085, 5091, IGP-V-243, 244, 245, 251, 268, 269, 270, 271, 272, 275, 276, 277, 279, 284, 285, 286, 287, 292).

11 **Loc. Hacienda El Americano** (Iturralde-Vinent and Norell, 1996: p. 14).

Location: Sheet La Palma, coordinates: x 240,300 y 321,400. Outcrops of the Tithonian El Americano Member of Guasasa Formation are found north and northeast of the "bungalow".

Vertebrate fauna: Skull and fragmentary skeleton of a marine reptile destroyed during mining operation (Furrazola-Bermúdez in Gasparini and Iturralde-Vinent, 2006). Scattered fish imprints and vertebrae (Pszczólkowski and Myczyński, 2010).

12 **Loc. Mogote Pico Chico**

Location. Sheet La Palma, coordinates: x 342,400 y 321,300. Described as Oxfordian "Camada de Quesso" [*sic*]. Jagua Vieja Member of the Jagua Formation (?).

Vertebrate fauna. This locality has yielded *Gyrodus* sp. (MCZ 10417, 10418, 10425, 10426), *Hypsocormus* sp. (MCZ 10243), *Hypsocormus leedsi* (MCZ 7013, 7014, 7015, 7016), and *Caturus deani* (MCZ 8329).

13 **Loc. Hoyo del Palmar** (Iturralde-Vinent and Norell, 1996: p. 13).

Location. Sheet La Palma, coordinates: x 227,800 y 321,000. The Jagua Formation outcrops on the slopes of a small valley.

Vertebrate fauna. The locality was visited by Iturralde-Vinent and Norell (1996: p. 13) and very fragmentary bones of marine reptiles were observed. Furthermore, because it is the probable source of the pterosaur *Nesodactylus hesperius* (AMNH 2000), this is an important paleontological site. Vertebrate fauna also include the reptiles (MNHNCu P3883), cf. *Luisichthys vinalesensis* (MNHNCu P2102), *Gyrodus* cf. *Gyrodus macrophthalmus cubensis* (MNHNCu P2104, 2107), and other indeterminate forms (MNHNCu P2103, 2124, 2125, 2129, 3883, 5044, 5084).

14 **Loc. Hoyo de la Sierra** (Iturralde-Vinent and Norell, 1996: p. 13).

Location. Sheet Herradura, coordinates: x 243,550 y 316,800. The locality is along the slope surrounding the small valley. Jagua Formation.

Vertebrate fauna. Plesiosaur mandible (MNHNCu P3069), indeterminate plesiosaurian bones (USNM PAL 18712) and several fish (MNHNCu P3872, 3884, 5073, 5075, 5076, 5077, 5083, 3067, 3907, 5307, 5308), *Gyrodus* cf. *Gyrodus macrophthalmus cubensis* (MNHNCu P5070, 5071, 5079, 5081).

15 **Loc. Caiguanabo** (Iturralde-Vinent and Norell, 1996: p. 12).

Location. Sheet Herradura, coordinates: x 244,200 y 316,900. Northern slope of the Sierra de Caiguanabo. Jagua Formation.

Vertebrate fauna. Type locality for pliosaur *Gallardosaurus iturraldei* (MNHNCu P3005). Abundant isolated indeterminate reptile bones (IGP-V-252, 254, 255, 256, 257, 264). Plesiosaur femur (MNHNCu P3004) and plesiosaur remains identified as *Cryptocleidus*? [*sic*] (IGP-V-248). Fish remains identified as *Gyrodus* cf. *Gyrodus macrophthalmus cubensis* (MNHNCu P2091, 2093, 2094), *Gyrodus macrophthalmus* (IGP-V-242) and *Lepidotes* sp. (MNHNCu P2122). Several unidentified fish specimens (*e.g.* MNHNCu P2090, 2092, 2099, 2100, 2101, 2106, 2113, 2117, 2120, 5104, IGP-V-246, 281).

16 **Loc. Niceto Pérez (Rancho Mundito)** (A. Pszczólkowski, *personal commun.*, 2009).

Location. Sheet San Cristobal, coordinates: x 370,500 y 324,500. Black Tithonian limestones of La Zarza Member, Artemisa Formation.

Vertebrate fauna. An unidentified reptilian bone fragment now lost.

17 **Loc. Rangel Arriba**

Location. Sheet San Cristobal, coordinates: x 275,600 y 326,500. Described as Jurassic. Jagua Formation (?).

Vertebrate fauna. Only a single unidentified record appears in collections (MCZ 12487).

18 **Loc. Puerta de la Muralla** (Iturralde-Vinent and Norell, 1996: p. 15).

Location. Sheet San Cristobal, coordinates: x 284,600 y 325,300. Outcrops of the Late Oxfordian to Lower Cretaceous Artemisa Formation. Sierra del Rosario, NW of San Cristobal, along the road known as "Camino de Cinco Pesos".

Vertebrate fauna. This site yielded a fragmentary plesiosaur limb girdle (MNHNCu P3006) and plesiosaurian bone (IGP-V-263).

19 **Loc. "No 2 near Cinco Pesos"** (Kutek *et al.*, 1976: p. 301).

Location. Coordinates: x 282,550 y 328,650. Francisco Formation.

Vertebrate fauna. Fish remains are frequently noted at this locality in the stratigraphic description of the Francisco Formation (Kutek *et al.*, 1976; Pszczólkowski, 1978, 1999), but no taxa have thus far been identified.

20 **Loc. "1 km N of Cinco Pesos"** (Kutek *et al.*, 1976: p. 303).

Location. Coordinates: x 282,100 y 328,800. Francisco Formation. The exposure is situated in the NE escarpment of the road, 500 m W of the locality No 2.

Vertebrate fauna. The limestones yield badly preserved ammonites, as well as fish fragments.

21 **Loc. Punta de la Sierra** (Iturralde-Vinent and Norell, 1996: p. 14).

Location. Sheet San Juán y Martínez, coordinates: x 191,500 y 280,000. Jagua Formation. Isolated blocks of limestone in a small river.

Vertebrate fauna. Two alleged "large reptilian bone fragments", now lost (Gutiérrez, 1981), probably epidiagenetic siliceous aggregates.

22 **Loc. "Finca Grau, near La Palma"** (Iturralde-Vinent and Norell, 1996: p. 15).
Location. Precise locality unknown. Described as Jagua Formation.

Vertebrate fauna. Indeterminate plesiosaurian bones (USNM PAL 18697).

23 **Loc. "Vega Nueva"** (E. Linares, *personal commun.*, 2013).

Location. Vega Nueva quarry, west of La Palma. Artemisa Formation.

Vertebrate fauna. A single fossil fish specimen about 20 centimeters long with very well preserved vertebrae.

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