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## Fossil echinoderms of Mexico - An overview of the National Collection of Paleontology “Maria del Carmen Perrilliat”, Institute of Geology, UNAM (Mexico)

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1           **Fossil Echinoderms of Mexico - An overview of the National Collection of**  
2           **Paleontology “Maria del Carmen Perrilliat”, Institute of Geology, UNAM (Mexico).**

3

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14

1 **ABSTRACT**

2 The National Paleontology Collection is the most important paleontological collection in  
3 Mexico due to the relevance of its specimens, curation, and service to the scientific  
4 community; and requires a taxonomic update. This work is based on the revision of the  
5 echinoderms deposited into the Collection of Types of the National Collection of  
6 Paleontology. We obtained the echinoderm database of the National Paleontology  
7 Collection, being collated with the specimens and their labels. All these specimens are  
8 included with their catalog number, taxonomy, localities, and geological age. The  
9 nomenclature and taxonomy of each species were revised based on the most recent  
10 references. The geological information (nomenclature, age, or unit) was derived from the  
11 original publications, updated, and complimented with more recently published data, in  
12 congruence with the Stratigraphic Lexicon of Mexico. The CNP houses a total of 385  
13 records classified in 107 species: 19 Crinoidea, 1 Asteroidea, 1 Ophiuroidea, 84  
14 Echinoidea, and 2 Holothuroidea; 27 changes in their taxonomy were done. The  
15 echinoderm records come from 69 localities, 52 assigned to 31 formations/units across the  
16 country, and 17 not assigned yet. The Cretaceous is the best represented period with 14  
17 formations/units and 6 localities. San Juan Raya (Puebla) is the most diverse formation  
18 with 12 species of Echinoidea; The Tlayúa formation (Puebla), due to its excellent quality o  
19 preservation, is the only one with fossil ophiuroid and holothuroid species reported in  
20 Mexico. This paper is the beginning of a series of publications focused on the analysis of  
21 the systematics, paleodiversity, past ecosystem structures, and paleobiogeography of the  
22 Mexican fossil echinoderms and applying novel approaches.

23

24 Keywords: Echinodermata; Alpha Diversity; Taxonomy; Heritage; Cretaceous.

## 1 **1. Introduction**

2 The National Paleontology Collection (Colección Nacional de Paleontología, CNP) is  
3 the most important scientific collection of fossils in Mexico, due to its history, the  
4 relevance of the fossils and information it protects, as well as the services that it provides to  
5 the scientific, economic, and social development of this country (Perrilliat et al., 1986;  
6 Cristin and Perrilliat, 2011; Alvarado-Ortega, 2021).

7 The creation of a paleontological collection in Mexico did not originate in an explicit  
8 act; rather, this arises as a natural and necessary consequence to fulfill the tasks entrusted to  
9 the Geological Commission (the first Mexican institution dedicated to the recognition of  
10 geological resources in Mexico), explicit in a presidential decree dated in 1988 by President  
11 Porfirio Díaz. This fact allowed the beginning of the systematic study of fossil resources in  
12 Mexico, and the establishment of a national institution in charge of the protection,  
13 conservation, and administration of the fossils and their associated data. Between 1917 and  
14 1929, this institution became part of the Departamento de Exploraciones y Estudios  
15 Geológicos of the Secretaria de Industria, Comercio y Trabajo, under the name of the  
16 Instituto de Geología, which in 1929 was incorporated into the National Autonomous  
17 University of Mexico (UNAM). Since that moment, this university became the depository  
18 of the most important paleontological collection in the country and the institution with the  
19 largest and most diverse group of paleontologists. Between 1978 and 1979, the Department  
20 of Paleontology of the Instituto de Geología (IGL-UNAM) issued the first regulation to  
21 incorporate, house, conserve and administer the fossils. The current and historical  
22 "national" relevance of the fossils deposited in the IGL-UNAM was recognized in 2004, by  
23 the rector Juan Ramón de la Fuente Ramírez, who named this as the Colección Nacional de  
24 Paleontología.

1       Currently, the CNP is located in the Institute of Geology, of the National Autonomous  
2 University of Mexico (UNAM), Mexico City, and consists of five sections: 1) The Type  
3 Collection (Colección de Tipos) that includes specimens belonging to specific type series as  
4 well as voucher specimens identified as hypotypes. 2) The Reference Geographical  
5 Collection (Colección Geográfica de Referencia) includes not studied or are not yet  
6 formally published specimens. 3) The Foreign Materials Collection (Colección de  
7 Materiales Extranjeros) contains fossils from other countries with comparative purposes. 4)  
8 The Recent Material Collection (Colección de Materiales Recientes) is a collection of the  
9 skeleton and hard parts of living species used for comparative purposes. 5) Molds  
10 Collection (Colección de Moldes) includes casts and molds made in plaster or resin of  
11 specimens that are part of the other CNP sections.

12       The National Paleontology Collection is currently the most representative of Mexico.  
13 Historically, this includes some of the first specimens from the country described as well as  
14 specimens of practically all its localities and geological sequences where echinoderms have  
15 been collected. Contrary, other young Paleontological Collections of Mexico include fossils  
16 of a regional and temporally limited domain; many of which are also already part of the  
17 National Collection of Paleontology. A direct comparison between the number and status of  
18 specimens deposited in the CNP, and other Paleontological Collections in Mexico is not  
19 possible at the moment, because the size and quality of the lasts have not been the subject  
20 of any accurate analysis, with restricted access, and have no open-access databases.

21       The scientific study of the Mexican echinoderms only started in the 18th century, when  
22 Nyst and Galeotti (1839) reported the mollusks and echinoderms from San Juan Raya,  
23 Puebla. During the 1900s, numerous fossils of echinoderms, mainly crinoids, and  
24 echinoids, were reported and their taxonomical and field data were organized into different

1 catalogs (Caso,1951; Maldonado-Koerdell, 1953; Buitrón-Sánchez, 1968; Buitrón-Sánchez,  
2 1990a).

3 At the end of the 20th century, Buitrón-Sánchez and Solís-Marín (1993) published the  
4 last review of fossil and recent Mexican echinoderms revealing that the fossil record of this  
5 country includes 15 species of Crinoidea (10 Carboniferous, 1 Permian, 2 Jurassic, 2  
6 Cretaceous), 1 species of Asteroidea (*Astropecten* sp. Cretaceous), 1 species of Ophiuroidea  
7 (?*Ophiura* sp. Cretaceous), 217 species of Echinoidea (2 Jurassic, 88 Cretaceous, 117  
8 Tertiary, and 1 Quaternary), and 2 species of Holothuroidea (?*Holothuria* sp. and ?*Caudina*  
9 sp., both from the Cretaceous of Puebla). This report enlists the species and only gives the  
10 age and the states of Mexico where the specimens were found; no information about  
11 localities or catalog numbers is included.

12 Solís-Marín et al. (2013) revised the echinoderms of Mexico, including a mention of the  
13 fossil record. They mention a total of 248 species: 1 Eocrinoidea, 17 Crinoidea, 1  
14 Asteroidea (*Pentasteria* sp.), 6 Ophiuroidea (*Ophiactis applegatei*; *Ophiura* sp.; aff.  
15 *Amphiura*, aff. *Ophiomusium*; aff. *Stegophiura*, and aff. *Ophiura*), 221 Echinoidea, and 2  
16 Holothuroidea.

17 All the echinoderm fossil record from Mexico needs a revision and update. We can  
18 notice inconsistencies between those papers, and a lack of information in those revisions.  
19 The CNP is the largest, the best curated, and the only one open-access collection in the  
20 country; nevertheless, it constantly offers service to national and international researchers,  
21 giving access and preparing loans of the material, which inevitably results in not all the  
22 material being physically in the collection, and available for the users. Besides, during the  
23 history of the collection, not all the published catalog numbers were deposited; that is why  
24 the need to physically corroborate the databases with specimens and their labels.

1 This work is based on the revision of the described and referred echinoderms deposited  
2 into the Collection of Types of the National Collection of Paleontology. Data and images of  
3 the Mexican fossil echinoderm deposited in the CNP were accessed through the different  
4 bibliographic studies here referenced as well as the public information and images exposed  
5 in two different web pages. The first of these websites is  
6 <https://datosabiertos.unam.mx/biodiversidad/> (Departamento de Paleontología, Instituto de  
7 Geología, 2020), supported by the Coordination of Digital University Collections (CCUD),  
8 whose main objective is to develop and implement technologies, methodologies, and legal  
9 regulations for university digital repositories that guarantee the online publication of digital  
10 university collections, and research data that are owned or are under the custody of the  
11 UNAM, promoting interoperability, open access and its preservation (Dirección General de  
12 Repositorios Universitarios, 2021). The second electronic site corresponds to Unidad  
13 Informática para la Paleontología (UNIPALEO), in  
14 <http://www.unipaleo.unam.mx/index.php>. UNIPALEO is the Informatics Unit developed  
15 by the Institute of Geology (UNAM). This unit provides the information contained in the  
16 paleontological collections under the protection of the IGL; UNIPALEO aims to  
17 systematize and publish the information found in various paleontological collections of the  
18 Institute of Geology (Instituto de Geología, 2021).

19

## 20 **2. Materials and methods**

21 We obtained the echinoderm database of the National Paleontology Collection (CNP)  
22 from the published databases UNIPALEO y CCUD and the catalog of the type specimens  
23 of fossil invertebrates of the CNP (Perrilliat, 1981). This database was collated with the

1 specimens housed in the CNP and their labels. All these specimens are included with their  
2 catalog number (IGM), taxonomy, localities (IGM-loc), and geological age.

3 The nomenclature and taxonomy of each species were revised based on most recent  
4 references: Moore and Jeffords (1968) for Crinoidea; Gale (2005) for Asteroidea; O'Hara et  
5 al. (2017) for Ophiuroidea; Miller et al. (2017) for Holothuroidea, Kroh and Smith (2010)  
6 for Echinoidea at order and family levels, for genera and species levels we based on Kroh  
7 and Mooi (2019). The publication by Moore and Jeffords (1968) is based on the  
8 parataxonomy of dissociated parts of crinoid columns, therefore all the species there  
9 described have to be considered as form-species.

10 The geological information (nomenclature, age, or unit) was derived from the original  
11 publications, updated, and complimented with more recently published data, in congruence  
12 with the Stratigraphic Lexicon of Mexico (Servicio Geológico Mexicano, 2020) was  
13 verified. The map was created with QGIS software version 3.12 (QGIS Development  
14 Team, 2018).

15

### 16 **3. Results**

17 The CNP houses a total of 385 records classified in 107 species (19 Crinoidea, 1  
18 Asteroidea, 1 Ophiuroidea, 84 Echinoidea, and 2 Holothuroidea). Here we present the  
19 systematic paleontology of the records. † is for extinct taxa. Any incongruence with the  
20 CNP-UNAM online database found during the process was included as comments to the  
21 corresponding species. We also include the Geological context of Mexican echinoderms,  
22 giving the geological description for each of the 31 Formations and units here reported; this  
23 part is presented in alphabetic order. A table with all the records data organized by  
24 formation/unit is attached as supplementary material.



1

2 *3.1. Systematic Paleontology*

3 PHYLUM Echinodermata Bruguière, 1791

4 CLASS Crinoidea Miller, 1821

5 SUBCLASS Articulata Miller, 1821

6 ORDER Millericrinida† Sieverts-Doreck, 1952

7 FAMILY Millericrinidae† Jaekel, 1918

8 Genus *Angulocrinus*† d'Orbigny, 1840

9 *Angulocrinus polyclonus*† (Felix, 1891)

10 Vouchers. IGM 5214-IGM 5223 (Buitrón-Sánchez, 1990b).

11 Localities and age IGM-loc 1899; Tecomazuchil creek, Puebla; geological formation

12 indeterminate; Oxfordian, Late Jurassic. IGM-loc 1671; Road Guadalupe Hidalgo-

13 Tlaxiaco, Oaxaca; geological formation indeterminate; Oxfordian, Late Jurassic.

14 ORDER *Incertae sedis*

15 FAMILY Pentacauliscidae† Moore and Jeffords, 1968

16 Comments. The family is classified in the database within the informal group Pentameri.

17 Genus *Pentagonomischus*† Moore and Jeffords, 1968

18 *Pentagonomischus plebeius*† Moore and Jeffords, 1968

19 Voucher. IGM 4868 (Villanueva-Olea et al., 2016).

20 Locality and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;

21 Pennsylvanian, Carboniferous.

22 FAMILY Cyclomischidae† Moore and Jeffords, 1968

23 Comments. The family is classified in the database within the informal group Cyclici.

24 Genus *Axilinucrinus*† Villanueva-Olea and Sour-Tovar, 2011

1 *Axilinucrinus angustus*† Villanueva-Olea, Castillo-Espinoza, Sour-Tovar, Quiroz-Barroso  
2 and Buitrón-Sánchez, 2011  
3 Voucher. IGM 4869 (Villanueva-Olea et al., 2016).  
4 Locality and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco formation;  
5 Pennsylvanian, Carboniferous.  
6 Genus *Cylindrocauliscus*† Moore and Jeffords, 1968  
7 *Cylindrocauliscus fiski*† Moore and Jeffords, 1968  
8 Vouchers. IGM 2695 (Buitrón-Sánchez, 1977); IGM 4335 (Buitrón-Sánchez et al., 1987);  
9 IGM 4863 (Buitrón-Sánchez et al., 2017).  
10 Localities and age. IGM-loc 3157; Aguacate river, between La Concordia and  
11 Chicomuselo, Chiapas; Santa Rosa lower Formation; Late Mississippian-Late  
12 Pennsylvanian, Carboniferous. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation;  
13 Pennsylvanian, Carboniferous. IGM-loc 4004; Pemuxco, Hidalgo; Tuzancoa Formation;  
14 Permian.  
15 Genus *Baryschyr*† Moore and Jeffords 1968  
16 *Baryschyr anosus*† Moore and Jeffords, 1968  
17 Voucher. IGM 4336 (Buitrón-Sánchez et al., 1987); IGM 8987, IGM 9524 (Buitrón-  
18 Sánchez et al., 2017).  
19 Localities and age. IGM-loc 2514; Calnali, Hidalgo; Dsel Monte Formation;  
20 Pennsylvanian, Carboniferous. IGM-loc 4004; Pemuxco, Hidalgo; Tuzancoa Formation;  
21 early Permian.  
22 Genus *Cyclocaudex*† Moore and Jeffords, 1968  
23 *Cyclocaudex cf. costatus*† Moore and Jeffords, 1968  
24 Voucher. IGM 4337 (Buitrón-Sánchez et al., 1987).

1 Locality and age. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation; Pennsylvanian,  
2 Carboniferous.

3 *Cyclocaudex insaturatus*† Moore and Jeffords, 1968

4 Voucher. IGM 4338 (Buitrón-Sánchez et al., 1987).

5 Locality and age. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation; Pennsylvanian,  
6 Carboniferous.

7 *Cyclocaudex jucundus*† Moore and Jeffords, 1968

8 Vouchers. IGM 4339 (Buitrón-Sánchez et al., 1987); IGM 4870, IGM 4871 (Villanueva-  
9 Olea et al., 2016); IGM 8988 (Buitrón-Sánchez et al., 2017).

10 Localities and age. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation; Pennsylvanian,  
11 Carboniferous. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;  
12 Pennsylvanian, Carboniferous. IGM-loc 4004; Pemuxco, Hidalgo; Tuzancoa Formation;  
13 Permian.

14 Comments. The specimens were referenced in the database as *Cyclici* indet.

15 *Cyclocaudex plenus*† Moore and Jeffords, 1968

16 Voucher. IGM 8989 (Buitrón-Sánchez et al., 2017).

17 Locality and age. IGM-loc 4004; Pemuxco, Hidalgo; Tuzancoa Formation; Permian.

18 Genus *Mooreanteris*† Miller, 1968b

19 *Mooreanteris waylandensis*† Miller, 1968b

20 Voucher. IGM 4340 (Buitrón-Sánchez et al., 1987).

21 Locality and age. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation; Pennsylvanian,  
22 Carboniferous.

23 FAMILY Floricyclidae† Moore and Jeffords, 1968

24 Comments. The family is classified in the database within the informal group *Cyclici*.

- 1                                   Genus *Floricyclus*† Moore and Jeffords, 1968
- 2                                   *Floricyclus angustimargo*† Moore and Jeffords, 1968
- 3   Voucher. IGM 4872 (Villanueva-Olea et al., 2016).
- 4   Locality and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;
- 5   Pennsylvanian, Carboniferous.
- 6                                   *Floricyclus granulosis*† Moore and Jeffords, 1968
- 7   Voucher. IGM 4873 (Villanueva-Olea et al., 2016).
- 8   Locality and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;
- 9   Pennsylvanian, Carboniferous.
- 10                                  Genus *Plummeranteris*† Moore and Jeffords, 1968
- 11                                  *Plummeranteris sansaba*† Moore and Jeffords, 1968
- 12   Voucher. IGM 4341 (Buitrón-Sánchez et al., 1987).
- 13   Locality and age. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation; Pennsylvanian,
- 14   Carboniferous.
- 15                                  Genus *Lamprosterigma*† Moore and Jeffords, 1968
- 16                                  *Lamprosterigma mirificum*† Moore and Jeffords, 1968
- 17   Vouchers. IGM 2688-IGM 2694 (Buitrón-Sánchez, 1977).
- 18   Locality and age. IGM-loc 3157; Aguacate river, between La Concordia and Chicomuselo,
- 19   Chiapas; Santa Rosa lower Formation; Late Mississippian-Late Pennsylvanian,
- 20   Carboniferous.
- 21                                  FAMILY Leptocarphiidae† Moore and Jeffords, 1968
- 22   Comments. The family is classified in the database within the informal group Cyclici.
- 23                                  Genus *Cyclocrista*† Moore and Jeffords, 1968
- 24                                  *Cyclocrista cheneyi*† Moore and Jeffords, 1968

1 Referred specimen. IGM 4874 (Villanueva-Olea et al., 2016).  
2 Locality and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;  
3 Pennsylvanian, Carboniferous.  
4                                   Genus *Preptoprennum*† Moore and Jeffords, 1968  
5                                   *Preptoprennum rugosum*† Moore and Jeffords, 1968  
6 Vouchers. IGM 4875 (Villanueva-Olea et al., 2016); IGM 5079 (González-Arreola et al.,  
7 1994).  
8 Localities and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;  
9 Pennsylvanian, Carboniferous. IGM-loc 2478; between Olinalá, Huamuxtitlán and Cualác,  
10 Guerrero; Los Arcos Formation; middle Permian.  
11                                   Genus *Heterostelechus*† Moore and Jeffords, 1968  
12                                   *Heterostelechus keithi*† Miller, 1968a  
13 Voucher. IGM 4342 (Buitrón-Sánchez et al., 1987).  
14 Locality and age. IGM-loc 2514; Calnali, Hidalgo; Del Monte Formation; Pennsylvanian,  
15 Carboniferous.  
16 Comments. This specimen is included as a paratype in the collection database, but it is not  
17 reported in the original description of the species.  
18                                   Genus *Cycloscapus*† Moore and Jeffords, 1968  
19                                   *Cycloscapus laevis*† Moore and Jeffords, 1968  
20 Vouchers. IGM 4876 (Villanueva-Olea et al., 2016); IGM 4910 (Buitrón-Sánchez et al.,  
21 2017).  
22 Localities and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco formation;  
23 Pennsylvanian, Carboniferous. IGM-loc 4004; Pemuxco, Hidalgo; Tuzancoa Formation;  
24 early Permian.

1                           *Genus Cyclocaudiculus*† Moore and Jeffords, 1968

2                           *Cyclocaudiculus regularis*† Moore and Jeffords, 1968

3   Voucher. IGM 4877 (Villanueva-Olea et al., 2016).

4   Locality and age. IGM-loc 4013; Sierra Las Mesteñas, Sonora; Caliza Naco Formation;

5   Pennsylvanian, Carboniferous.

6

7                           **CLASS ASTEROIDEA DE BLAINVILLE, 1830**

8                           ORDER Paxillosida Perrier, 1884

9                           FAMILY Porcellanasteridae Sladen, 1883

10                          Genus *Paleoctenodiscus*† Blake, 1988

11   Comments. This is a monospecific genus.

12                          *Paleoctenodiscus campaniurnus*† Blake, 1988

13   Type specimen. Holotype IGM 4290.

14   Locality and age. IGM-loc 3055; El Rosario, Baja California; geological formation

15   indeterminate; Late Campanian, Late Cretaceous.

16   Comments. Type and only species of the genus, and the first fossil of the family. In the

17   original paper it is spelled as both “*campaniurnis*” and “*campaniurnus*”, but in the

18   description, and Gale (2005) it is spelled as the latter. This species was originally assigned

19   to Family Ctenodiscidae Sladen, 1889, but Gale (2005) reassigned the genus to the family

20   Porcellanasteridae.

21

22                           **CLASS OPHIUROIDEA GRAY, 1840**

23                           ORDER Ophiurida Müller and Troschel, 1840

24                           FAMILY Ophiactidae Matsumoto, 1915

1 Genus *Ophiactis* Lütken, 1856

2 *Ophiactis applegatei*† Martín-Medrano, Thuy, and García-Barrera, 2009

3 Type specimens. Holotype IGM 9298. Paratype IGM 9290.

4 Vouchers. IGM 9291-IGM 9297, IGM 9299-IGM 9301.

5 Localities and age. IGM-loc 370, 1995, 2432, 2513, 2772; Tepexi de Rodríguez, Puebla;

6 Tlayúa Formation; Albian, Early Cretaceous.

7 Comments. The only other Paratype mentioned in the paper is the FCMP 602 (from the

8 Museum of Paleontology, School of Sciences, UNAM). Note that in the database, all the

9 referred specimens are incorrectly assigned as paratypes.

10

11 **CLASS ECHINOIDEA LESKE, 1778**

12 ORDER Cidaroida Claus, 1880

13 Cidaroida indet.

14 Vouchers. IGM 5915-IGM 5917 (Squires and Demetron, 1992).

15 Localities and age. IGM-loc 1686; Mesa La Salina, San José de Gracia, Baja California

16 Sur; Bateque Formation; Eocene, Paleogene. IGM-loc 1692; Mezquital river, San Isidro,

17 Baja California Sur; Bateque Formation; Eocene, Paleogene.

18 FAMILY Psychocidaridae Ikeda, 1936

19 Genus *Caenocidaris*† Thiéry, 1928

20 *Caenocidaris cf. cucumifera*† (L. Agassiz, 1840a)

21 Vouchers. IGM 2459- IGM 2464 (Buitrón-Sánchez, 1974c).

22 Locality and age. IGM-loc 3152; Sierra de Las Águilas, Chihuahua; geological formation

23 indeterminate; Late Jurassic.

24

FAMILY Cidaridae Gray, 1825





1 Locality and age. IGM-loc 2680; Between Las Huertas and Fundición del Sol de Mayo  
2 Mine, Tlaxiaco, Oaxaca; Calizas con *Cidaris* unit; Oxfordian, Late Jurassic.

3 SUPERORDER Carinacea Kroh and Smith, 2010

4 Comments. Classified as Hemicidaroida before the establishment of the Carinacea Kroh  
5 and Smith, 2010.

6 FAMILY Hemicidaridae† Wright, 1857

7 Genus *Pseudocidaris*† Étallon, 1859

8 *Pseudocidaris clunifera*† (L. Agassiz, 1836)

9 Vouchers. IGM 2193-IGM 2208 (Buitrón-Sánchez, 1970a); IGM 2287-IGM 2289  
10 (Buitrón-Sánchez, 1970b).

11 Localities and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya  
12 Formation; Aptian, Late Cretaceous. IGM-loc 3247; Tlaxiaco, Oaxaca; Capas Tlaxiaco  
13 unit; Late Jurassic.

14 *Pseudocidaris lusitanica*† De Loriol, 1890

15 Vouchers. IGM 2775-IGM 2778 (Buitrón-Sánchez, 1978).

16 Locality and age. IGM-loc 3130; Loc. A731, Constitución section, NW Oaxaca; San  
17 Ricardo Formation; Kimmeridgian, Late Jurassic.

18 *Pseudocidaris thurmanni*† (L. Agassiz, 1840a)

19 Vouchers. IGM 2779-IGM 2780 (Buitrón-Sánchez, 1978).

20 Locality and age. IGM-loc 3129; Loc. A661, Pueblo Viejo river section, W Chiapas; San  
21 Ricardo Formation; Kimmeridgian, Late Jurassic.

22 *Pseudocidaris* sp.†

23 Vouchers. IGM 2234-IGM 2239 (Buitrón-Sánchez, 1970a).

1 Localities and age. IGM-loc 901; Santa Ana Teloxtoc, Puebla; Zapotitlán Formation;  
2 Barremian, Early Cretaceous.

3 *Pseudocidaris cf. quenstedti*† (Mérian in Désor, 1855)

4 Voucher. IGM 2290 (Buitrón-Sánchez, 1978).

5 Locality and age. IGM-loc 2997; Pacheco ranch, Tlaxiaco, Oaxaca; Calizas con *Cidaris*  
6 unit; Oxfordian, Late Jurassic.

7 FAMILY Pseudodiadematidae† Pomel, 1883

8 Genus *Acrocidaris*† L. Agassiz, 1840b

9 *Acrocidaris nobilis*† L. Agassiz, 1840b

10 Voucher. IGM 2291 (Buitrón-Sánchez, 1970b).

11 Locality and age. IGM-loc 2997; Pacheco ranch, Tlaxiaco, Oaxaca; Calizas con *Cidaris*  
12 unit; Oxfordian, Late Jurassic.

13 Genus *Pseudodiadema*† Désor, 1855

14 *Pseudodiadema aguilerai*† (Maldonado-Koerdell, 1953)

15 Vouchers. IGM 2209, IGM 2210 (Buitrón-Sánchez, 1970a).

16 Locality and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya  
17 Formation; Aptian, Early Cretaceous.

18 Genus *Pedinopsis*† Cotteau, 1863

19 *Pedinopsis meridanensis*† Cotteau, 1863

20 Voucher. IGM 2633 (Buitrón-Sánchez, 1976).

21 Locality and age. IGM-loc 1558; Cuachalalatera Canyon, Atenango del Río, Guerrero;  
22 Cuautla Formation; Late Cenomanian-Early Turonian, Late Cretaceous.

23 Comments. Smith (in Smith and Kroh, 2011) mention that *Pedinopsis* is a stem group of  
24 Echinacea Claus, 1876. Here we keep it in the family Pseudodiadematidae.

1 ORDER Phymosomatoida Mortensen, 1904  
2 FAMILY Emiratiidae† Ali, 1990  
3 Genus *Loriolia*† Neumayr, 1881  
4 *Loriolia ornata*† (Goldfuss, 1826)  
5 Vouchers. IGM 2242-IGM 2244 (Buitrón-Sánchez, 1971).  
6 Locality and age. IGM-loc 423; Sierra San Ignacio, 4.3 km SW of El Milagro ranch,  
7 Chihuahua; Benigno Formation; Albian, Early Cretaceous.  
8 Comments. Initially, *Loriolia* was listed in the database as Hemicidaridae.  
9 *Loriolia rotulare*† (L. Agassiz, 1840b)  
10 Voucher. IGM 2211 (Buitrón-Sánchez, 1970a).  
11 Locality and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya  
12 Formation; Aptian, Early Cretaceous.  
13 Comments. Smith and Rader (2009) include this species in the genus *Polydiadema*  
14 Lambert, 1888.  
15 Genus *Tetragramma*† L. Agassiz, 1838  
16 *Tetragramma gloriae*† Buitrón-Sánchez, 1973b  
17 Type specimens. Syntypes IGM 2455, IGM 2456.  
18 Locality and age. IGM-loc 3232; Huetamo, Michoacán; San Lucas Formation; Hauterivian-  
19 Aptian, Early Cretaceous.  
20 Comments. The specimen IGM 2456 is lost.  
21 *Tetragramma malbosii*† (L. Agassiz, 1847) in L. Agassiz and Désor  
22 Vouchers. IGM 2245, IGM 2246 (Buitrón-Sánchez, 1971).  
23 Locality and age. IGM-loc 75; Cerro Las Conchas, Arivechi, Sonora; geological formation  
24 indeterminate; Aptian, Early Cretaceous.

- 1 *Tetragramma picteti*† (Désor, 1856)
- 2 Vouchers. IGM 2212-IGM 2216 (Buitrón-Sánchez, 1970a).
- 3 Locality and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya
- 4 Formation; Aptian, Early Cretaceous.
- 5 *Tetragramma streeruwitzi*† (Cragin, 1893)
- 6 Vouchers. IGM 2247, IGM 2248 (Buitrón-Sánchez, 1971).
- 7 Locality and age. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation
- 8 indeterminate; late Albian, Early Cretaceous.
- 9 *Tetragramma cf. variolare*† (Brongniart, 1822)
- 10 Voucher. IGM 2217 (Buitrón-Sánchez, 1970a).
- 11 Locality and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya
- 12 Formation; Aptian, Early Cretaceous.
- 13 FAMILY Phymosomatidae† Pomel, 1883
- 14 Genus *Phymosoma*† Haime, in D'Archiac and Haime, 1853
- 15 *Phymosoma mexicanum*† Böse, 1910
- 16 Type specimens. Syntypes IGM 2249, IGM 2250 (Buitrón-Sánchez, 1971).
- 17 Voucher. IGM 2218 (Buitrón-Sánchez, 1970a).
- 18 Localities and age. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation
- 19 indeterminate; Late Albian, Early Cretaceous. IGM-loc 775; San Juan Raya, Tehuacán,
- 20 Puebla; San Juan Raya Formation; Aptian, Early Cretaceous.
- 21 ORDER Salenioida Delage and Herouard, 1903
- 22 FAMILY Saleniidae L. Agassiz, 1838
- 23 Genus *Heterosalenia*† Cotteau, 1861
- 24 *Heterosalenia tlaxiacensis*† Buitrón-Sánchez, 1970b

1 Type specimen. Syntype IGM 2284.

2 Locality and age. IGM-loc 2680; Between Las Huertas and Fundición del Sol de Mayo  
3 mine, Tlaxiaco, Oaxaca; Calizas con *Cidaris* unit; Oxfordian, Late Jurassic.

4 Genus *Salenia* Gray, 1835

5 *Salenia mexicana*† Schlüter, 1887

6 Vouchers. IGM 2190-IGM 2192 (Buitrón-Sánchez, 1970a); IGM 2240, IGM 2241  
7 (Buitrón-Sánchez, 1971); and IGM 2285, IGM 2286 (Buitrón-Sánchez, 1970b).

8 Localities and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya  
9 Formation; Aptian, Early Cretaceous. IGM-loc 388; La Encantada, W Placer de Guadalupe,  
10 Chihuahua; geological formation indeterminate; Albian, Early Cretaceous. IGM-loc 2997;  
11 Pacheco ranch, Tlaxiaco, Oaxaca; Capas Tlaxiaco unit; Late Jurassic.

12 Comments. The specimen IGM 2286 (Buitrón-Sánchez, 1970b) is lost.

13 *Salenia texana*† Credner, 1875

14 Voucher. IGM 2457 (Buitrón-Sánchez, 1973a).

15 Locality and age. IGM-loc 3195; Between Jala and el Túnel, Colima; Potomac Division  
16 unit; Albian, Early Cretaceous.

17 ORDER Stomopneustoida Kroh and Smith, 2010

18 FAMILY Stomechinidae† Pomel, 1883

19 Comments: Previously classified as Phymosomatoida, until the description of  
20 Stomopneustoida Kroh and Smith, 2010

21 Genus *Stomechinus*† Désor, 1856

22 *Stomechinus semiplacenta*† (L. Agassiz, 1847), in Agassiz and Desor.

23 Vouchers. IGM 2292-IGM 2294 (Buitrón-Sánchez, 1970b).

1 Locality and age. IGM-loc 2997; Pacheco ranch, Tlaxiaco, Oaxaca; Calizas con *Cidaris*  
2 unit; Oxfordian, Late Jurassic.

3 FAMILY Stomopneustidae Mortensen, 1903

4 Genus *Stomopneustes* (L. Agassiz, 1841)

5 *Stomopneustes pristinus* Jackson, 1937

6 Vouchers. IGM 11213-IGM 11228 (Martínez-Melo, 2019b).

7 Locality and age. IGM-loc 3880; Chacamax river, Palenque, Chiapas; Tulijá Formation;  
8 Miocene, Neogene.

9 ORDER Arbacioida Gregory, 1900

10 FAMILY Acropeltidae Lambert and Thiery, 1914

11 Genus *Goniopygus*† L. Agassiz, 1838

12 *Goniopygus (Goniopygus) zitteli*† W.B. Clark, 1891

13 Vouchers. IGM 2219-IGM 2224 (Buitrón-Sánchez, 1970a).

14 Locality and age. IGM-loc 901; Santa Ana Teloxtoc, Puebla; Zapotitlán Formation;  
15 Barremian, Early Cretaceous.

16 FAMILY Arbaciidae Gray, 1855

17 Genus *Codiopsis*† L. Agassiz, in Agassiz and Désor, 1846

18 *Codiopsis lorini*† Cotteau, 1851

19 Voucher. IGM 2295 (Buitrón-Sánchez, 1970a).

20 Locality and age. IGM-loc 3247; Tlaxiaco, Oaxaca; Capas Tlaxiaco unit; Late Jurassic.

21 FAMILY INCERTAE SEDIS

22 Genus *Magnosia*† Michelin, 1853

23 Comments. Smith and Kroh (2011) place them as a stem group in order Arbacioida, with  
24 no assignment to a family.

1 *Magnosia (Magnosia) lens*† Désor, 1858  
2 Voucher. IGM 2225 (Buitrón-Sánchez, 1970a).  
3 Locality and age. IGM-loc 936; Salina, Paraje La Chica, Zapotitlán, Puebla; Zapotitlán  
4 Formation; Barremian, Early Cretaceous.

5 ORDER Holoctypoida Duncan, 1889  
6 FAMILY Holoctypidae† Lambert, 1900  
7 Genus *Coenholoectypus*† Pomel, 1883  
8 *Coenholoectypus planatus*† (Römer, 1849)  
9 Voucher. IGM 2251 (Buitrón-Sánchez, 1971).  
10 Locality and age. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation  
11 indeterminate; late Albian, Early Cretaceous.

12 *Coenholoectypus transpecosensis*† (Cragin, 1893)  
13 Vouchers. IGM 2226 (Buitrón-Sánchez, 1970a); IGM 2252, IGM 2253 (Buitrón-Sánchez,  
14 1971).  
15 Localities and age. IGM-loc 775; San Juan Raya, Tehuacán, Puebla; San Juan Raya  
16 Formation; Aptian, Early Cretaceous. IGM-loc 3194; Sierra de Tlahualilo, Coahuila;  
17 Aurora Formation; late Albian, Early Cretaceous. IGM-loc 387; Cerro de Muleros,  
18 Chihuahua; geological formation indeterminate; late Albian, Early Cretaceous.

19 Genus *Discooides*† Parkinson, 1811  
20 *Discooides cordobai*† Buitrón-Sánchez, 1971  
21 Type specimens. Holotype IGM 2257. Paratypes IGM 2254-IGM 2256, IGM 2258.  
22 Locality and age. IGM-loc 3133; Sierra de La Ranchera, Chihuahua; Lágrima Formation;  
23 middle Albian, Early Cretaceous.

24 ORDER Echinoneoidea H. L. Clark, 1925

- 1 FAMILY Conulidae† Lambert, 1911
- 2 Genus *Conulus*† Leske, 1778
- 3 *Conulus chiapasensis*† Lambert, 1936
- 4 Vouchers. IGM 2541-IGM 2543 (Buitrón-Sánchez, 1974a).
- 5 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation; Late
- 6 Cretaceous.
- 7 *Conulus cookei*† Buitrón-Sánchez, 1974a
- 8 Type specimens. Holotype IGM 2544. Paratype IGM 2545.
- 9 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation; Late
- 10 Cretaceous.
- 11 *Conulus lamberti*† Buitrón-Sánchez, 1974a
- 12 Type specimen. Holotype 2546.
- 13 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation; Late
- 14 Cretaceous.
- 15 *Conulus raulini*† (D'Orbigny, 1853)
- 16 Vouchers. IGM 2547-IGM 2549 (Buitrón-Sánchez, 1974a).
- 17 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation; Late
- 18 Cretaceous.
- 19 *Conulus cf. stephensoni*† Cooke, 1953
- 20 Voucher. IGM 2550 (Buitrón-Sánchez, 1974a).
- 21 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation; Late
- 22 Cretaceous.
- 23 Genus *Globator*† L. Agassiz, 1840a
- 24 *Globator cf. orbignyana*† (L. Agassiz, 1840a)



1 Voucher. IGM 2551 (Buitrón-Sánchez, 1974a).  
2 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation; Late  
3 Cretaceous.  
4 *Globator parryi*† (Hall, 1857) in Conrad  
5 Vouchers. IGM 2259, IGM 2260 (Buitrón-Sánchez, 1971).  
6 Locality and age. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation  
7 indeterminate; late Albian, Early Cretaceous.  
8 ORDER Cassiduloida L. Agassiz and Désor, 1847  
9 FAMILY Cassidulidae L. Agassiz and Désor, 1847  
10 Genus *Cassidulus* Lamarck, 1801  
11 *Cassidulus ellipticus*† Kew, 1920  
12 Vouchers. IGM 6384-IGM 6386 (Squires and Demetrion, 1995).  
13 Locality and age. IGM-loc 1698; Mesa La Ladera, San José de Gracia, Baja California Sur;  
14 Bateque Formation; early Eocene, Paleogene.  
15 ORDER Echinolampadoidea Kroh and Smith, 2010  
16 FAMILY Echinolampadidae Gray, 1851  
17 Genus *Calilampas*† Squires and Demetrion, 1995  
18 *Calilampas californiensis*† Squires and Demetrion, 1995  
19 Type specimens. Holotype IGM 6387. Paratypes IGM 6388-IGM 6391.  
20 Localities and age. IGM-loc 1697; La Tortuga river, San José de Gracia, Baja California  
21 Sur; Bateque Formation; early Eocene (Paleogene). IGM-loc 1695; Mesa La Salina, San  
22 José de Gracia, Baja California Sur; Bateque Formation; early Eocene, Paleogene. IGM-loc  
23 1699; Mesa La Ladera, San José de Gracia, Baja California Sur; Bateque Formation; early  
24 Eocene, Paleogene.

1 Genus *Echinolampas* Gray, 1825

2 *Echinolampas aldrichi*† Twitchell, 1915 in Clark and Twitchell

3 Vouchers. IGM 2555 (Buitrón-Sánchez, 1974b); IGM 11229-IGM 11233 (Martínez-Melo,  
4 2019b); IGM 4123 (Buitrón-Sánchez et al., 2019).

5 Locality and age. IGM-loc 3206; Simojovel, Chiapas; geological formation indeterminate;  
6 Oligocene, Paleogene. IGM-loc 3879; Don Eber site, Palenque, Chiapas; Tulijá Formation;  
7 Miocene, Neogene. IGM-loc 3880; Chacamax river, Chiapas; Tulijá Formation; Miocene,  
8 Neogene. IGM-loc 4039; between Hacienda de San Marcos and Mesón, Veracruz;  
9 Coatzintla Formation; Oligocene, Paleogene.

10 Comments. Specimen IGM 2555 is lost. Initially identified as *Cassiduloida* indet., the  
11 classification of the specimens has been updated in Martínez-Melo (2019b) and Buitrón-  
12 Sánchez et al. (2019).

13 *Echinolampas veracruzensis*† Buitrón-Sánchez, Solís-Marín, Conejeros and Caballero,

14 2019

15 Type specimen. Holotype IGM 4124.

16 Locality and age. IGM-loc 4039; between Hacienda de San Marcos and Mesón, Veracruz;  
17 Coatzintla Formation; Oligoceno, Paleogene.

18 *Echinolampas* sp.

19 Vouchers. IGM 5918, IGM 5919 (Squires and Demetrion, 1992).

20 Localities and age. IGM-loc 1693 and IGM-loc 1694; San Juan de Abajo river, San José de  
21 Gracia, Baja California Sur; Bateque Formation; Eocene, Paleogene.

22 ORDER Clypeasteroidea L. Agassiz, 1835

23 FAMILY Faujasiidae† Lambert, 1905

24 Genus *Hardouinia*† Haime in D'Archiac and Haime, 1853

1 *Hardouinia aequorea*† (Morton, 1834)  
2 Voucher. IGM 6259 (Martínez-Melo, 2019a).  
3 Locality and age. IGM-loc 956; Cárdenas, San Luis Potosí; Cárdenas Formation;  
4 Campanian–Maastrichtian, Cretaceous.  
5 FAMILY Oligopygidae† Duncan, 1889  
6 Comments. Previously classified in Holoctypoida but here updated as Clypeasteoida.  
7 Genus *Haimea*† Michelin, 1851  
8 *Haimea bajasurensis*† Squires and Demetron, 1994  
9 Type specimens. Holotype IGM 5934. Paratypes IGM 5935-IGM 5937.  
10 Locality and age. IGM-loc 3054; 1.25 km E from Transpeninsular highway, Baja California  
11 Sur; Tepetate Formation; early Miocene, Neogene.  
12 Genus *Oligopygus*† De Loriol, 1887  
13 *Oligopygus rotundus*† Cooke, 1942  
14 Voucher. IGM 2905 (Buitrón-Sánchez and Silva, 1979).  
15 Locality and age. IGM-loc 3028; 1km E Tantoyuca, Veracruz; Tantoyuca Formation; late  
16 Eocene, Paleogene.  
17 *Oligopygus wetherbyi*† De Loriol, 1887  
18 Voucher. IGM 2552 (Buitrón-Sánchez, 1974b).  
19 Locality and age. IGM-loc 3095; Amatán, Chiapas; geological formation indeterminate;  
20 Oligocene, Paleogene.  
21 FAMILY Clypeasteridae L. Agassiz, 1835  
22 Genus *Clypeaster* Lamarck, 1801  
23 *Clypeaster chiapasensis*† Müllerried, 1951  
24 Type specimen. Neotype IGM 11234 (Martínez-Melo, 2019b).

1 Vouchers. IGM 11235-IGM 11256 (Martínez-Melo, 2019b).  
2 Locality and age. IGM-loc 3636; El Gato, Palenque, Chiapas; Tulijá Formation; Miocene,  
3 Neogene.

4 *Clypeaster pileus*† Israelsky, 1924

5 Voucher. IGM 2553 (Buitrón-Sánchez, 1974b).  
6 Locality and age. IGM-loc 3206; Simojovel, Chiapas; geological formation indeterminate;  
7 Oligocene, Paleogene.

8 *Clypeaster rogersi*† (Morton, 1834)

9 Voucher. IGM 2554 (Buitrón-Sánchez, 1974b).  
10 Locality and age. IGM-loc 3207; Teapa, Chiapas; geological formation indeterminate;  
11 Oligocene, Paleogene.

12 FAMILY Echinarachniidae Lambert in Lambert and Thiéry, 1914

13 Genus *Astrodapsis*† Conrad, 1856

14 *Astrodapsis bajasurensis*† Squires and Demetron, 1993

15 Type specimens. Holotype IGM 5926. Paratypes IGM 5927-IGM 5933.  
16 Locality and age. IGM-loc 1700; mouth of Mezquital river, Baja California Sur; Isidro  
17 Fomation; middle Miocene, Neogene.

18 Genus *Vaquerosella*† Durham, 1955

19 *Vaquerosella perrillatae*† Martínez-Melo and Alvarado-Ortega, 2020

20 Type specimens. Holotype IGM 11463. Paratypes IGM 11464-IGM 11470.  
21 Vouchers. IGM 11471-IGM 11483.  
22 Locality and age. IGM-loc 248; San Ignacio River, Baja California Sur; San Ignacio  
23 Formation; Miocene, Neogene. IGM-loc 265; Nacho River, Baja California Sur; San  
24 Ignacio Formation; Miocene, Neogene.

1 Comments. This is the first species of the genus reported out of California, USA, and the  
2 most plesiomorphic form (Martínez-Melo and Alvarado-Ortega, 2020).

3 FAMILY Mellitidae Stefanini, 1912

4 Genus *Encope* L. Agassiz, 1840a

5 *Encope grandis inezana*† Durham, 1950

6 Type specimens. Paratypes IGM 2825-IGM 2827.

7 Locality and age. IGM-loc 3156; Loc. A-3584, Santa Inés Bay, Baja California Sur;  
8 geological formation indeterminate; Pleistocene, Quaternary.

9 *Encope loretoensis*† Durham, 1950

10 Type specimens. Paratypes IGM 8150, IGM 8151.

11 Locality and age. IGM-loc 108; Algodones ranch, Baja California Sur; geological  
12 formation indeterminate; late Pliocene, Neogene.

13 *Encope michoacanensis*† Durham, 1994

14 Type specimens. Holotype IGM 7057. Paratypes 7058-IGM 7061.

15 Locality and age. IGM-loc 906; La Mira, Michoacán; geological formation indeterminate;  
16 early Miocene, Neogene.

17 *Encope micropora* L. Agassiz, 1841

18 Voucher. IGM 7062 (Durham, 1994).

19 Locality and age. IGM-loc 3211; Santa Cruz, Oaxaca; geological formation indeterminate;  
20 Pliocene, Neogene to Pleistocene, Quaternary.

21 Comments. In the database is found as *Encope perspective* L. Agassiz, 1841.

22 *Encope shepherdi*† Durham, 1950

23 Vouchers. Paratypes IGM 2822-IGM 2824.

1 Locality and age. IGM-loc 3155; Loc. A-3517, Marquer Bay, El Carmen island, Baja  
2 California Sur; Marquer Formation; late Pliocene, Neogene.

3 *Encope tatetlaensis*† Böse, 1906

4 Type specimens. Syntypes IGM 147, IGM 148, IGM 7154.

5 Locality and age. IGM-loc 2178; Santa María Tatetla, Veracruz; geological formation  
6 indeterminate; Pliocene, Neogene.

7 ORDER Spatangoida L. Agassiz, 1840a

8 FAMILY Toxasteridae† Lambert, 1920

9 Genus *Heteraster*† d'Orbigny, 1855

10 *Heteraster aguilerai*† Buitrón-Sánchez, 1970a

11 Type specimen. Holotype IGM 2227.

12 Locality and age. IGM-loc 932; Barranca Salitrillo, Tehuacán, Puebla; San Juan Raya  
13 Formation; Aptian, Early Cretaceous.

14 *Heteraster alencasterae*† Buitrón-Sánchez, 1970a

15 Type specimens. Holotype IGM 2228. Paratype IGM 2229.

16 Locality and age. IGM-loc 932; Barranca Salitrillo, Tehuacán, Puebla; San Juan Raya  
17 Formation; Aptian, Early Cretaceous.

18 *Heteraster bravoensis*† (Böse, 1910)

19 Type specimens. Syntypes of *Enallaster bravoensis* IGM 404, IGM 405, IGM 7223, IGM  
20 2274-IGM 2278 (Buitrón-Sánchez, 1971).

21 Locality and age. IGM-loc 392; Loc. 8, Chihuahua; geological formation indeterminate;  
22 late Albian, Cretaceous. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation  
23 indeterminate; late Albian, Cretaceous.

1 Comments. The initial description considered more than 60 specimens. The specimen IGM  
2 404, and probably several others are lost. Note that Buitrón-Sánchez (1971) cited the  
3 species as *Whashitaster bravoensis*.

4 *Heteraster mexicanus*† (Cotteau, 1890)

5 Voucher. IGM 2458 (Buitrón-Sánchez, 1973a).

6 Locality and age. IGM-loc 3196; Loma Noral, Rosario, Colima; Potomac Division unit;  
7 Albian, Early Cretaceous.

8 *Heteraster cf. mexicanus*† (Cotteau, 1890)

9 Voucher. IGM 402 (Böse, 1910).

10 Locality and age. IGM-loc 388; La Encantada close to Placer de Guadalupe, Chihuahua;  
11 geological formation indeterminate; Albian, Cretaceous.

12 Comments. Included as Vraconian, which is a subdivision of the Albian age, used mostly in  
13 western Europe.

14 *Heteraster cf. obliquatus*† (W.B. Clark, 1893)

15 Voucher. IGM 403 (Böse, 1910).

16 Locality and age. IGM-loc 388; La Encantada close to Placer de Guadalupe, Chihuahua;  
17 geological formation indeterminate; Albian, Early Cretaceous.

18 Comments. Included as Vraconian, which is a subdivision of the Albian age, used mostly in  
19 western Europe.

20

21 Genus *Macraster*† Römer, 1888

22 *Macraster aguilerae*† (Böse, 1910)

23 Type specimen. Syntype IGM 2261 (Buitrón-Sánchez, 1971).

1 Locality and age. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation  
2 indeterminate; Albian, Early Cretaceous.

3 *Macraster cf. texanus*† Römer, 1888

4 Voucher. IGM 407 (Böse, 1910).

5 Locality and age. IGM-loc 3117; Cerro de Muleros, between Bisbee and Southern Pacific  
6 trains, close to Río Bravo, Chihuahua; geological formation indeterminate; Albian, Early  
7 Cretaceous.

8 Comments. Included as Vraconian, which is a subdivision of the Albian age, used mostly in  
9 western Europe.

10 *Macraster dartoni*† (Cooke, 1955)

11 Vouchers. IGM 2262, IGM 2263 (Buitrón-Sánchez, 1971).

12 Locality and age. IGM-loc 3133; Sierra de La Ranchera, Chihuahua; Lágrima Formation;  
13 middle Albian, Early Cretaceous.

14 *Macraster cf. dartoni*† (Cooke, 1955)

15 Voucher. IGM 5236 (Buitrón-Sánchez, 1990a).

16 Locality and age. IGM-loc 2588; Sierra El Chanate, Sonora; Morita Formation; Aptian,  
17 Early Cretaceous.

18 Comment. The species is excluded from the genus *Macraster* by Kamyabi-Shadan et al.  
19 (2014).

20 *Macraster cf. nodopyga*† Lambert, 1920

21 Voucher. IGM 2264 (Buitrón-Sánchez, 1971).

22 Locality and age. IGM-loc 429; Sierra Banco de Lucero, Chihuahua; Lucero Formation;  
23 late Albian, Early Cretaceous.

24 Genus *Washitaster*† Lambert, 1927



1                                *Washitaster longisulcus*† (Adkins and Winton, 1920)  
2    Voucher. IGM 2279 (Buitrón-Sánchez, 1971).  
3    Locality and age. IGM-loc 387; Cerro de Muleros, Chihuahua; geological formation  
4    indeterminate; late Albian, Early Cretaceous.  
5                                FAMILY Hemiasteridae H.L. Clark, 1917  
6                                Hemiasteridae indet.  
7    Vouchers. IGM 11397-IGM 11400 (Alvarado-Ortega et al, 2020).  
8    Locality and age. IGM-loc 3995; Tzimol, Chiapas, Mexico; Angostura Formation;  
9    Campanian, Late Cretaceous.  
10                              Genus *Hemiaster*† Désor, in Agassiz and Désor, 1847  
11                              *Hemiaster calvini*† W.B. Clark, 1893  
12    Vouchers. IGM 2267-IGM 2270 (Buitrón-Sánchez, 1971).  
13    Locality and age. IGM-loc 3194; Sierra de Tlahualilo, Coahuila; Aurora Formation; late  
14    Albian, Early Cretaceous.  
15                              *Hemiaster cf. jacksoni*† Maury, 1936  
16    Voucher. IGM 2634 (Buitrón-Sánchez, 1976).  
17    Locality and age. IGM-loc 1558; Barranca de La Cuachalalatera, Atenango del Río,  
18    Guerrero; Cautla Formation; late Cenomanian-Turonian, Late Cretaceous.  
19                              *Hemiaster* sp.  
20    Vouchers. IGM 2265, IGM 2266 (Buitrón-Sánchez, 1971).  
21    Locality and age. IGM-loc 423; Sierra San Ignacio, 4.3 km SW of El Milagro ranch,  
22    Chihuahua; Benigno Formation; Albian, Early Cretaceous.  
23                              *Hemiaster whitei*† (W.B. Clark, 1891)

1 Vouchers. IGM 2230-IGM 2233 (Buitrón-Sánchez, 1970a); IGM 2271-IGM 2273  
2 (Buitrón-Sánchez, 1971, Martínez-Melo et al. 2017).  
3 Localities and age. IGM-loc 932; Barranca Salitrillo, Tehuacán, Puebla; San Juan Raya  
4 Formation; Aptian, Early Cretaceous. IGM-loc 432; Sierra de Juárez, Chihuahua; Benigno  
5 Formation; Albian, Early Cretaceous.

6 FAMILY Micrasteridae Lambert, 1920

7 Genus *Micraster*† L. Agassiz, 1835

8 *Micraster (Gibbaster) sonorensis*† Buitrón-Sánchez, 1971

9 Type specimen. Holotype IGM 2280.

10 Locality and age. IGM-loc 75; Cerro Las Conchas, Arivechi, Sonora; geological formation  
11 indeterminate; Aptian, Early Cretaceous.

12 FAMILY Schizasteridae Lambert, 1905

13 Genus *Linthia*† Désor, 1853

14 *Linthia variabilis*† Slocom, 1909

15 Voucher. IGM 5879 (Michaud, 1984).

16 Locality and age. IGM-loc 1996; Ocozocoautla, Chiapas; Ocozocoautla Formation;  
17 Maastrichtian, Late Cretaceous.

18 Genus *Schizaster*† L. Agassiz, 1836

19 *Schizaster dumblei* Israelsky, 1924

20 Vouchers. IGM 11308-IGM 11310 (Martínez-Melo, 2019b)

21 Localities and age. IGM-loc 3636; El Gato, Palenque, Chiapas; Tulijá Formation; Miocene,  
22 Neogene. IGM-loc 3880; Chacamax river, Palenque, Chiapas; Tulijá Formation; Miocene,  
23 Neogene.

24 *Schizaster (Paraster) aff. lecontei*† Merriam, 1899

1 Type specimen. Syntype IGM 5921 (Squires and Demetrion, 1992).  
2 Voucher. IGM 5920 (Squires and Demetrion, 1992).  
3 Localities and age. IGM-loc 1693; San Juan de Abajo creek, San José de Gracia, Baja  
4 California Sur; Bateque Formation; early Eocene, Paleogene. IGM-loc 1686; Mesa La  
5 Salina, San José de Gracia, Baja California Sur; Bateque Formation; early Eocene,  
6 Paleogene.

7 FAMILY Prenasteridae Lambert, 1905

8 Genus *Agassizia* Valenciennes, 1846

9 *Agassizia regia*† Israelsky, 1924

10 Vouchers. IGM 11257-IGM 11307 (Martínez-Melo, 2019b).  
11 Locality. IGM-loc 3636; El Gato site, Palenque, Chiapas; Tulijá Formation; Miocene,  
12 Neogene.  
13 Comment: The specimen of *Agassizia regia* was published with the collection number  
14 IGM-11527 by Martínez-Melo (2019b); this is a typographic mistake, and the collection  
15 number must be corrected to IGM 11257.

16 FAMILY Mretiidae Lambert, 1905

17 Genus *Eupatagus* L. Agassiz, in Agassiz and Désor, 1847

18 *Eupatagus batequensis*† Squires and Demetrion, 1992

19 Type specimens. Holotype IGM 5922. Paratype IGM 5923.  
20 Locality and age. IGM-loc 1693; San Juan de Abajo creek, San José de Gracia, Baja  
21 California Sur; Bateque Formation; early Eocene, Paleogene.

22 *Eupatagus (Eupatagus) mooreanus*† Pilsbry, 1914

23 Voucher. IGM 2906 (Buitrón-Sánchez and Silva, 1979).

1 Locality and age. IGM-loc 3028; 1 km E Tantoyuca, Veracruz; Tantoyuca Formation; late  
2 Eocene, Paleogene.

3

4 **CLASS HOLOTHUROIDEA DE BLAINVILLE, 1834**

5 ORDER Dendrochirotida Grube, 1840

6 FAMILY Cucumariidae Ludwig, 1894

7 Genus *Paleopentacta*† Applegate, Buitrón-Sánchez, Solís-Marín, and Laguarda-Figueras,  
8 2009

9 *Paleopentacta alencasterae*† Applegate, Buitrón-Sánchez, Solís-Marín, and Laguarda-  
10 Figueras, 2009

11 Type specimen. Holotype IGM 6853.

12 Locality and age. IGM-loc 2513; Tepexi de Rodríguez, Puebla; Tlayúa Formation; middle-  
13 late Albian, Early Cretaceous.

14 Comments. The species is spelled either *Paleopentacta alencasterae* or *Paleopentacta*  
15 *alencasterai* in the original publication. In the CNP database, the species is wrongly  
16 recorded as “*Paleopentacta*” but correctly spelled as “*alencasterae*”.

17 FAMILY Psolidae Burmeister, 1837

18 Genus *Parapsolus*† Applegate, Buitrón-Sánchez, Solís-Marín and Laguarda-Figueras, 2009

19 *Parapsolus tlayuensis*† Applegate, Buitrón-Sánchez, Solís-Marín, and Laguarda-Figueras,  
20 2009

21 Type specimen. Holotype IGM 6850.

22 Locality and age. IGM-loc 370; Tepexi de Rodríguez, Puebla; Tlayúa Formation; middle  
23 Albian, Early Cretaceous.

1 Comments. The original description assigned the genus *Parapsolus* to the family Psolidae  
2 Perrier, 1902. However, the family Psolidae was named by Burmeister, 1837. Erroneously  
3 this species was also referred to as *Parapsolus thayuensis* in the original publication.  
4 *Parapsolus thayuensis* is retained in the CNP database.

5

### 6 *3.2 Geological context of Mexican echinoderms*

7 Echinoid fossils housed in the Type Collection of CNP are from 13 of the 31 Mexican  
8 states. They are from 48 localities that represent 35 distinct lithostratigraphic units or  
9 formations. These geological units are:

10 **Angostura Formation.** This Campanian-Maastrichtian formation includes marls,  
11 limestones, and sandstones interbedded, were deposited in shallow marine waters with low  
12 energy, and now are exposed in Chiapas and Tabasco (Sánchez-Montes de Oca, 1969;  
13 Quezada-Muñetón, 1987).

14 **Aurora Formation.** Also referred as the Aurora Group or Aurora Shale, this unit is a  
15 sequence of Albian-Cenomanian homogeneous limestone with flint nodules, dolomite  
16 banks, and calcareous breccia, deposited in shallow shelf, lagoonal and reef conditions, and  
17 exposed in the different northern regions of Mexico, in Chihuahua, Coahuila de Zaragoza,  
18 Durango (Burrows, 1910; Tardy, 1972; González et al., 2007; Ramírez-Gutiérrez, 2011;  
19 Buitrón-Sánchez, 1971).

20 **Bateque Formation.** This Eocene sequence consists of very fine-grained sandstone  
21 interbedded with fossiliferous lenses, deposited into a delta with shallow and warm-water  
22 conditions, and exposed the region between Laguna San Ignacio to San Juanico, northern  
23 Baja California Sur (Squiries and Demetrion, 1992).

1 **Benigno Formation.** The Albian strata of this unit are exposed in the Sierra de Fresnos,  
2 northern Chihuahua, and consist of medium to thick and massive fossiliferous limestones  
3 that were deposited in a shallow open marine platform (Nichols, 1958; Haenggi, 1966;  
4 Monreal and Longoria, 1999; López-Doncel et al., 2005).

5 **Caliza Chimeco Formation.** This Oxfordian fossiliferous formation is exposed near  
6 Petlalcingo, southern Puebla, and is composed of sandy and clayey limestones and  
7 calcarenites that were deposited on a coastal environment with high energy and fluvial  
8 inputs (Pérez-Ibargüengoitia et al., 1965; Alencáster and Buitrón-Sánchez, 1965; Caballero-  
9 Miranda, et al., 1989; Grimaldo, 2010).

10 **Caliza Naco Formation.** Also considered as a Group, this Carboniferous-Permian  
11 geological unit consists of shallow platform marine deposits that are exposed in Arizona as  
12 well as Chihuahua and Sonora (Blodgett et al., 2002).

13 **Calizas con *Cidaris* unit.** This informally named Oxfordian-Kimmeridgian geological unit  
14 is exposed between Puebla and Oaxaca, is a sequence of marls, limestones, and calcareous  
15 coquinas interbedded that were deposited under a shallow marine condition of low energy  
16 (Erben, 1956; Carrasco-Ramírez, 1981; Alvarado-Ortega et al., 2014).

17 **Capas Tlaxiaco unit.** The late Jurassic marine fauna of the Capas Tlaxiaco unit exposed  
18 near Tlaxiaco, Oaxaca were reported by Buitrón-Sánchez (1970b), with an age potentially  
19 ranging from the Portlandian (Tithonian, Late Jurassic) to the Neocomian (Berriasian to  
20 Hauterivian, Early Cretaceous). This is a sequence of yellowish sandstones and marly  
21 shales deposited in nearshore shallow marine conditions.

22 **Cárdenas Formation.** This is a Maastrichtian sequence consists of shales, calcareous  
23 shales, and sandstones, calcarenites, limestones, and sandy shale and limonite interbedded:  
24 was deposited in a marine deep platform of high energy, and is exposed in the Sierra Madre

1 Oriental, in Tamaulipas, Nuevo León, and San Luis Potosí (Myers, 1968; Carrillo-Bravo,  
2 1971).

3 **Coatzintla Formation.** This is a late Oligocene-early Miocene marine sequence and is well  
4 exposed around the border between Veracruz and Tamaulipas, consists of clays and  
5 sandstones with reef limestone lenses interbedded, and was deposited into the Tampico  
6 Misantla Basin into a continental platform with localized slope conditions (Salas, 1949a;  
7 Barker and Blow, 1976; Buitrón-Sánchez et al., 2019).

8 **Cuautla Formation.** This late-Cenomanian-late Turonian of thick to massive gray  
9 limestones deposited in transitional shallow and deep open marine conditions, in territories  
10 that now are part of Morelos, Estado de México, and Hidalgo (Fries, 1960; Aguilera-  
11 Franco, 2003).

12 **Del Monte Formation.** This Carboniferous-Pennsylvanian unit is a sequence of carbonated  
13 sand and siltstones deposited in a shallow platform with high energy, and exposed in the  
14 Huizachal-Peregrina region, Tamaulipas (Carrillo-Bravo, 1961; Malpica and De La Torre,  
15 1980).

16 **Isidro Formation.** The Miocene strata of this unit consist of green, white, and yellow  
17 stratified sandstone interbedded with gypsum and greenish shales, which were deposited in  
18 coastal and neritic conditions, and are exposed near the Los Cabos, southern Baja  
19 California Sur (Darton, 1921; Heim, 1922; McLean et al., 1987).

20 **Lágrima Formation.** This Albian sequence of thick-bedded marls, limestones, and  
21 sandstones exposed northeastern Chihuahua, was deposited in well-oxygenated waters of a  
22 shallow marine platform (Haengii, 1966; Ortuño-Arzate, 1985; Monreal and Longoria,  
23 1999).

1 **Los Arcos Formation.** This unit also named the Olinalá Formation is a Permian sequence  
2 exposed near Olinalá town, Guerrero, which consists of basal conglomerates and siltstones  
3 plus carbonate sandstones that were deposited into deltaic environment enclosed in a large  
4 Bay (Corona-Esquivel, 1981; Flores de Dios and Buitrón-Sánchez, 1982; Vachard et al.,  
5 1993)

6 **Lucero Formation.** This Albian marine unit described by Rodríguez-Torres and Guerrero-  
7 García (1969) is exposed in northern Chihuahua, is a sequence of limestones interbedded  
8 with calcareous shales deposited into a shallow marine shelf to the continental slope  
9 (Rodríguez-Torres and Guerrero-García, 1969; Santiago-Bautista et al., 2019).

10 **Marquer Formation.** This is a Pliocene sequence of calcareous conglomerates with  
11 volcanic pebbles, calcareous sandstones, marls, coquina, algal limestone, and coral-reef  
12 materials, which were deposited in shallow marine conditions, and exposed near the La  
13 Salada ranch, Baja California Sur (Anderson, 1950; Durham, 1950; Kirkland et al., 1966;  
14 Simian and Johnson, 1997; Carreño and Smith, 2007; López-Pérez, 2008).

15 **Morita Formation.** This Aptian marine sedimentological unit exposed in Sierra El Chanate  
16 Hills, northern Sonora, is a sequence of siltstones and calcareous sandstones deposited into  
17 a deltaic plain with sporadic sea raids (Jacques-Ayala et al., 1990; Ramírez-López and  
18 Jaimes-Deloya, 2016; González-León and Jacques-Ayala, 1988; García-Barragán and  
19 Jacques-Ayala, 2011). Madhavaraju and González-León (2012) mention that this could be  
20 part of a major marine transgression during Aptian–Albian.

21 **Ocozocoautla Formation.** This unit exposed in central Chiapas is composed of quartzitic  
22 gravel within a red clayed matrix; calcareous sandstone; sandy shales interbedded with  
23 calcareous sandstones and sandy limestones; fine-grained sandstone interbedded with  
24 shales and calcareous sandstones (Sapper, 1894; Sánchez-Montes de Oca, 1969). This



1 carries abundant early Maastrichtian fossils of different inner and outer shelf environments,  
2 including shallow marine coastal and restricted lagoonal conditions (Buitrón-Sánchez,  
3 1974a; García-Barrera, et al., 1998; González-Barba et al., 2001; Vega-Vera et al., 2001;  
4 Filkorn et al., 2005; Omaña, 2006; Than-Marchese et al., 2011).

5 **Potomac Division unit.** Angermann (1907) suggests that a marine stratum exposed near  
6 the Colima-Manzanillo railroad track, in Colima, there are similar to the Cretaceous  
7 Potomac Formation in the eastern coastal plain, USA. These mid-Albian Mexican strata are  
8 bituminous and well-stratified calcareous and clayey layers that were deposited in shallow-  
9 water conditions (Corona-Esquivel, 1993; Eguiluz-de Antuñano et al., 2019).

10 **San Ignacio Formation.** Miocene marine sequence of whitish volcanoclastic sandstones  
11 interlayered with conglomeritic sandstones, marls, coquinas, and lutites that was named by  
12 Mina-Uhink (1956, 1957); this geological unit shows porphyry intrusions and is  
13 discordantly covered by continental strata composed of late Miocene-early Pliocene  
14 andesitic breccias, rhyolites, fluvial gravels, and sandstones, polymictic conglomerates, and  
15 even basalt flows belonging to the Comondú Group (Carreño and Smith, 2007).

16 **San Juan Raya Formation.** This rich fossil Aptian sequence of green to gray shales with  
17 layers of purple shales and calcareous shales that are intercalated with sandstones and  
18 calcareous sandstones deposited around the San Juan Raya town, southern Puebla  
19 (Aguilera, 1906; Burckhardt, 1930; Alencáster, 1956; Calderón-García, 1956; Reyes-  
20 Navarro, 1963; Buitrón-Sánchez, 1970a; Barceló-Duarte, 1978, Buitrón-Sánchez and  
21 Barceló-Duarte, 1980). The fossil and lithology data suggest that this unit was deposited  
22 under shallow marine waters, in the shelf zone, and under oxygenated and with little or no  
23 disturbance (Salas, 1949b; Alencáster, 1956; Escalante-Ruiz and Quiroz-Barroso, 2006).

1 **San Lucas Formation.** This unit exposed in Michoacán and Guerrero was deposited under  
2 pelagic conditions and is a sequence of shales, siltstones sandstones with lenses of  
3 limestone and rudists, fine-grained conglomerates, and few horizons of volcanic pyroclastic  
4 materials and lava flows (Pantoja-Alor, 1959; Pantoja-Alor, 1990b). The fossils assemblage  
5 as far recovered indicates that this is a Late Valanginian to Late Aptian deposit (Buitrón-  
6 Sánchez, 1973b; Gómez-Luna et al., 1993; Alencáster and Pantoja-Alor, 1996; Guerrero-  
7 Suástegui, 1997; Pantoja-Alor et al., 2004; Omaña et al., 2005).

8 **San Ricardo Formation.** This Callovian-Aptian? unit is present between Chiapas and  
9 Oaxaca, Chiapas, as a sequence of green to gray shales, siltstones, gypsum beds,  
10 limestones, marls, and medium- to coarse-grained sandstones deposited in shallow, coastal  
11 and continental shelf environments (Richards, 1963; Silva-Pineda, 1977; Buitrón-Sánchez,  
12 1978; Michaud, 1988; Mandujano-Velásquez and Vázquez-Meneses, 1996).

13 **Santa Rosa Formation.** This Carboniferous-Mississippian unit is a sequence of carbonated  
14 sandstones and siltstones interbedded deposited in shallow marine waters and exposed  
15 around the border of Chiapas and Guatemala (Dollfus and Montserrat, 1868; Hernández-  
16 García, 1973).

17 **Tantoyuca Formation.** The Tantoyuca Formation is a Mid to Late Eocene sequence of  
18 sandstones, conglomerate with coarse to fine sediment, sandy shale lenses, and scarce flints  
19 that were deposited close shoreline under uniform and moderate depth conditions into the  
20 Tampico-Misantla Basin, northwestern Veracruz (Dumble, 1923; VerWiebe, 1924;  
21 Buitrón-Sánchez and Silva, 1979; Nava-Pérez and Alegría-Luna, 2001).

22 **Tepetate Formation.** These strata exposed near the Tepetate ranch, west-central Baja  
23 California Sur, is a sequence of green sandstones interbedded with well-stratified grayish  
24 sandstones and a gray to purple shales (Darton, 1921; Heim, 1922) that also was named as

1 the Monterey and the Rosario formations (Heim, 1922; McWilliams et al., 1951). Its Early  
2 Eocene micro and nano fossils suggest that this is a deep marine deposit (Miranda-Martínez  
3 and Carreño, 2008; García-Cordero and Carreño, 2009).

4 **Tlayúa Formation.** The Albian deposits of this formation exploited near Tepexi de  
5 Rodríguez, southern Puebla, consists of laminated and parallel limestones interbedded with  
6 thin and red clay strata that were deposited into a shallow lagoon with cyclic connection to  
7 the open sea (Cantú-Chapa, 1987; Pantoja-Alor, 1990a; Espinosa-Arrubarena and  
8 Applegate, 1996).

9 **Tulijá Formation.** The Miocene unit is exposed in low land in the eastern region of  
10 Chiapas; this consists of dark blue and brownish grey clays, sandstones, and limestones  
11 interbedded with coquinas that were deposited near shore or lagoonal environments under  
12 high energy and shallow marine conditions (Quezada-Muñeton, 1987).

13 **Tuzancoa Formation.** Deposits of this Permian geological unit are exposed near Calnalí  
14 town, Hidalgo, and show volcanic beds as well as turbiditic, carbonated detritic, and  
15 conglomerates that were deposited into a deep marine basin (Ochoa-Camarrillo, 1996;  
16 Rosales-Lagarde et al., 2005).

17 **Zapotitlán Formation.** The Barremian sequence of this unit exposed near Hill Zapotitlán,  
18 southern Puebla, consists of sandstones interbedded with shales, calcareous shales and  
19 marls (Aguilera, 1906; Buitrón-Sánchez, 1970a; Buitrón-Sánchez and Barceló-Duarte,  
20 1980; Hernández-Estévez, 1980; Feldmann et al., 1995). Fossil and lithological data shows  
21 that this is a marine low-depth littoral sequence (Müllerried, 1933; Alencáster, 1965;  
22 Barceló-Duarte, 1978; Mendoza-Rosales, 2010; Vega-Vera et al., 2019).

23

#### 24 **4. Discussion**

1 *4.1 Summary of the current Echinoderm collection housed at CNP-UNAM*

2 The present review of the CNP-UNAM reveals that this has 107 echinoderm species,  
3 which represent five classes, and ages ranging between the Carboniferous and the  
4 Pleistocene. These include 19 crinoids (17 Carboniferous, 1 Permian, 1 Jurassic), 1 asteroid  
5 (Cretaceous), 1 ophiuroid (Cretaceous), 85 echinoids (11 Jurassic, 48 Cretaceous, 14  
6 Paleogene, 13 Neogene, and 1 Pleistocene), and 2 holothuroids (Cretaceous) (Figure 1).  
7 This number could be significantly higher; however, at the dawn of the 19th century  
8 (Figure 2), when the first research projects aimed at the formal study of the fossil and  
9 extant echinoderms began, the scientific institutions in Mexico were still incipient, and the  
10 efforts to establish a scientific paleontological collection were unsuccessful. Therefore,  
11 many of the first fossil echinoderms studied were deposited outside of the country or were  
12 lost. Indisputably, the greatest contribution to the knowledge of the Mexican fossil  
13 echinoderms is found in the efforts of Dr. Blanca Estela Buitrón Sánchez who, between  
14 1965 and 1990, worked intensively in this phylum, mainly in echinoids and crinoids.  
15 Unfortunately, this first impulse lost intensity, resulting in the reduction of the number of  
16 studies performed, and in the reduction of the number of specimens incorporated into the  
17 CNP-UNAM per year.

18 Since 1995 to date, only eight new echinoderms have entered the CNP-UNAM (Figure  
19 1). These records are very important because they include complete and well-preserved  
20 specimens of three species representing the first occurrence of two echinoderm classes, one  
21 ophiuroid and two holothuroid species, which are part of the Albian assemblage of the  
22 Tlayúa Lagerstätte. Today, additional research on holothurian and ophiuroid microfossils is  
23 required to recognize more broadly and completely the diversity that these organisms had  
24 over time within the Mexican territory.

1 A peculiarity of the Mexican fossil crinoids, observed in the 43 specimens cataloged  
2 and deposited in the CNP-UNAM, is its low diversity and bad preservation. Hardly, these  
3 are fragmented, incomplete, and disintegrated specimens or icnofossils. This fact has only  
4 allowed their identification following the parataxonomic criteria established by Moore and  
5 Jeffords (1968), as part of 19 form-taxa, 17 of them from the Carboniferous. This is an  
6 apparent bias that reflects the scarce Paleozoic marine deposits present in Mexico as well as  
7 the abundance of post-Paleozoic shallow marine fossiliferous sites scattered throughout the  
8 country.

9 The paleontological studies on Mexican echinoderms already published are entirely  
10 focused on their taxonomy, with little or no attention to other important paleontological  
11 aspects, such as their taphonomic and paleoenvironmental implication, or their use as  
12 defining elements into phylogenetic and biogeographical studies. Except for Martínez-Melo  
13 and Alvarado-Ortega (2020), these studies did not determine the phylogenetic meaning of  
14 such fossils nor addressed the paleoenvironmental or palaeoecological implications of these  
15 organisms.

16

#### 17 *4.2 Updates of the CNP-UNAM database*

18 The present review of those 107 echinoderm species recorded into the CNP-UNAM  
19 allowed to update the taxonomical status of 23 taxa, which are cataloged into this collected  
20 with invalid names (Table 1). Additionally, during this exercise, missing catalogued  
21 specimen that actually were recorderd; these are IGM-2456 *Tetragramma gloriae* Buitrón-  
22 Sánchez (Buitrón-Sánchez, 1973b), IGM-2555 *Echinolampas aldrichi* Twitchell (Buitrón-  
23 Sánchez, 1974b), and IGM-2286 *Salenia mexicana* (Buitrón-Sánchez, 1970). Several  
24 specimens received IGM catalog numbers before publication, but have not yet been

1 deposited in the CNP-UNAM: IGM-4873 *Floricyclus granulosus* Moore and Jeffords;  
2 IGM-4875 *Preptopremnum rugosum* Moore and Jeffords; IGM-4876 *Cycloscapus laevis*  
3 Moore and Jeffords and IGM-4877 *Cyclocaudiculus regularis* Moore and Jeffords, all  
4 published in Villanueva-Olea et al. (2016).

5 Buitrón-Sánchez et al. (2015) reported seven asteroids from the Tlayúa lagerstätte  
6 (Puebla), which unfortunately were not properly deposited into the CNP-UNAM and were  
7 published with incorrect IGM-numbers previously assigned to ammonoids: *Astropecten* sp.  
8 (IGM-3742 to IGM-3744), *Plutonaster* sp. (IGM-3745), *Tamaria* sp. (IGM-3746),  
9 *Ophidiaster* sp. (IGM-3747), and *Echinaster* sp. (IGM-3748). Besides, the specimens IGM-  
10 3743 and IGM-3746 are the part and counterpart of the same specimen.

11 Finally, we noted that the holothuroids species described by Applegate et al. (2009) have  
12 inconsistent spellings throughout their description. The nomenclatural acts of these species  
13 correspond to *Paleopentacta alencasterae* and *Parapsolus tlayuensis*; however, in other  
14 parts of the paper, the specific epithets of these species are erroneously typed as  
15 *alencasterai*, and *thayuensis* respectively. Our species list highlights the correct spellings  
16 (Figure 3).

17

### 18 *4.3 Geological summary*

19 The Mexican fossil echinoderms here reported have been recovered from 31 geological  
20 units or formations with ages ranging from the Carboniferous to Neogene. These records  
21 include 3 Carboniferous, 2 Permian, 4 Jurassic, 13 Cretaceous, 4 Paleogene, and 5  
22 Neogene. In the present manuscript, it is remarkable the presence of unavailable geological  
23 data (ND) of different localities with specimens included in this work. These localities  
24 include 2 Jurassic, 5 Cretaceous, 1 Paleogene, 3 Neogene, and 1 Quaternary (Figure 4); ND

1 data are derived from inaccurate or unfinished geological studies that have already been  
2 published. Although the CNP-UNAM is tasked with updating this information, the  
3 geological belonging of these localities has not been determined yet. In the future, these  
4 sites should be visited again to supplement their geological information.

5 The Capas Tlaxiaco unit covers a range from the Portlandian (Tithonian, Late Jurassic)  
6 to the Neocomian (Berriasian to Hauterivian, Early Cretaceous). The localities with catalog  
7 numbers IGM-loc 2997 and IGM-loc 3247 have been assigned to the Early Cretaceous,  
8 “Capas Tlaxiaco” unit; nevertheless, the original description of the specimens (Buitrón-  
9 Sánchez, 1970b) refers to a region as “to the west of Tlaxiaco town (Oaxaca)”, where only  
10 Jurassic outcrops are to be found. These inconsistencies can be solved only by having the  
11 precise coordinates of the collection site. (*Salenia mexicana*, *Codiopsis lorini*, and  
12 *Pseudocidaris clunifera*)

13 The Potomac Division unit (Colima) has been described as a shallow water  
14 paleoenvironment (Corona-Esquivel, 1993), where two species of echinoderms were  
15 reported, *Salenia texana* and *Heteraster mexicanus*. In the surrounding area (Sierra de los  
16 Libros, Colima), the Madrid Formation has been described as a succession of carbonates  
17 formed by facies of a relatively deep environment that includes the deposit of turbidites  
18 made up of benthic microfossils and allochemical material transported to the basin Eguiluz-  
19 de Antuñano et al. (2019). Genus *Heteraster* has been reported in environments up to 100  
20 m in depth (Forner and Castany, 2010); while the living reports of genus *Salenia* can reach  
21 2,000 m in depth (Pawson and Pawson, 2013). With further information, we would propose  
22 to assign the Potomac Division records to the Madrid Formation.

23 The San Juan Raya Formation carries the most diverse assemblage of echinoids in  
24 México, in which 12 species have been identified. In this report, we assigned the San Juan

1 Raya Formation records to the Aptian (Cretaceous). Analysis based on calcareous  
2 nannoplankton analysis carried out at the Barranca Agua de Burro and Barranca El Gavilán  
3 sections of the San Juan Raya Formation, indicate a late Valanginian? – early Hauterivian  
4 age (González-León et. al., 2015). A recent analysis based on coral diversity Löser (2021)  
5 reports that at least some parts of the San Juan Raya Formation are older and may have an  
6 Upper Valanginian to Lower Hauterivian age, even though a Barremian age and even  
7 Aptian also cannot be excluded.

8 The Tlayúa Formation (Puebla), due to its excellent quality of preservation, is the only  
9 one with fossil ophiuroid and holothuroid species reported in Mexico. This formation also  
10 has been reported for the class Asteroidea (Buitrón-Sánchez et al., 2015), but those  
11 specimens are not properly deposited in the CNP-UNAM yet. Crinoids have been described  
12 in Tlayúa, but the formal description of the echinoids from this formation is in progress.

13 The CNP-UNAM does not have fossil echinoderms from the North-eastern, Center, or  
14 Center-Pacific Mexican regions, nor Yucatán Peninsula (Figure 5). The collects have been  
15 focused on outcrops more attractive for science, but also easier to be reached. It is  
16 necessary to conduct more fieldwork along with the whole country, to recognize new  
17 localities with fossil records of echinoderm species.

18

## 19 **5. Conclusions**

20 The CNP houses a total of 385 records classified in 107 species: 19 Crinoidea, 1  
21 Asteroidea (*Paleoctenodiscus campaniurnus*), 1 Ophiuroidea (*Ophiactis applegatei*), 84  
22 Echinoidea, and 2 Holothuroidea (*Paleopentacta alencasterae* and *Parapsolus tlayuensis*);  
23 27 changes in their taxonomy were done (Table 1).



1 The echinoderm records come from 69 localities, 52 assigned to 31 formations/units  
2 across the country, and 17 not assigned yet (IGM-loc 75, 108, 387, 388, 392, 906, 1671,  
3 1899, 2178, 3055, 3095, 3117, 3152, 3156, 3206, 3207, and 3211). The Cretaceous is the  
4 best represented period with 14 formations/units and 6 localities not yet assigned.

5 San Juan Raya (Puebla) is the most diverse formation with 12 species of Echinoidea:  
6 *Cidaris muellerriedi*, *Coenholectypus transpecosensis*, *Hemiaster whitei*, *Heteraster*  
7 *aguilerai*, *Heteraster alencasterae*, *Heteraster alencasterae*, *Loriolia rotulare*, *Phymosoma*  
8 *mexicanum*, *Pseudocidaris clunifera*, *Pseudodiadema aguilerai*, *Salenia mexicana*,  
9 *Tetragramma cf. variolare*, and *Tetragramma picteti*.

10 The Tlayúa formation (Puebla), due to its excellent quality of preservation, is the only  
11 one with fossil ophiuroid and holothuroid species reported in Mexico. This formation also  
12 has reports for the class Asteroidea (Buitrón-Sánchez et al., 2015), but those specimens are  
13 not properly deposited in the CNP.

14 The Colección Nacional de Paleontología (CNP) collections of Mexican fossil  
15 echinoderms are the most important in Mexico/the world; with these updates, it can now be  
16 reliably used to inform future collecting and investigations. This paper is the beginning of a  
17 series of publications focused on the analysis of the systematics, paleodiversity, past  
18 ecosystem structures and paleobiogeography of the Mexican fossil echinoderms and  
19 applying novel approaches.

20

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1

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3 None

4

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21 diagnostici generum novorum vel minus cognitorum. Petitpierre, Neuchâtel.

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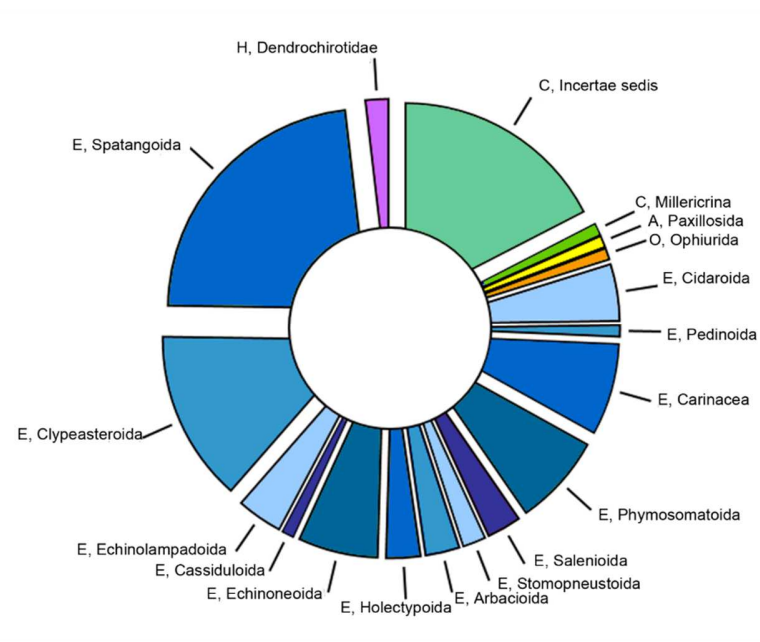
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### FIGURES AND TABLE CAPTIONS



2

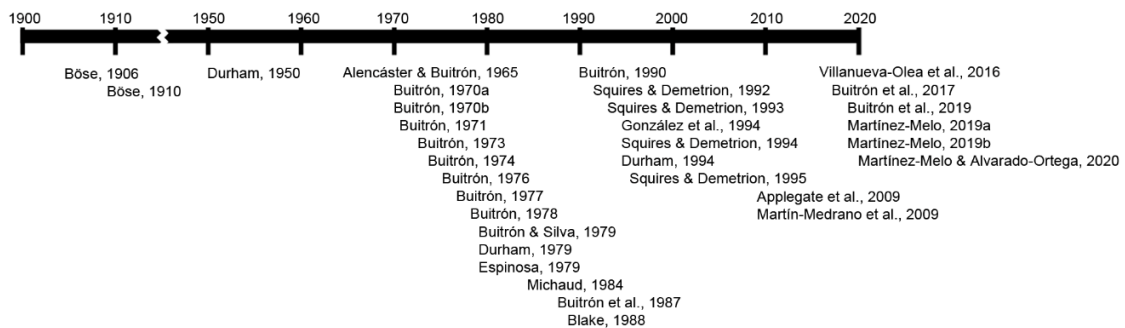
3 Figure 1. Taxonomic diversity. Diversity of the echinoderm groups represented in the 109  
 4 species in the CNP-UNAM. The pie-chart illustrates the percentage of species per  
 5 echinoderm orders. H, Holothuroidea (pink); C, Crinoidea (green); A, Asteroidea (yellow);  
 6 O, Ophiuroidea (orange); E, Echinoidea (blue).

7

- in color, two columns-

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1 Figure 2. Chronology of the publications that described echinoderm specimens currently  
2 housed into the CNP-UNAM.

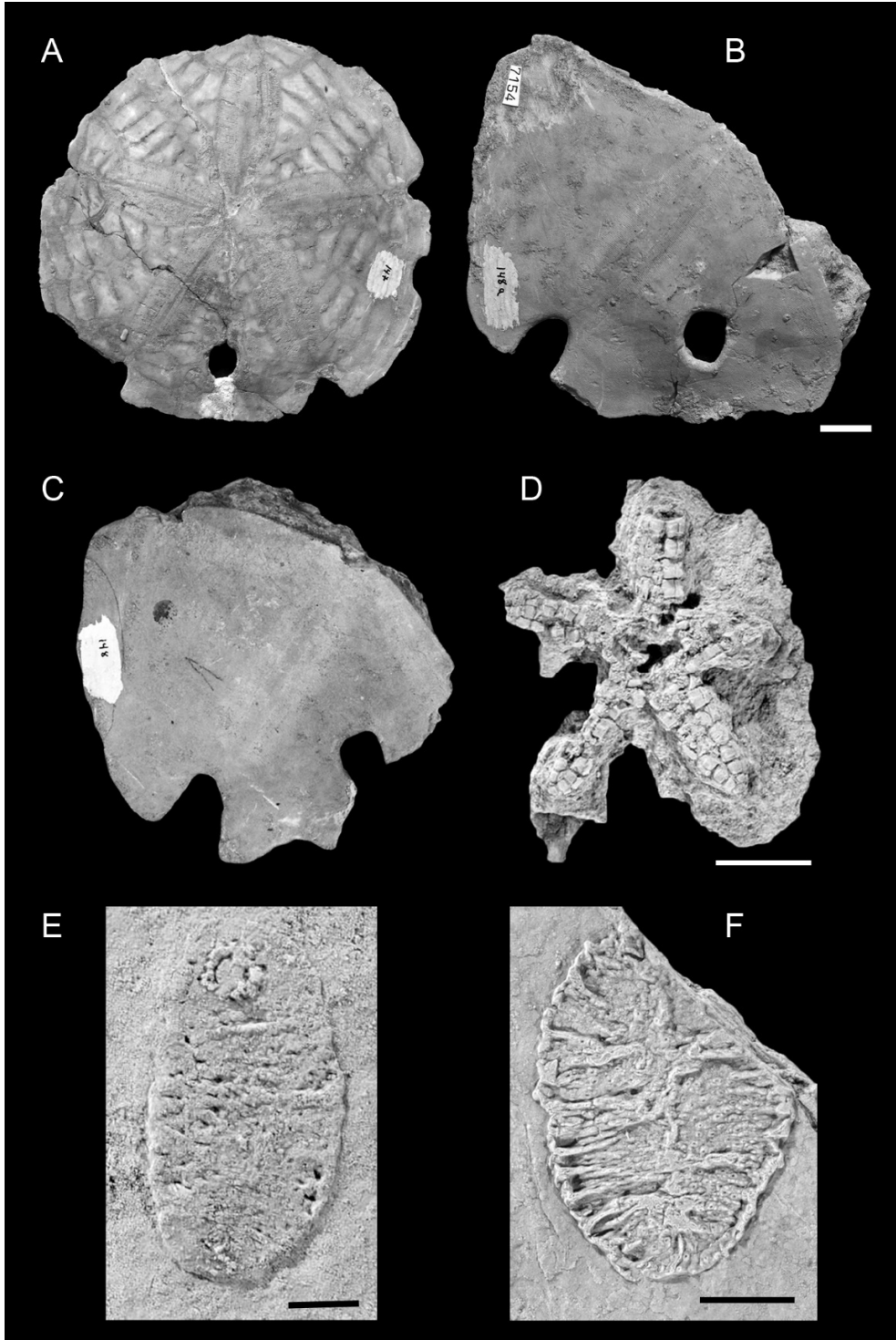
3 -two columns-

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2 -two columns-

3 Figure 3. Relevant specimens. The first echinoderms housed in the CNP; A, *Encope*

4 *tatetlaensis*† Böse, 1906 IGM 147; B, *E. tatetlaensis*† IGM 7154; and, C, *E. tatetlaensis*†

1 IGM 148 (Pliocene, Santa María Tatetla, Veracruz). The single fossil asteroid housed in the  
2 CNP; D, *Paleoctenodiscus campaniurnus*† Blake, 1988 Holotype IGM 4290 (Late  
3 Campanian, Baja California). The only two species of fossil holothuroids collected in  
4 Mexico; E, *Parapsolus tlayuensis*† Applegate, Buitrón-Sánchez, Solís-Marín, and  
5 Laguarda-Figuera, 2009 Holotype IGM 6850 (Albian, Tlayúa Formation, Puebla); F,  
6 *Paleopentacta alencasterae*† Applegate, Buitrón-Sánchez, Solís-Marín, and Laguarda-  
7 Figuera, 2009 Holotype IGM 6853 (Albian, Tlayúa Formation, Puebla).

8 -two columns-

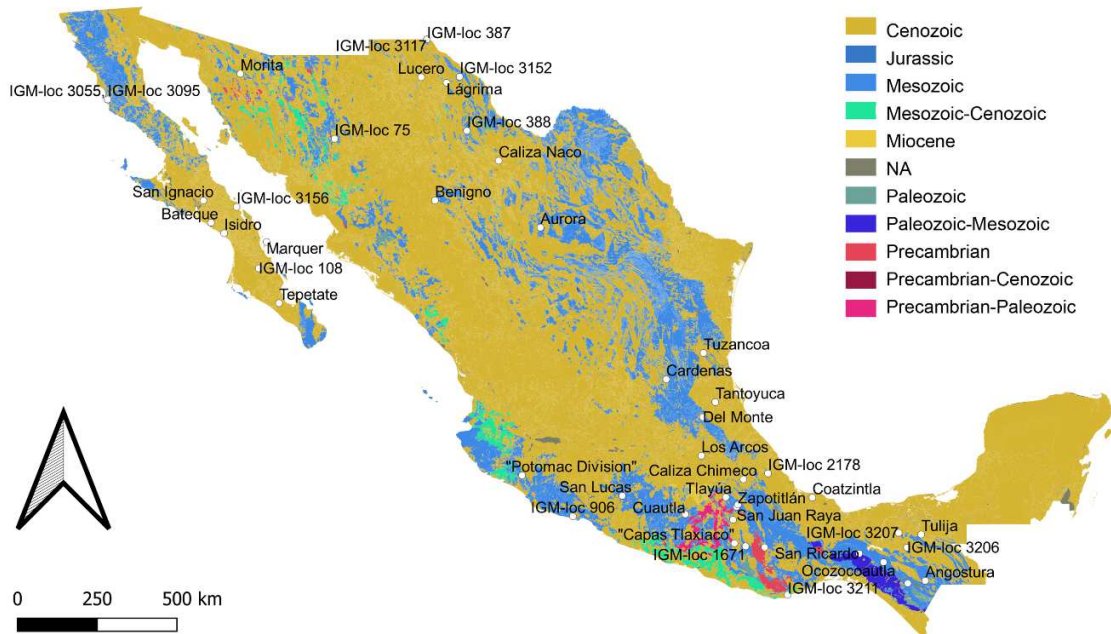
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Phanerozoic	Cenozoic	Quat.	Holocene	
			Pleistocene	IGM-loc 3156
		Neogene	Pliocene	IGM-loc 108, 2178, 3211, Marquer, Tantoyuca
			Miocene	San Ignacio, Isidro, Tulija IGM-loc 906
			Oligocene	IGM-loc 3095, 3206, 3207, 4039, Coatzintla Tantoyuca
		Paleogene	Eocene	Tepetate Bateque
			Paleocene	
		Mesozoic	Cretaceous	Upper
	Lower			Cuatla, IGM-loc 387, 392 Tlayúa, Aurora, Lucero, IGM-loc 388, 3117, Lágrima, "Potomac Division", Benigno, San Juan Raya IGM-loc 75, Morita, Zapotitlán, San Lucas "Capas Tlaxiaco", San Ricardo, IGM-loc 1671, 1899, 3152, C. Chimeco, "Calizas con <i>Cidaris</i> "
	Jurassic		Upper	
			Middle	
			Lower	
	Triassic		Upper	
		Middle		
		Lower		
	Paleozoic	Permian	Lopingian	
			Guadalupian	Los Arcos
Cisuralian			Tuzancoa	
Carboniferous		Penn.	Upper	Caliza Naco, Del Monte
		Miss.	Middle	
Lower				
Upper	Santa Rosa Inferior			
	Middle			
	Lower			

1 Figure 4. Stratigraphy distribution. Stratigraphic distribution of the formations, geological  
 2 units, and localities with fossil echinoderm records. Localities with IGM-loc have not been  
 3 assigned yet to a formation or unit.

4 - in color, one column-



7  
 8 Figure 5. Geologic map. Map of the fossiliferous localities in Mexico with echinoderm  
 9 reports. (Based on Servicio Geológico Mexicano, 2017).

10 - in color, two columns -



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8 Table 1. Taxonomic corrections. Checklist of the taxonomic changes to the database.

TAXON	IN DATABASE	CORRECT
CLASS CRINOIDEA		
<i>Cyclomischidae</i>	Cyclici	<i>Incertae sedis</i>
<i>Floricyclidae</i>	Cyclici	<i>Incertae sedis</i>
<i>Leptocarphiidae</i>	Cyclici	<i>Incertae sedis</i>
CLASS ASTEROIDEA		
<i>Paleoctenodiscus</i>	Ctenodiscidae	Porcellanasteridae
CLASS ECHINOIDEA		
<i>Acrocidaris</i>	Hemicidaroida	Pedinoida
<i>Calilampas</i>	Cassiduloida:	Echinolampadoida:
	Pliolampadidae	Echinolampadidae
Carinacea	Hemicidaroida	Superorder Carinacea
<i>Conulus</i>	Holactypoida	Echinoneoida
<i>Discoides</i>	Discooididae	Holactypidae
<i>Encope micropora</i>	<i>Encope perspective</i>	

<i>Eupatagus</i>	Brissidae	Maretiidae
<i>Globator</i>	Holactypoida	Echinoneoidea
<i>Goniopygus</i>	Arbaciidae	Acropeltidae
<i>Haimea</i>	Clypeasteroidea: Echinarachniidae	Oligopygidae
<i>Hemiaster</i>	Toxasteridae	Hemiasteridae
<i>Heterosalenia</i>	Acrosaleniidae	Saleniidae
<i>Loriolia</i>	Pseudodiadematidae	Emiratiidae
<i>Magnosia</i>	Arbaciidae	Incertae sedis
Oligopygidae	Holactypoida	Clypeasteroidea
<i>Pedinopsis</i>	Hemicidaroida	Pedinoida
<i>Pseudodiadema</i>	Hemicidaroida	Pedinoida
Stomechinidae	Phymosomatoida	Stomopneustoida
Stomechinidae	Phymosomatoida	Stomopneustoida
<i>Temnocidaris</i> ( <i>Stereocidaris</i> )	<i>Stereocidaris</i>	
<i>Tetragramma</i>	Pseudodiadematidae	Emiratiidae
<i>Washitaster</i> <i>bravoensis</i>	<i>Enallaster bravoensis</i>	

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CLASS HOLOTHUROIDEA

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<i>Paleopentacta</i>	<i>Paleopenctata</i>
<i>alencasterae</i>	<i>alencasterae</i>

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