

Lower Cretaceous (Albian) Asteroidea (Echinodermata) from Tepexi de Rodriguez, Puebla, Mexico

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Abstract: Seven asteroids are described from the Tlayua quarries (18° 35' N - 97° 56' W), recovered from the Middle Member of the Tlayua Formation. Tlayua quarries are 94 km southeast of Puebla and 2 km northeast of the town of Tepexi de Rodriguez in the Eastern part of central Mexico. The Middle Member is fossiliferous and composed mainly of a micritic lithographic limestone with layers having packs that consist of as much as 30 % hematite. The fossils are confined to these iron rich layers. These Middle Member are about 28 m thick. Due to the abundance, variety and conservation of its paleobiota, the Tlayua quarry is one of the most important fossiliferous localities from North America's Cretaceous. About 5 000 samples of invertebrate and vertebrate fossils have been collected from this locality and have been studied. The seven specimens belong to the Cretaceous strata and are believed to be of Lower Cretaceous (Albian) age. The asteroids described are referred to the genus *Astropecten*, *Plutonaster*, *Tamaria* and *Echinaster*. This is the first report of Cretaceous asteroids for Mexico. Rev. Biol. Trop. 63 (Suppl. 2): 7-15. Epub 2015 June 01.

Key words: Lower Cretaceous, Asteroidea, Echinodermata, Mexico.

The Tepexi de Rodriguez region, located in the meridional part of the State of Puebla, Mexico (Fig. 1) is famous because of its fossiliferous localities from Cretaceous-Tertiary, where Tlayua quarries (Albian) and "Pie de Vaca" outcrop (Pliocene-Pleistocene) stands out. Due to the abundance, variety and conservation of its paleobiota, the Tlayua quarry is one of the most important fossiliferous localities from the Cretaceous of North America. About 3 500 samples of invertebrate fossils have been collected from this locality, which were studied or are being studied in the Institute of Geology of the Universidad Nacional Autónoma de México, as much as in many

foreign institutions. The best preserved material belongs to vertebrates represented by fishes and reptiles; the fishes include, more than 50 different holosteans and teleosteans (Applegate & Espinosa-Arrubarrena, 1984; Espinosa-Arrubarrena & Applegate, 1996).

Due to the characteristics facies and the environmental conditions, Mollusca are not abundant; within them there have been collected gastropods (cassiopids) and cephalopods ammonoids of the genus *Mortonicerias* and belemnoids of the genus *Neohibolites*. Among the ichnofossils are found *Ophiomorpha nodosa*, and insects of the family Tipulidae. Various species of echinoderms are also found crinoids,

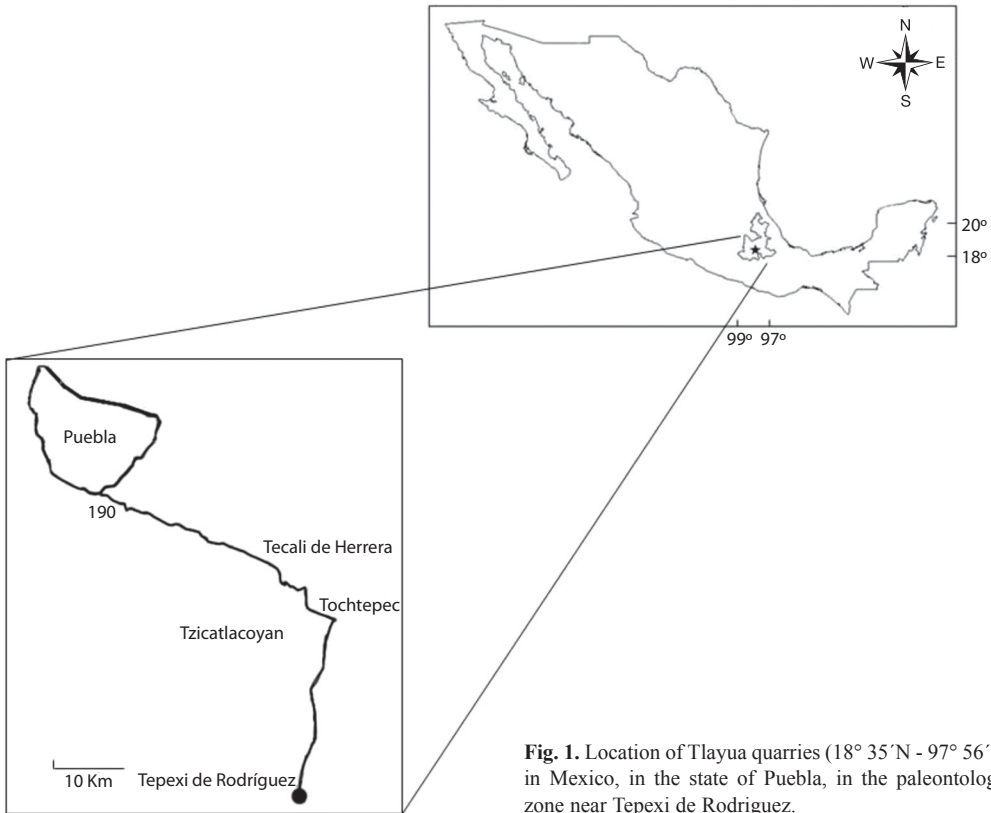


Fig. 1. Location of Tlayua quarries ($18^{\circ} 35' N - 97^{\circ} 56' W$), in Mexico, in the state of Puebla, in the paleontological zone near Tepexi de Rodríguez.

ophiuroids, asteroids, holoturoids and echinoids (Buitrón & Olivos, 1987; Buitrón, 1991).

Geologic setting: The Albian limestones that crop out in the Barranca de Tlayua have been formally designate with the name of Tlayua Formation which includes a sequence with a thickness of about 300 m, divided in three members; lower, medium and upper (Fig. 2).

The lower member consists in a fine grain limestone sequence (mudstone to wackstone), micritic, with few intraclasts and abundant miliolids. Its stratification changes from massive to thick, with thin biostromes, with thicknesses between 20 cm and 50 cm of rudists like *Toucasia polygyra* (Alencaster, 1973), and ostreids from of the genus *Chondrodonta*. Within the limestones appear white and black chert concretions and dark flint glasses, in some areas the fossils are completely silicified (Espinosa-Arrubarrena & Applegate,

1996). The medium member consists of a 48 to 50 m sequence, of thinly stratified, laminated, micritic limestone (mudstone) of cream to reddish colors. The stratification changes its thickness from few millimeters to 15 cm. Inside of the beds there are dark flint glasses of a thickness from a few millimeters to 15 cm and 70 cm long. In some fracture planes, widened by the water and differential dissolution, the lamination is emphasized remarkably, phenomenon that is seen clearly in the wall of the quarry. The bed surfaces are covered by a very thin layer of hematite that gives to the flagstones a characteristic red color. This material represents carpets of Cyanophyta seaweeds microorganisms from normal to hipersaline sea environments.

The best outcrop of the medium member is exposed at the quarry of Tlayua, the one that was worked in the upper intermediate part of the section, where most of the fossiliferous

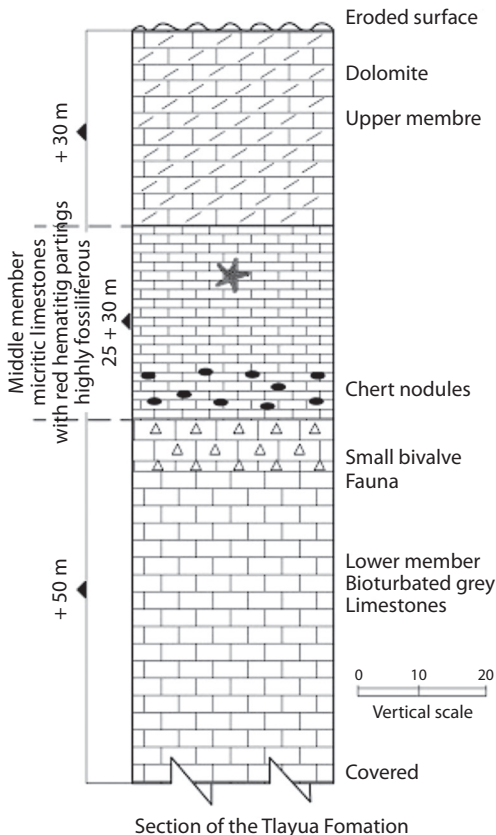


Fig. 2. A stratigraphic section of the Tlayua Formation with an enlargement of the Middle member, showing the approximate location of the fossil asteroids described this paper.

material have been recollected. The specimens consist of cephalopods (ammonoids, belemnoids), regular echinoids (cidaroids) crinoids, asteroids, ophiuroids, holothuroids, ichnofossils (*Ophiomorpha nodosa*), insects (Diptera), and leaves of gymnosperms (*Podozamites*), seaweed carpets, fishes and marine or continental reptiles. The age of this member is established by the ammonoids *Hysterocheras*, *Mortoniceras* and cf. *Anisoceras* (Cantú-Chapa, 1987), and by the belemnoids *Neohibolites praeultimus* Spaeth, *N. aff. minimus* Stolley, *N. minimus clavaformis* Seibertz and Buitrón, which indicates a medium and late-Albian age (Seibertz & Buitrón, 1987). The faunistic content proves a mixed thanatocenosis.

The presence of seaweed carpets in the locality (Seibertz & Buitrón, 1987) indicates in general, shallow depth. The rock appears as laminated “mudstone” seaweeds with intercalations of “pellets”. The presences of galleries or small holes on some of the fossils indicates the activity of *Ophiomorpha nodosa* and the ashes and feldesphatic sandstone and clay between some beds indicates volcanic activity during the Middle Albian time (Frey et al., 1978) so it is concluded that depth, must have corresponded shallow sea. It is considered that intermittent or low energy currents have existed, as *O. nodosa* increases the size of its population in superficial calm and protected seas, in the locality the number is scarce. On the other hand, Applegate (1987) comments that in the same level small fishes with the heads aligned in the same direction have been found; this might be understood as occasional currents being responsible of this arrangement.

About the continental environment, the presence of a *Pseudocarcerus* or alike insect genus (Diptera, Tipulidae) indicates that they were predators but they also visited flowers and nectar (Downs & Smith, 1969). The adults of Tipulidae are usually found between the weeds and in the shade of trunks with vegetation near aquatic deposits.

Two thirds of the species of the Hybotinae (Diptera, Hybotinae) are found in the tropics and subtropics of the oriental and Neotropical regions (Chuala, 1983 in Waters, 1989) that is why it is supposed a warm-humid climate in this locality. The Upper member consists in an incomplete sequence of medium to thick dolomite and dolomitic limestone beds, gray colored with light and dark tonality whose best outcrops are on the septentrional margin of Tlayua cliff. The dolomite goes transitionally to a fine-grained micritic limestone, from medium to thin bedding, and it is observed in road to the Agua de Luna ranch. The petrographic study shows that there are two microfacies. In both cases, the dolomite is secondary (Malpica-Cruz et al., 1989; Pantoja, et al., 1989). This precarious secondary dolomitization occurs generally in the fresh water-sea water interface

(Friedman & Sanders, 1967). The Tlayua Formation is correlated with the Morelos Formation (Fries, 1960) with the Orizaba Limestone from the sierra of Tentso (Padilla, 1973) and with part of the Teposcolula Limestone of the Mixteca Alta (Ferrusquía, 1976).

Paleoenvironments: The Albian of the region consist of an extended platform covered by a sea with low depth and moderate energy, with some elevated areas that generate island and lagoons environments a calcareous substratum which depositional conditions were very similar to the presently developing at the Bahamas. The lower member of the Tlayua Formation was deposited in an inner platform, near a litoral zone of moderate to low energy. The facies of this member is distinguished by the presence of micritic limestone, with some intraclasts and benthic foraminifera. Intercalated in this section there are zones with banks of requienid (packstones), and banks of oysters (packstones) that presents bars or islets that delimits the inner platform from the high energy seas zones. In the nearest facies to the intermediate member is observed a transitional change between micritic and microsparitic limestone, with some fractures filled with recrystallized calcite in form of dogs teeth and meniscus shaped that indicates diagenetic processes in the vadose zone with predominance of fresh over the sea water. The medium member was deposited in the intertidal zone of a lagoon environment. The microsparitic limestone with thin laminated beds are mainly formed by micrite and in a lower percentage by several characteristic. The main one is by micritic with foraminifers and in general with a benthonic fauna of lagoon environment. Likewise, transitional changes are shown between micritic and microsparite and another that contains incipient microstilolits. The horizontal laminated stratification was produced by the influence of high dynamic currents (by traction) and changes of salinity temperature, pH and in the rate of sedimentation. The intraclasts and the benthonic foraminifers sustain the proposed environment (Malpica-Cruz et al., 1989).

Based on the microfacies and paleoenvironmental studies, Malpica-Cruz et al. (1989) proposed a conceptual model, with local characteristics, for the medium member. The depositional environment belongs to an intertidal zone in a lagoon environment with a wide inundation-desiccation surface with arrival of exogenous fauna (coming from reefs, and open sea) during the high tide and the storms. The fauna was caught, during the low tide in puddles and hollows formed by-digging and desiccation.

MATERIALS AND METHODS

The geologic-paleontological prospection on Tepexi de Rodriguez area was realized in different times since 2010. The asteroids fossils from Tlayua quarry consist of impressions that indicate a rapid burial coupled with very diagenetic formation. The colors of these fossils are from honey to almost ivory-colored calcite. The skin has also been replaced by amorphous deposits of calcite which at times may be fragmentary or composed of very small crystals (0.3 - 0.4 mm).

Seven asteroids were deposited in the Colección Nacional de Paleontología, Instituto de Geología, Universidad Nacional Autónoma de México, Mexico City. The catalog number correspond to IGM-3742-IGM-3748. Also some measures were taken, major radius (R), length from centre of the disc to tip of an arm, and minor radius (r), from centre of disc to interradial edge.

RESULTS

SYSTEMATIC PALEONTOLOGY

Class Asteroidea, Blainville, 1830

Order Paxillosida Perrier, 1884

Family Astropectinidae Gray, 1840

Diagnosis: A family of mainly infaunal Paxillosida widely ranking bathymetrically; normally with five arms of various length usually merging with the disc to form rounded or at least blunt-angled interradial arcs; abactinal

plates highly paxilliform, small and crowded; an apical (epiproctal) cone evident in some specimens; papulae either present over the whole paxillar area or absent centrally and midradially; both series of marginal plates more or less block-like, conspicuous laterally and usually also dorsally and ventrally, armed with more or less conspicuous spinelets or granules and often with some large spines, especially on the inferomarginals, adambulacral plates broad, the farrow margin most often short and angular or convex but sometimes longer and nearly straight, armed with large furrow and subambulacral spines; oral plates large, usually modified triangular in shape but sometimes constricted and bar-shaped (Clark & Downey, 1992).

Genus *Astropecten* Gray, 1840

Astropecten sp.

Figs. 3, 4, 5

Description: The specimen with the number IGM-3742 (R = 13.68 mm, r = 4.29 mm) represent the actinal surface with ambulacral grooves are well defined, the adambulacral plates are differentiated from inferomarginal plates. Due to the size this organism was a juvenile of the genus *Astropecten* (Fig. 3). The sea star with the number IGM-3743 (R =

15.09 mm, r = 4.77 mm) represent the abactinal surface of an asteroid; arms are triangular, wider at the bottom than at the tip (1.70 mm), pointed, although this is blunt, there are rows of superomarginal and abactinal plates, epiproctal cone is observed, which indicates that an organism was a juvenile of the genus *Astropecten* (Fig. 4). The specimen with the number IGM-3744 (R = 15.58 mm, r = 5.19 mm) represent the actinal surface, arms are wider at the bottom than at the tip, blunt. The ambulacral grooves are broad at the bottom of the arm and

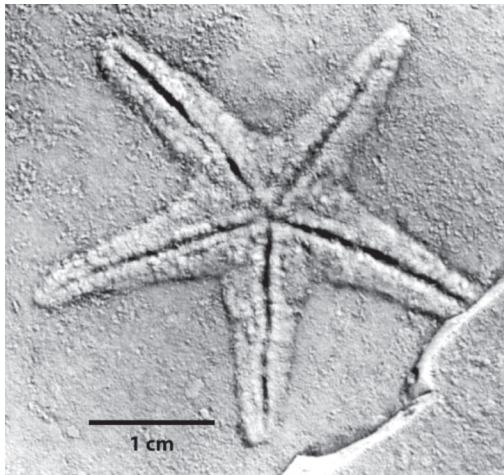


Fig. 3. *Astropecten* sp. from Tepexi de Rodriguez, Puebla, Mexico, IGM-3742.

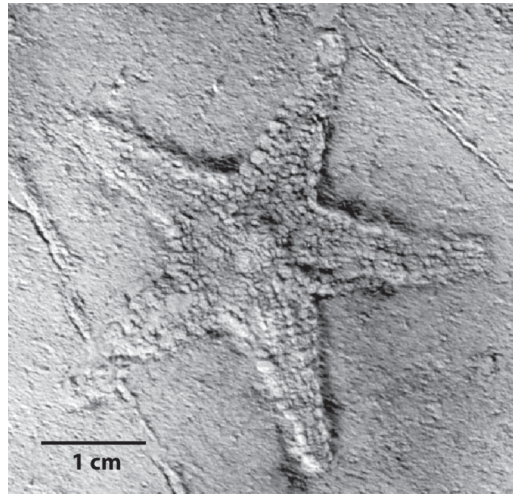


Fig. 4. *Astropecten* sp. from Tepexi de Rodriguez, Puebla, Mexico, IGM-3743.

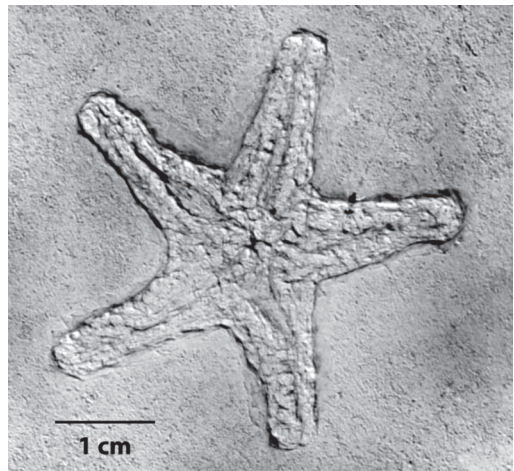


Fig. 5. *Astropecten* sp. from Tepexi de Rodriguez, Puebla, Mexico, IGM-3744.

gets narrower toward the tip, also shows that the oral plates are prominent and have a median groove. Due to the size this organism was a juvenile of the genus *Astropecten* (Fig. 5).

Genus *Plutonaster* Sladen 1889

Plutonaster sp. Fig. 6

Diagnosis: The sea star with the number IGM-3745 ($R =$, $r = 12.50$ mm) correspond of the actinal surface, ambulacral grooves are observed and they are narrow, the adambulacral plates are differentiated from inferomarginal plates. The actinal plates are observed and they possibly have one spine on each plate. These characteristics indicate that this organism was a juvenile of the genus *Plutonaster*.

Order Valvatida Perrier, 1884

Family Ophidiasteridae Verrill, 1870

Diagnosis: A family of Valvatida with small disc, arms usually long, slender, cylindrical, or sometimes trigonal in cross-section, four to seven (usually five); body usually covered with granular membrane; abactinal plates tessellate; marginal in two series, generally not conspicuous, equal, opposite, lateral, plates arranged in longitudinal series parallel to the furrow; actinal areas small; adambulacral furrow margin without apophyses, furrow spines usually small, blunt; pedicellariae, when present, alveolar (Clark & Downey, 1992).

Genus *Tamaria* Gray, 1840

Diagnosis: A genus of Ophidiasteridae with heavy, rigid skeleton; arms tapering or petaloid; abactinal plates in regular longitudinal series; body covering granulose; popular pore areas in 4-6 longitudinal rows, none below inferomarginals; alveolar pedicellariae present and usually abundant (Clark & Downey, 1992).

Tamaria sp. Fig. 7

Description: The sea star with the number IGM-3746 ($R = 11.77$ mm, $r = 5.75$



Fig. 6. *Plutonaster* sp. from Tepexi de Rodriguez, Puebla, Mexico, IGM-3745.

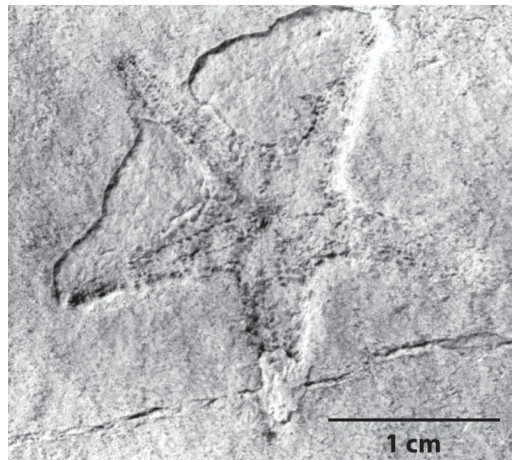


Fig. 7. *Tamaria* sp. from Tepexi de Rodriguez, Puebla, Mexico, IGM-3746.

mm) represent the abactinal surface; arms are wider at the bottom (5.64 mm) than at the tip (1.70 mm). The supermarginal plates are well defined, also it have paxillae in the arms. The epiroctal cone is observed, which indicates that this organism was a juvenile of the genus *Tamaria*.

Genus *Ophidiaster* Agassiz, 1836

Diagnosis: A genus of Ophidiasteridae with small disc, arms moderately long, cylindrical, rarely tapering; abactinal plates in regular longitudinal and transverse series; skin

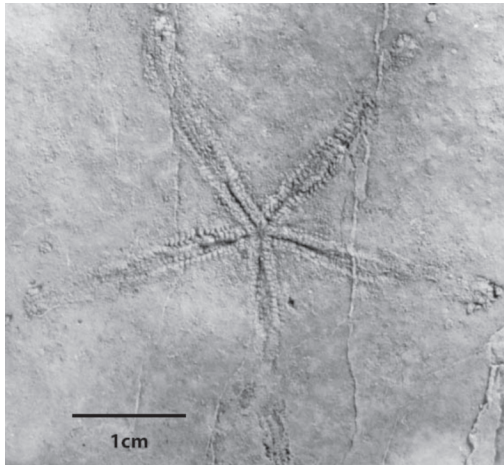


Fig. 8. *Ophidiaster* sp. from Tepexi de Rodriguez, Puebla, Mexico, IGM-3747.

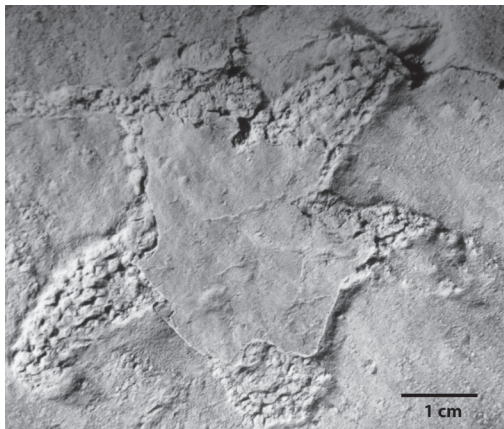


Fig. 9. *Echinaster* sp. from Tepexi de Rodriguez, Puebla, Mexico. IGM-3748.

uniformly granulose; papular areas in eight longitudinal series, one series each side below inferomarginal plates; pedicellariae, when present, sugartongs form in well-developed alveoli.

Ophidiaster sp. Fig. 8

Description: The star with the number IGM-3747 has five long, slender and cylindrical arms and abactinal plates in regular

longitudinal series, these series are interspersed with the popular areas which indicates that this organism was of the genus *Ophidiaster*.

Orden Spinulosida Perrier, 1884
Family Echinasteridae Verrill, 1870
Genus *Echinaster* Müller & Troschel, 1840

Diagnosis: Small disc, cylindrical arms, abactinal skeleton reticular; armament ranging from moderately fine with coarse spinelets or small spines, usally single on each plate, sometimes only on the primaries; abactinal and intermarginal meshes occupied by a mixture of papulae and epidermal glands; papulae rares or absent below the inferomarginals (Clark & Downey, 1992).

Echinaster sp. Fig. 9

Description: The star with the number IGM-3748 represent the abactinal surface; abactinal plates form a reticule fine and irregular, with the papular areas in the spaces of the grid, the tips of the arms are more or less tapering.

DISCUSSION

The Tlayua quarry Cretaceous (Albian) has an age of 110 Ma., and has a thanatocenosis which is formed by plants, ichnofossil of invertebrates, molluscs (gastropods, ammonoids), insects, echinoderms (crinoids, asteroids, ophiuroids, echinoids, holothurians) fishes, reptiles (Buitrón & Malpica, 1987; Cantú-Chapa, 1987; Seibertz & Buitrón-Sanchez, 1987; Applegate, 1988; Feldmann et al., 1998; Buitrón-Sanchez, et al, 2009). This is the first record of Cretaceous asteroids of Mexico. Although the conservation of the specimens of asteroids is not very good, morphological aspects that allowed generic identification were observed. Some measures could not be taken, because in some specimens is not visible disk center and others have the tips of the arms.

RESUMEN

Asteroidea (Echinodermata) del Cretácico inferior (Albaniano) de Tepexi de Rodríguez, Puebla, México. Siete asteroideos son descritos de las canteras de Tlayua (18° 35' N - 97° 56' W), recuperados del miembro medio de la formación Tlayua. Las canteras de Tlayua se encuentran a 94 km al sureste de Puebla, y a 2 km de noreste del pueblo de Tepexi de Rodríguez en la parte este del centro de México. El miembro medio es fosilífero y está compuesto principalmente de basamentos micríticos litográficos con capas con grupos que consisten de la menos 30 % de hematita. Los fósiles están confinados a estas ricas capas en hierro. Estos miembros medios poseen un espesor de aproximadamente 28 m. Debido a la abundancia, variedad y conservación de su paleobiota, la cantera de Tlayua es una de las localidades fosilíferas más importantes del Cretácico de Norte América. Cerca de 5 000 muestras de fósiles de invertebrados y vertebrados han sido colectadas y estudiadas de esta localidad. Las siete especies pertenecen al estrato del Cretácico y se cree que pertenecen a la edad del Cretácico inferior (Albaniano). Los asteroideos descritos se refieren a los géneros *Astropecten*, *Plutonaster*, *Tamaria* y *Echinaster*. Este es el primer registro de asteroideos del Cretácico para México.

Palabras claves: Cretácico inferior, Asteroidea, Echinodermata, México.

REFERENCES

- Alencáster, Y. G. (1973). Una nueva especie de *Toucasia* en el Cretácico Medio de los estados de Oaxaca y Puebla. *Paleontología Mexicana*, 36, 4-20.
- Applegate, P. S. (1987). A preliminary study of the Tlayua Quarry near Tepexi de Rodríguez, Puebla. *Revista de la Sociedad Mexicana de Paleontología*, 1, 40-54.
- Applegate, P. S. (1988). A new genus and species of holostian beonging to the Family Ophiopsidae, *Teoichithys kallistos* from the Cretaceous near Tepexi de Rodríguez, Puebla. *Revista Instituto de Geología*, 7, 200-205.
- Applegate, P. S. & Espinosa, A. L. (1984). *Libreto-guía de la Excursión "Las calizas litográficas de la Cantera Tlayúa en Tepexi de Rodríguez, Puebla*. VII Convención Nacional. México: Sociedad Geológica Mexicana ().
- Buitrón, B. E. & Malpica, C. R. (1987). *Libreto-guía de la excursión "Tepexi de Rodríguez, Puebla, una localidad fosilífera famosa de México*. I Congreso Nacional de Paleontología. México: Sociedad Mexicana de Paleontología.
- Buitrón, B. E. & Olivos, F. (1987). Una holoturia del Cretácico Medio de México. In C. J. Barbarin, H. J. Gursky & P. Meiburg (Eds.), *El Cretácico de México y América Central* (pp. 125). Linares, México: Actas de la Facultad de Ciencias de la Tierra, Universidad Autónoma de Nuevo León.
- Buitrón, B. E. (1991). *Los equinodermos del Cretácico Temprano*. Consejo Nacional de Ciencia y Tecnología (CONACYT). *Información Científica y Tecnológica*, 13, 15-18.
- Cantú-Chapa, A. (1987). Las amonitas del Albiano Superior de Tepexi de Rodríguez, Puebla. *Sociedad Mexicana de Paleontología*, 1, 159-160.
- Clark, A. M. (1993). An index of names of recent Asteroidea. Part 2. Valvatida. In M. Jangoux & J. M. Lawrence (Eds.), *Echinoderm Studies* (pp. 187-366). Rotterdam: A. A. Balkema.
- Clark, A. M., & M. E. Downey. (1992). *Starfishes of the Atlantic*. London: Chapman and Hall.
- Downes, J. A., & Smith, S. M. (1969). New or little-known feeding habits in Empididae (Diptera). *Canadian Entomology*, 101, 404-408.
- Espinosa-Arrubarrena, L., & Applegate, S. P. (1996). A paleoecological model of vertebrate bearing beds in the Tlayúa quarries, near Tepexi de Rodríguez, Puebla, México. In G. Arratia & G. Viohl (Eds.), *Mesozoic fishes-Systematics and Paleoecology* (pp. 539-550). München: Verlag.
- Feldmann, M. R., Vega, V. F., Applegate, P. S., & Bishop G.A. (1998). Early Cretaceous Arthropods from the Tlayúa Formation at Tepexi de Rodríguez, Puebla, México. *Journal of Paleontology*, 72, 79-90.
- Ferrusquía, V. I. (1976). Estudios geológico-paleontológicos en la región Mixteca, pt. 1: Geología del área Tamazulapan-Teposcolula-Yanhuitlán, Mixteca Alta, Estado de Oaxaca, México. *Boletín Instituto de Geología, Universidad Nacional Autónoma de México*, 97, 1-160.
- Frey, R. W., Howard, J. D., & Pryor, W. A. (1978). *Ophiomorpha*: Its morfologic, taxonomic, and environmental significance. *Palaeogeography, Palaeoclimatology and Palaeoecology*, 23, 199-229.
- Friedman, G. H., & Sanders, J. E. (1967). Origin and occurrence of dolostomes. In G. V. Chilingar, H. J. Bissell & R.W. Fairbrige (Eds.), *Carbonate rocks* (pp. 267-348). Amsterdam: Elsevier.
- Fries, C. J. (1960). Geología del Estado de Morelos y partes adyacentes de México y Guerrero, región central y meridional de México. *Boletín, Instituto de Geología, Universidad Nacional Autónoma de México*, 60, 1-236.
- Malpica, C. V., Pantoja, A. J., & Galguera, R. G. (1989). *Microfacies de la Cantera de Tlayúa, Puebla*. Memoria Tercer Simposio sobre Geología Regional de México. Universidad Nacional Autónoma de México, México.

- Padilla, S. R. (1973). *Estudio geológico general de la Sierra de El Tenzo, Estado de Puebla* (Tesis Profesional). Facultad de Ingeniería, Universidad Nacional Autónoma de México, México D. F.
- Pantoja, A. J., Malpica, C. V., & Galguera, R. G. (1989). *Geología de los alrededores de la Cantera de Tlayúa, Tepexi de Rodríguez, Puebla*. Memoria Tercer Simposio sobre Geología Regional de México, México.
- Seibertz, E., & Buitron-Sanchez, B. E. (1987). Paleontología y estratigrafía de los *Neohibolites* del Albiano de Tepexi de Rodríguez, Edo. de Puebla (Cretácico Medio). *Revista de la Sociedad Mexicana de Paleontología*, 1, 285-299.
- Waters, S. B., (1989). A new Hybotine Dipteran from the Cretaceous of Botswana. *Paleontology*, 32, 657-667.

