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.

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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

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

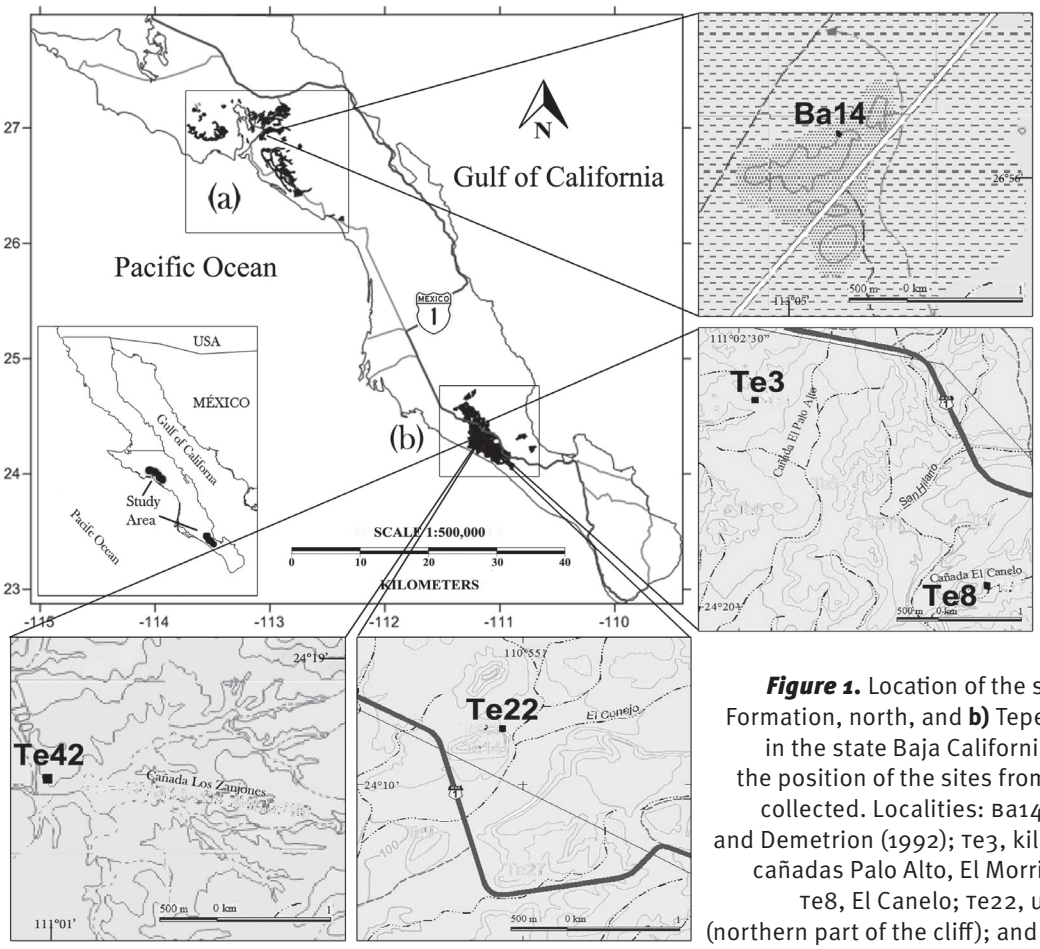

Figure 1. Location of the study areas: **a)** Bateque Formation, north, and **b)** Tepetate Formation, south, in the state Baja California Sur, México, showing the position of the sites from which echinoids were collected. Localities: Ba14, locality 1219, Squires and Demetrion (1992); Te3, kilometer 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

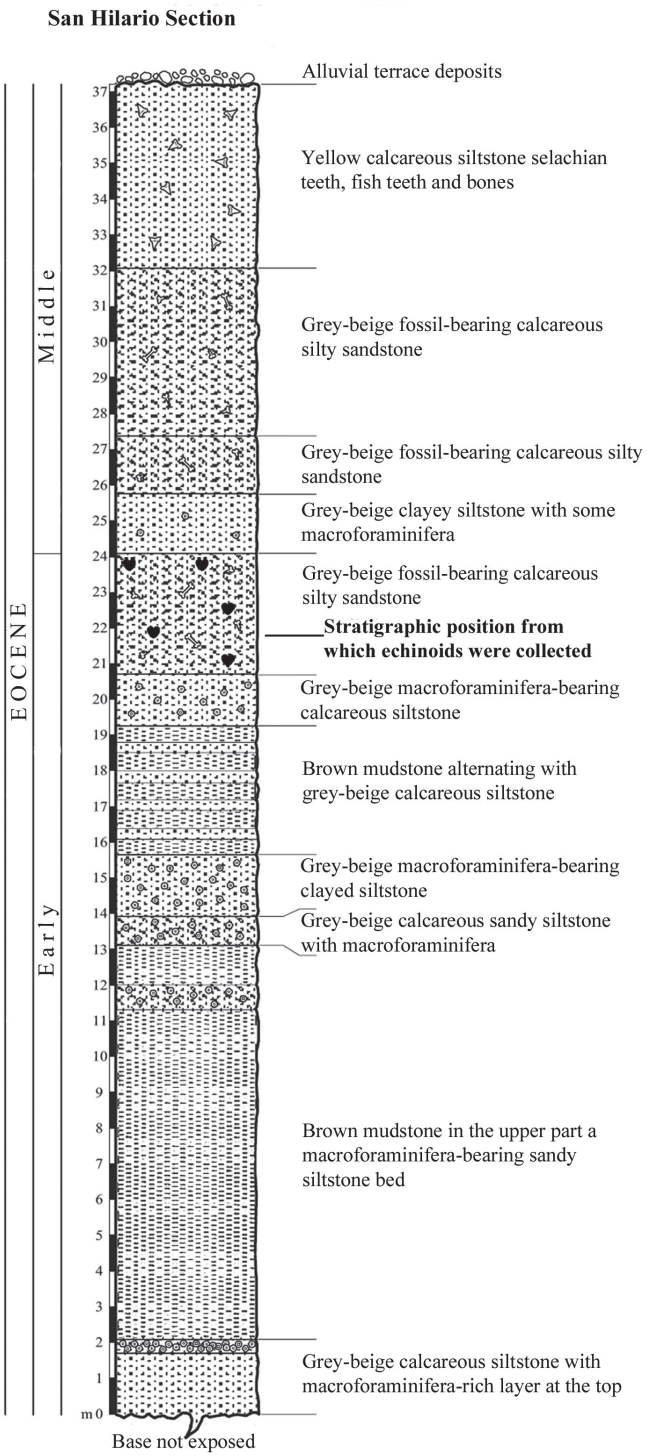

Figure 2. Composite stratigraphic section of the San Hilario locality (modified section of Schweitzer *et al.*, 2002) of the Tepetate Formation showing the stratigraphic position from which echinoids were collected.

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,

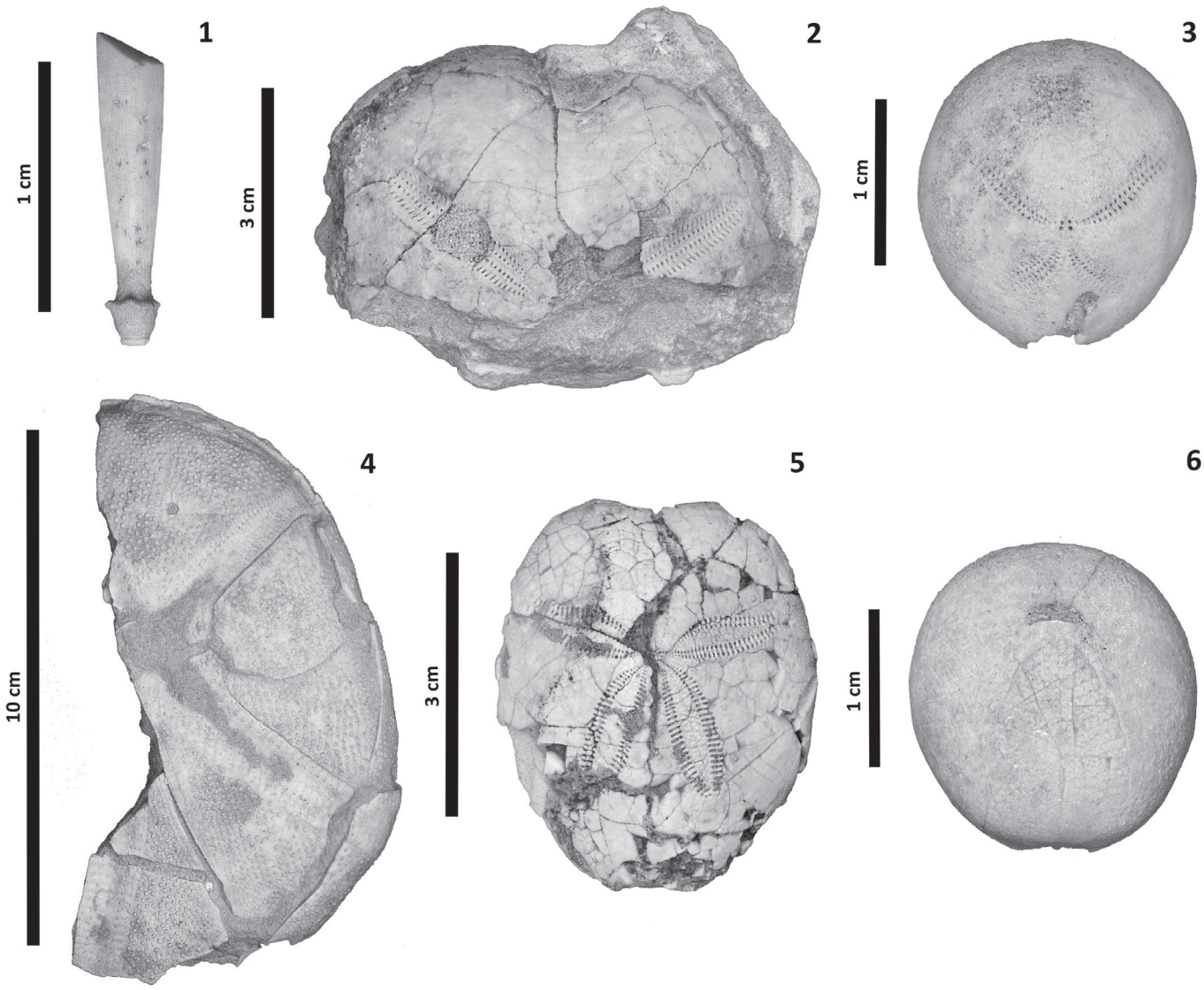

***Figure 3*. 1)** Cidaroida?, indet. spine D, MHN-UABCS Ba14/33/46, frontal view; **2)** *Pericosmus?* sp., MHN-UABCS Te8/74/921, aboral view; **3** and **6**, *Agassizia* sp., MHN-UABCS Te42/95/330: **3)** aboral view; **6)** oral view; **4)** *Asterostoma* sp., MHN-UABCS Te8/9b/257, oral view; **5)**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

Agassiz, A., 1904, The Panamic Deep Sea Echini: Memoirs of the Museum of Comparative Zoölogy at Harvard College, 31, ix, 1–243.

Agassiz, L., 1840a, Catalogus systematicus Ectyporum Echinodermatum fossilium Musei Neocomiensis, secundum ordinem zoologicum dispositus; adjectis synonymis recentioribus, nec non stratis et locis in quibus reperiuntur. Sequuntur characters diagnostici generum novorum vel minus cognitorum: Petitpierre, Neuchatel, 20 pp.

Agassiz, L., Desor, P. J. E., 1846–1847, Catalogue raisonnè des familles, des genres, et des espèces de la classe des èchinodermes: Annales des Sciences Naturelles, Troisième Série, Zoologie, 6 (1846), 305–374, pls. 15–16; 7 (1847), 129–168; 8 (1847), 5–35, 355–380.

Alvarado, J. J., Zeledón, L. A., Boyd, R., 2006, Notas sobre equinodermos fósiles de Costa Rica: Revista de Biología Tropical (San José), 54 (Suppl. 1), 287–299.

Arnold, B. W., Clark, H. L., 1927, Jamaican Fossil Echini. With descriptions of new species of Cainozoic Echinoidea: Memories of the Museo of Comparative Zoölogy, Cambridge, United States of America, 1 (1), 1–84 p., 22 pls.

Buitrón, B. E., Silva-Sánchez, B., 1979, Dos especies de Equinoides (Echinodermata – Echinoidea) del Eoceno Tardío de Tantoyuca, Veracruz: Universidad Nacional Autónoma de México, Instituto de Geología, Revista, 3 (2),122–125.

Cooke, W., 1959, Cenozoic Echinoids of Eastern United States, United States Geological Survey: Professional Paper, 321, 1–106 p., 43 pls.

Coppard, S. E., 2008, A comparative analysis of the spatangoid echinoid genera *Brissopsis* and *Metalia*: a new genus and species of spatangoid (Echinodermata: Echinoidea: Brissopsidae) from the Philippines and reassignment of *Brissopsis persica* to *Metalia*: Zootaxa, 1760, 1–23.

Claus, C. F.W., 1880, Grundzüge der Zoologie, 4th edition: Elwertsche N. G., Universitätsbuchhandlung, Marburg and Leipzig, 1, vii, 821 p., 2, iv, 522 p.

Donovan, S. K., 1988, A Preliminary Biostratigraphy of the Jamaican Fossil Echinoidea, *in* Burke, R. D., P. V. Mladenov, P. Lampert and R. L. Parsley (eds.), Echinoderm Biology: Proceedings of the Sixth International Echinoderm Conference, Victoria Rotterdam, 23–28, 125–131

Fletcher, J. M., Grove, M., Kimbrough, D., Lovera, O., Gehrels, G. E., 2007, Ridge-trench interactions and the Neogene tectonic evolution of the Magdalena shelf and southern Gulf of California: Insights from detrital zircon U-Pb ages from the Magdalena fan and adjacent areas: Geological Society of America Bulletin, 119 (11/12), 1313–1336.

Flynn, J. J., 1989, Chronology of early Eocene marine and terrestrial strata, Baja California, México: Geological Society of America Memoir Bulletin, 101, 1182–1196.

Gastil. R. G., Morgan, G., Krummenacher, D., 1981, The tectonic history of peninsular California and adjacent México, *in* Ernst, W. G. (ed.), The geotectonic development of California, Rubey Volume I: Englewood Cliffs, New Jersey, Practice-Hall, 284–306.

González-Barba, G., 2003, Descripción de asociaciones faunísticas de elasmobranquios fósiles del Eoceno Superior (Priaboniano) de las Formaciones Tepetate y Bateque de Baja California Sur, México: Baja California Sur, México, Instituto Politécnico Nacional, CICIMAR-IPN, Tesis de Maestría, 243 pp.

González-Barba, G., Schwennicke, T., Goedert, J. L., Barnes, G., 2002, Earliest Pacific Basin record of the Pelagornithidae (Aves: Pelecaniformes): Journal of Vertebrate Paleontology, 22(3), 722–725.

Grant, U. S. I., Hertlein, L. G., 1938, The West American Cenozoic Echinoidea: Publications of the University of California at Los Angeles in Mathematical and Physical Sciences, 2, 1–225.

Gray, J. E., 1855, Catalogue of the Recent Echinida, or Sea Eggs, in the Collection of the British Museum, Part I, Echinida Irregularia: Woodfall and Kinder, London, 69 pp.

Kier, P. M. 1972. Tertiary and Mesozoic Echinoids of Saudi Arabia: Smithsonian Contributions to Paleobiology, 10, 242 p.

Kier, P. M. 1980. The echinoids of the Middle Eocene Warley Hill Formation, Santee Limestone and Castle Hayne Limestone of North and South Carolina: Smithsonian Contributions to Paleobiology, 39, 102 p.

Kier, P. M. 1984. Fossil Spantangoid Echinoids of Cuba: Smithsonian Institution Press. Washington, 336 p.

Kier, P. M., Lawson, M. H., 1978, Index of living and fossil echinoids 1924–1979: Smithsonian Contributions to Paleobiology, 34, 1–182.

Kroh, A., 2005, Catalogus fossilium Austriae: Ein systematisches Verzeichnis aller auf österreichischem Gebiet festgestellten Fossilien; Volumen 2, Echinoidea Neogenica, *in* Piller, W. E., (ed.), Verlag der Österreichischen Akademie der Wissenschaften, Wien, LVI, 210 p., 82 pls.

Kroh, A. 2010. Index of Living and Fossil Echinoids 1971–2008: Annalen des Naturhistorischen Museums in Wien, Serie A 112, 195–470.

Kroh, A., Smith. A. B., 2010, The phylogeny and classification of post-Palaeozoic echinoids: Journal of Systematic Palaeontology, 8 (2), 147–212.

Lambert, J., 1905, Notes sur quelques Èchinides èocéniques de l'Aude et de l'Hèrault, pp. 129–164, *in* L. Doncieux (ed.) Catalogue descriptif des fossiles nummulitiques de l'Aude et de l'H´erault: Annales de l'Université de Lyon, Nouvelle Série, I. Sciences, Médecine, 17, 129–164.

Leske, N. G., 1778, Jacobi Theodori Klein naturalis dispositio echinodermatum, edita et descriptionibus novisque inventis et synonomis auctorem aucta: Addimenta ad I. T. Klein naturalem dispositionem Echinodermatum, G. E. Beer, Leipzig, xxii, 278 pp.

Markov, A. V., Solovjev, A. N., 2001, Echinoids

of the family Paleopneustidae (Echinoidea, Spatangoida), morphology, taxonomy, phylogeny: Geos – Trudy Paleontologicheskogo Instituta, Rossikaia Akademia Nauk, Russian, 280, 1–108 pp.

Morales-Ortega, P., 2010, Registro de las asociaciones faunísticas de invertebrados en la Formación Tepetate (Paleoceno-Eoceno) en Baja California Sur, México: Baja California Sur, México, Tesis de Licenciatura en Biología Marina Universidad Autónoma de Baja California Sur, 125 pp.

Morales-Ortega, P., 2012, Correlación paleontológica de macroinvertebrados en las formaciones Tepetate y Bateque (Paleoceno – Eoceno) en Baja California Sur, México: Baja California Sur, México, Instituto Politécnico Nacional, CICIMAR-IPN, Tesis de Maestría, 148 pp.

NHM–Natural History Museum, London, United Kingdom, 2013, *in* Natural History Museum <http://www.nhm.ac.uk>, date of consultation: december 2013.

Pictet, F. J. 1857. Traité élémentaire de Paléontologie ou Histoire Naturelle des Animaux Fossiles considérés dans leurs rapports zoologiques et géologiques, Seconde Édition. Tome 4: J.-B. Baillière et Fils, Paris, xvi, 768 pp.

Plattner, C., Malservisi, R., Govers, R., 2009, On the plate boundary forces that drive and resist Baja California motion: Geology, 37 (4), 359–362.

Ruppert, E. E., Barnes, R. D., 1996, Zoología de los Invertebrados: McGraw-Hill Interamericana, México, 1114 pp.

Schwennicke T., Cortés-Martínez, M., Rickli, J., Plata-Hernández, E., Estrada-Moreno, E., 2004, Ambientes de depósito contrastantes en la Formación Tepetate, Baja California Sur, México: GEOS, 24 (2), 215–226.

Smith, A. B., 1984, Echinoid Palaeobiology: Allen and Unwin, London, x, 190 pp.

Squires, R. L., 1992, Eocene Mollusks from the Tepetate Formation, Baja California Sur, México: American Conchologist, 10–11 pp.

Squires, R. L., 2001, Additions to the Eocene Megafossil Fauna of the Llajas Formation, Simi Valley, Southern California: Contributions in Science, Natural History Museum, Los Angeles County, 489, 1–40.

Squires, R. L., Demetrion, R. A., 1992, Paleontology of the Eocene Bateque Formation, Baja California Sur, México: Contributions in Science, Natural History Museum, Los Angeles County, 434, 1–55.

Squires, R. L., Demetrion, R. A., 1994b, A New Species of the Oligopygoid Echinoid Haimea from the Lower Eocene of the Baja California Sur, México: Journal of Paleontology, 68 (4), 846–851.

Squires, R. L., Demetrion, R. A., 1995, A New Genus of Cassiduloid Echinoid from the Lower Eocene of the Pacific Coast of Western North America and a New Report of *Cassidulus ellipticus* Kew, 1920, from the Lower Eocene of Baja California Sur, Mexico, Journal of Paleontology, 69 (3), 509–515.

Stockley, B., Smith, A. B., Littlewood, T., Lessios, H. A., MacKenzie-Dodds, J. A., 2005, Phylogenetic relationships of spatangoid sea urchins (Echinoidea), taxon sampling density and congruence between morphological and molecular estimates: Zoologica Scripta, 34, 447–468.