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Geosites of paleontological importance in the Central region of Chiapas, Mexico: a first step to geoconservation in Chiapas

Avendaño Gil, Manuel Javier[a,*]; López, Sergio[b]; Carbot-Chanona, Gerardo[a]; Morales Iglesias, Horacio[c]

[a] Departamento de Paleontología, Dirección de Gestión, Investigación y Educación Ambiental, Secretaría de Medio Ambiente e Historia Natural, Calzada de los Hombres Ilustres S/N, Centro C.P. 29000, Tuxtla Gutiérrez, Chiapas.
[b] Laboratorio de Ecología Evolutiva, Instituto de Ciencias Biológicas, Universidad de Ciencias y Artes de Chiapas, Libramiento Norte Poniente 1150, Colonia Lajas Maciel C.P. 29039, Tuxtla Gutiérrez, Chiapas.
[c] Centro de Investigación de Riesgos y Cambio Climático, Universidad de Ciencias y Artes de Chiapas, Edificio 21, Ciudad Universitaria, Libramiento Norte Poniente No. 1150, Colonia Lajas Maciel C.P. 29039, Tuxtla Gutiérrez, Chiapas.

[*] javierdchiapas@gmail.com

Abstract

The systematic safeguarding and study of the paleontological heritage of Chiapas began in 1989, consolidating with the inauguration of the Museum of Paleontology "Eliseo Palacios Aguilera" and its Paleontological Collection in 2002. As a result of these activities, it has treasured bibliographic information, experience in cabinet and field research, among others. All these activities have led us to join national and international proposals such as being part of the Paleontological Council of the Instituto Nacional de Antropología e Historia (INAH) and the Global Indicative List of Geological Sites (GILGES, geosites and geoparks). The present work aims to point out and characterize the 13 geosites of paleontological importance located in the Central region of Chiapas, that have been investigated during the works that has been carried out by the staff of the Secretaría de Medio Ambiente e Historia Natural (SEMAHN). For each geosites is mentioned: their names, geographical location, fossils found, generated publications, chronostratigraphic position, environmental inference. Also, it is mentioned in each geosites: information that has begun to be disseminated to social sectors such as students, research professors, ejidatarios and providers of tourist services in order to raise awareness of the importance of the paleontological resource and its potential use (*e.g.* geotourism), activities that guide us to conservation of the environment and the resources.

Keywords: Fossil, geosites, paleontological heritage, natural heritage.

Resumen

El resguardo y estudio sistemático del patrimonio paleontológico de Chiapas se inició en el año de 1989, consolidándose con la inauguración del Museo de Paleontología "Eliseo Palacios Aguilera" y su Colección Paleontológica en 2002. Como resultado de las actividades se ha atesorado información bibliográfica, experiencia en investigación de gabinete y campo, entre otros, que nos han llevado sumarnos a propuestas nacionales e internacionales, como formar parte del Consejo de Paleontología del Instituto Nacional de Antropología e Historia (INAH) y del Global Indicative List of Geological Sites (GILGES). El presente trabajo tiene como objetivo destacar y caracterizar 13 geositios de importancia paleontológica ubicados en la región central poniente de Chiapas que han sido investigados durante los trabajos realizados por el personal de la Secretaría de Medio Ambiente e Historia Natural (SEMAHN). Para cada sitio se mencionan sus nombres, ubicación geográfica, fósiles encontrados y publicaciones generadas, posición cronoestratigráfica e inferencia ambiental, información que ha comenzado a difundirse en los sectores sociales como son, estudiantes, profesores-investigadores, ejidatarios y prestadores de servicios turísticos, con el fin de concientizar sobre la importancia del recurso paleontológico y su potencial uso educativo y turístico (e.g. geoturismo), actividades que nos encaminan a su conservación haciendo un uso sustentable de los recursos.

Palabras clave: *Fósil, geositio, patrimonio paleontológico, patrimonio natural.*

1. Introduction

In 1989 the Instituto de Historia Natural (IHN) systematically initiated the study of the paleontological and geological resources of Chiapas. As one of the tangible results was the creation of the Museum of Paleontology "Eliseo Palacios Aguilera" (MUPEPA), which is also the repository of a well-established paleontological collection that, to date, housed more than 5000 fossils (Avendaño *et al.*, 2004; Carbot-Chanona, 2015). The MUPEPA work as a platform from which efforts are added to integrate the paleontological and geological resources of the State of Chiapas with the integral conservation of the Natural Heritage initiated with the project GILGES (Global Indicative List of Geological Sites) in 1989. The GEOSITES project began between the years 1993-1995 and the International Geosciences and Geoparks Program was officially accepted in November 2017 by the UNESCO. This last program is characterized by a holistic vision that include the Cultural Heritage together with the Natural Heritage (Gallego, 1998; UNESCO, 2015).

In concordance with UNESCO's proposal and the international Union for Conservation of Nature strategy (UICN, 2020), MUPEPA has worked on the articulation of biological and geological heritage. Examples of this are the case of the Natural Reserve of Laguna Bélgica (Avendaño-Gil & Coutiño-José, 2009), as well as a property located in La Mesa de Copoya, within the urban area in the municipality of Tuxtla Gutiérrez. These examples highlight the presence of geological and paleontological characteristics and are used for educational and scientific purposes (Avendaño-Gil, 2011).

The assessment and protection of what is now known as geological heritage has increased considerably, not only in scientific and academic circles but also among those dedicated to the planning of the territory and its natural resources (Di-Gregorio and Ulzega, 2003). With this new trend, the concept of geological heritage has become very important as global scientific institutions and organizations. Different organizations recognize and promote the conceptual and practical development of the concept of geological heritages such as: UNESCO, the Union of Geological Sciences (IUGS), the International Geographical Union and the International Association of Geomorphologist (IAG). These organizations also recognize other related concepts such as: geoconservation, geotourism, geoproducts, geodiversity, geomorphosites, geomorphological monuments, geomorphological sites, geopark and geosites (Reynard, 2005; Palacio, 2013).

The systematization of the geosites is important for establishes bases for geoconservation, research and educational activities. In that sense, the paleontological information of the geosites is essential because is the start point to generate strategies for conservation. The present work aims to point out and characterize 13 geosites of paleontological importance located in the Chiapa de Corzo, Tuxtla Gutiérrez and Ocozocoutla de Espinosa municipalities, in the Central area of Chiapas. These 13 geosites have been investigated during the last two decades by the staff of the Secretaría de Medio Ambiente e Historia Natural (SEMAHN).

2. What are geosites?

Geosites (sites of geological importance) are sites that contain information about the conformation and dynamics of the Earth (Bruno *et al.*, 2014). Some of the most common aspects to consider in geosites are: (i) The representativeness and/or interest of the geological record and the time-range represented; (ii) exceptional geoforms; (iii) paleontological content; (iv) relevant tectonic and structural elements; (v) minerals, rocks and/or sedimentary structures unique or rare; and (vi) the possibility of identifying paleogeographies and/or paleoenvironments that reveal the geological evolution of the region (Carcavilla *et al.*, 2019). Geosites can be classified based on their facies: paleoecosystem, ichnological value, taphonomic patterns, catastrophic events and geoarchaeological importance (Bruno *et al.*, 2014). Some geosites contain several subtypes and some are especially important for the construction of paleogeographic maps (Bruno *et al.*, 2014).

Originally, the definition of geosites do not distinguish between sites of geological interest and sites of geomorphological interest, which is explained by the close relationship that in many cases exists between the two of them (Palacio, 2013). On the other hand, the differentiation between geosites and geomorphosites can be justified by their temporal and spatial character and emphasis, respectively. Geosites, like geology itself, are more associated with the temporal nature of the site helping to explain the evolution of a locality a region or the planet itself (Palacio, 2013). For its part, the geomorphosite involves a three-dimensional spatial connotation of the relief shapes which is associated with spatial attributes rather than temporal attributes, without them being absent. The shapes of the relief occupy a quantifiable space (length, width, height, depth, volume) while geosites reflect a process or phenomenon that is not necessarily characterized by its dimensions but by its location in time (Palacio, 2013).

This research emphasizes the temporal character of the geosites with the fossil material that it reports but recognizing that the Geosites would be located within a space (surface). A critical element in the assessment of geosites is the definition of the spatial feature on which that procedure will be executed. Generally speaking, the space unit or mapping unit must consist of a portion of land with specific characteristics (INE, 2004).

3. Geology and paleontology of the central west region of Chiapas

The location of the geosites pointed in this work embraces three municipalities in the central area of Chiapas: Tuxtla Gutiérrez, Chiapa de Corzo and Ocozocoautla de Espinosa (Figure 1). These municipalities are located to the west of the Central Depression and Altiplanicie of Chiapas (Mullerried, 1982). These physiographic regions are the product of regional geological dynamics characterized by the migration of the mountain range magmatic arc; fault movements to the north and south with mountainous uprisings to the west and that resulted in their withdrawal to the formation of successive coastal line; strong river erosion to the northeast and center during the Paleogene to the recent including movements of large landmass on the slopes of hills (Damon *et al.*, 1981; Ferrusquía-Villafranca, 1998). These processes gave rise to different formations and structures both geological-geomorphological and paleontological in the geosites considered. Thus, you can see with the naked eye in this region the geoforms such as the elevations and depressions of the La Mesa de Copoya, the Sabinal Sub-Basin or the Sumidero Canyon with its geological faults, escarpments, caves, chasms and, in several of these structures, present relevant fossil evidence that frames the evolutionary and environmental history of the area.

Most of the fossils found in the region belong to marine organisms that emerge in the limestone strata. These belong to organisms that have lived in shallow seawaters with mollusks being highlighted for their uniqueness in shape and number, among those who are rudists, actaeonellids and oysters, as well as deeper-water organisms such as ammonites and inoceramids (Böse, 1906; Alencáster, 1986, 1995). Another of the groups well represented are the crustaceans which mostly represent new taxa for science (Feldmann *et al.*, 1996; Vega *et al.*, 2001a, 2001b, 2006, 2018; Guinot *et al.*, 2019).

Crustaceans are found in association with different fossil groups such as: gastropods, bivalves, corals, echinoderms and some vertebrate remains. According to Michaud (1984), this fauna corresponds to shallow waters with a great input of detritic material. This author mentioned that the fauna is typical of the Caribbean area with the influence of the Tethys Sea. Alencáster (1995) mentions that the fauna of the geological past of Chiapas is characterized by its great

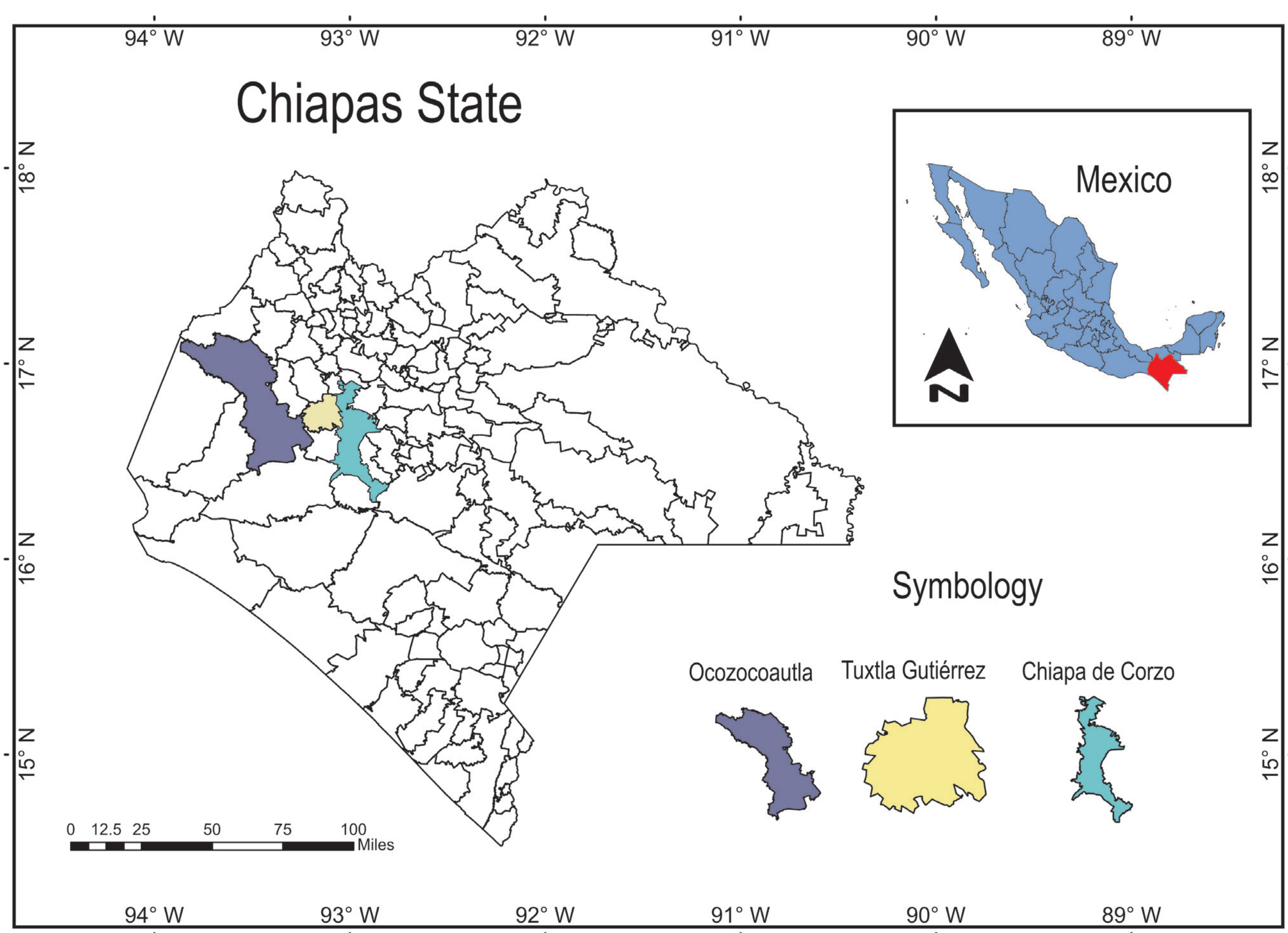

Figure 1. Location of the study area that shows the municipalities that contained the geosites proposed in this work.

abundance and diversity, especially the fossils contained in the rocks of the Cretaceous period that denote episodes of intense biological activity.

The first fossil localities with the presence of fish in the region were studied since the end of the last century and correspond to the Ocozocoautla Formation whose Maastrichtian deposits have sharks and bony fishes (González-Barba *et al.*, 2001; Carbot-Chanona & Than-Marchese, 2013). The record of terrestrial vertebrates is scarce. To date, only a few fossil remains of turtles, crocodyliforms and one non-avian dinosaur are known from the Maastrichtian-age sandy sediments (~68 Ma) of the Ocozocoautla Formation in the vicinity of the Meyapac Natural Area (Carbot-Chanona & Ovalles-Damian, 2013; Carbot-Chanona, 2014; Carbot-Chanona & Rivera-Sylva, 2011).

4. Results

4.1. Paleontological geosites in the Central region of Chiapas

The paleontological geosites considered in this work are characterized by bearing fossil evidence with temporal and environmental implications. The geosites were chosen by adopting the following criteria: 1) Presence of fossil specimens recognizable for their good preservation, abundance and/or diversity; 2) scientific research generated and their respective publications in specialized literature; 3) fossils mentioned in journals, technical reports or bachelor, master or doctoral thesis; 4) sites with fossil outcrops located in geomorphosites, that is, they can be located in a spatial place and mapped; 5) sites that have a previous social interest by local people due to their geological, paleontological, landscape, economic and cultural (*e.g.* religious) characteristics (modified from Gallego, 1998).

The location of paleontological geosites within the area considered can be seen in Figure 2. In general, the geosites of paleontological importance are located with a southeast-northwest direction within an area of approximately 1000 km^2 and encompass Chiapa de Corzo (Cueva El Chorreadero, Piedra Ahorcada, and Cahuare localities), Tuxtla Gutierrez (Copoya, El Jobo, and Cueva Los Laguitos localities) and Ocozocoautla de Espinosa (Tzu-Tzu, El Chango, El Espinal, El Cerebro, Sima de las Cotorras, and La Venta Canyon localities) municipalities (Figures 3 and 4).

The lists the geosites with their respective names correspond to sites known and named by the local people, an aspect of relevance for the dissemination of paleontological knowledge, which is intended to reach society using *in situ* and *ex situ* fossil evidence (Table 1). Carcavilla *et al.* (2019) mention that fossils are a powerful teaching tool useful for the conservation of priority areas which they consider to be "immutable and mobile geo-heritages". Each of the geosites examined in this work usually have an extension of 10000 m² (one hectare), although it should be noted that due to the geomorphology of the region the realization of a topographical map of each of them is still a pending task.

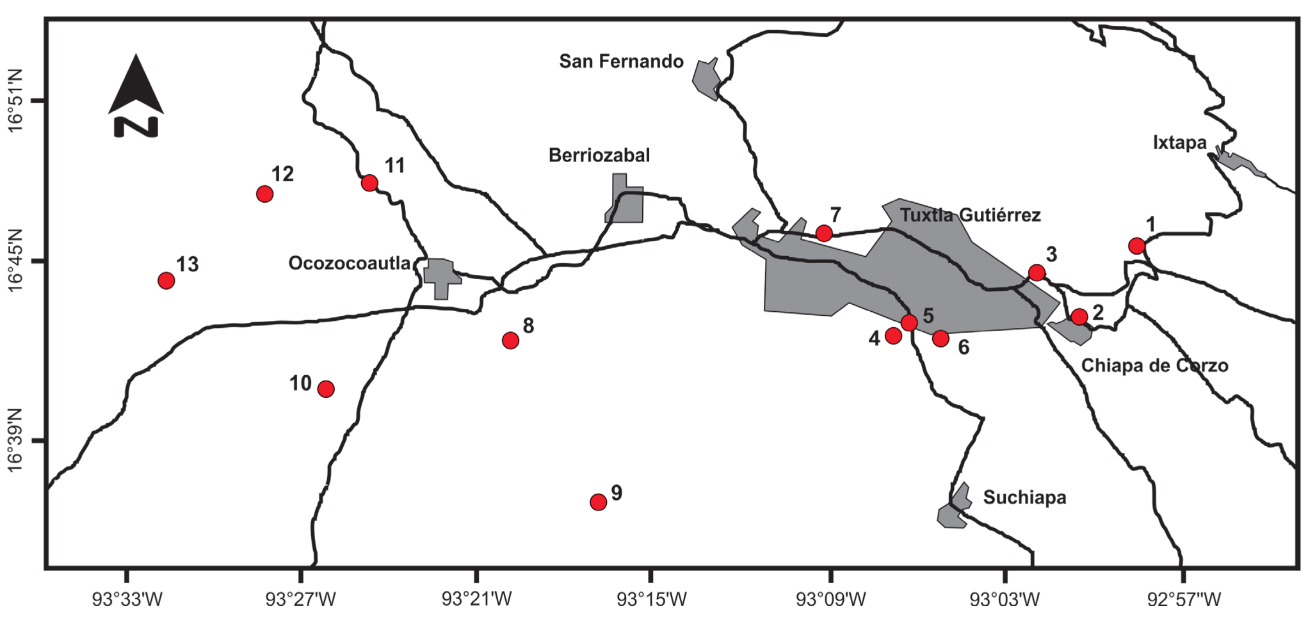

Figure 2. Map showing the location of the importance paleontological geosites. 1) El Chorreadero cave; 2) Piedra Ahorcada; 3) El Sumidero Canyon (Cahuaré); 4) Sandstone-limolite contact; 5) fossil corals locality, Copoya; 6) Microfossils, El Jobo; 7) Los Laguitos cave; 8) Tzu-Tzu; 9) El Chango quarry; 10) El Espinal quarry; 11) El Cerebro; 12) Sima de las Cotorras; 13) El Aguacero, La Venta Canyon.

5. Discussion

We consider that the 13 geosites proposed in this work have the characteristics to assign them the name "geosite" (Gallego, 1998) among which stand out: 1) They have paleontological heritage demonstrated by the fossil discoveries published; 2) several of the fossils are of relevant scientific importance as they include holotypes, paratypes, hypotypes, etc., which are sheltered in various scientific collections of public institutions; 3) have georeferenced, geographical location, extension, geology and stratigraphy; 4) seven of the geosites are located in protected natural areas and with tourist activities managed by local people (*e.g.* Cueva El Chorreadero, Sima de las Cotorras, La Venta Canyon, El Aguacero, El Sumidero Canyon, Caguare and Piedra Ahorcada) where the spread of the paleontological

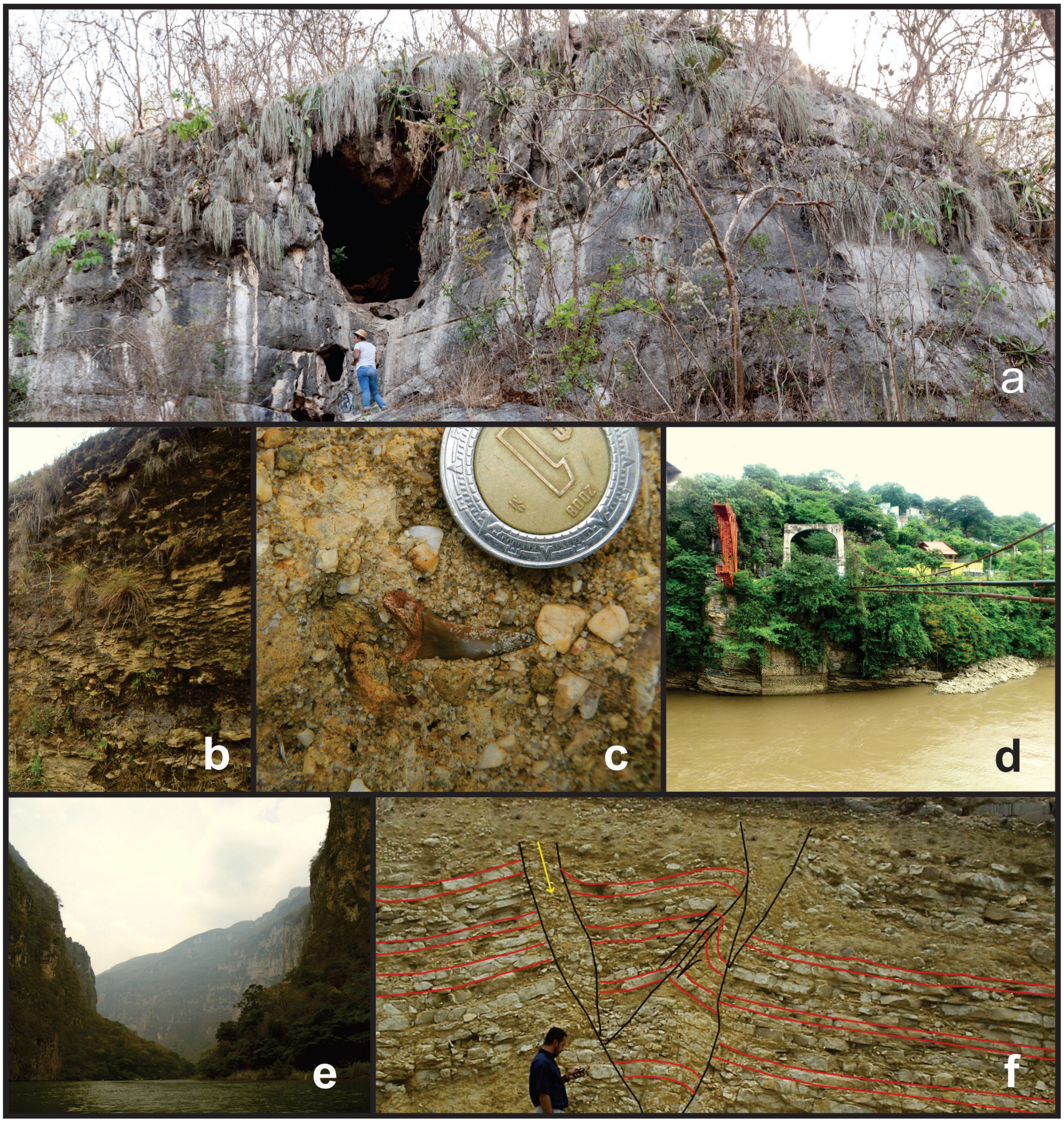

Figure 3. Selected geosites in Tuxtla Gutiérrez and Chiapa de Corzo municipalities: a) Los Laguitos cave; b) sandstone-limolite contact, Copoya; c) shark tooth from the Microfossils geosite, d) Cahuaré jetty; e) panoramic view of the Cañon del Sumidero; f) geological fold Rivera Las Flechas; note the folding and fracturing of limestone and shale strata of marine origin.

heritage has begun to have tourist value; 5) in most geosites have been carried out education activities aimed at teaching geology and paleontology. The study of the fossils of Chiapas has had results that have transcended its area of knowledge to dimensions with high social content with topics such as the conservation of natural heritage and education, both aspects intimately related and with great demand for the human survival.

On the subject of conservation, there is the protection and systematic registration of the paleontological heritage of Chiapas since 1989. This was strengthening with the inauguration of the Museum of Paleontology "Eliseo Palacios Aguilera" on October 21st of the year 2002 with the important curatorial work in the safeguard of the fossils (Avendaño *et al.*, 2004; Carbot-Chanona, 2015). With this paleontological acquis, intense work has been carried out to disseminate both scientific and outreach to the general public and to groups of students of all educational levels. The students are important for the conservation of the paleontological heritage of any region of Mexico since they will be responsible for the future care and conservation of it.

The fossil's rescue work carried out by the staff of the Museum of Paleontology "Eliseo Palacios Aguilera" has resulted in the identification of potential paleontological sites that in the near future can be used to provide various services. Among those are guided tours with teaching

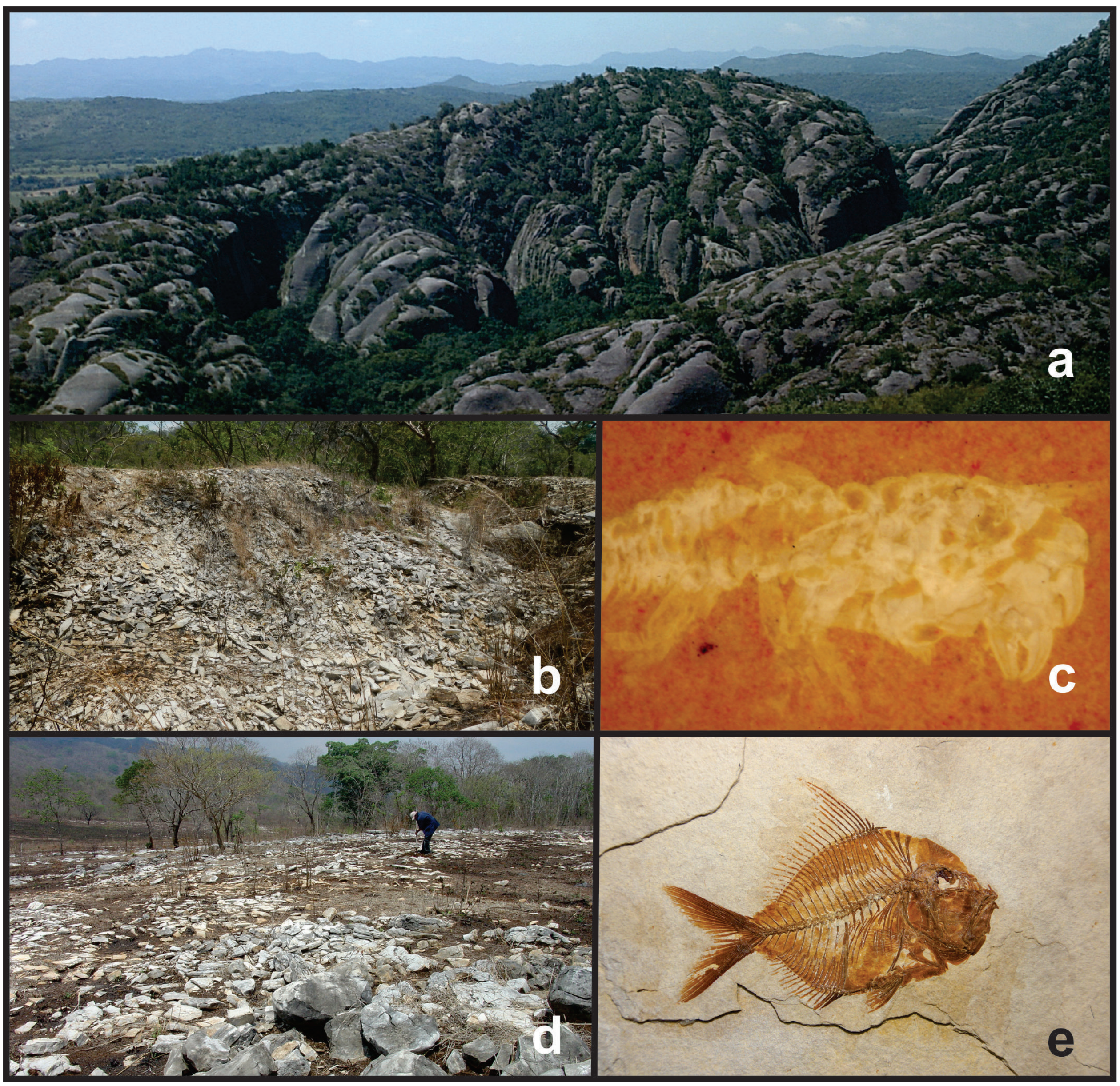

Figure 4. Selected geosites in Ocozocoautla de Espinosa: a) El Cerebro; b) El Espinal quarry; c) *Protoapseudoidus espinalensis* (Crustacea, Apseudomorpha, Tanaidacea) from El Espinal quarry; a tanaidacean that represent a new family, genus and species; d) panoramic view of El Chango quarry; e) *Zoqueichthys carolinae* (Teleostei, Acanthomorpha, Aipichthyoididae) from the El Chango quarry, a fish that represent a new genus and species for the science.

Table 1. Geosites with paleontological relevance. Are mentioned the geological age, fossils and paleoenvironmental inference for each one.

Geosite	Type of fossils	Holotypes	Geological age	Paleoenvironmental inference	References
1. El Chorreadero cave	Mollusks and rudist *in situ* . The material is under study	None so far	Late Cretaceous	Shallow, warm and low energy sea, reef environment	There are no specific works, but in nearby places are: Frost and Langenheim (1974), Alencáster (1986, 1995)
2. Piedra Ahorcada	Calcareous algae, cnidarians, mollusks, gastropods, bivalves and echinoderms *in situ*	None so far	Early Eocene	Shallow and warm sea, with medium to high energy, close to the coast	There are no specific works, but in nearby places are: Vega *et al.* (2001a), Perrilliat *et al.* (2006)
3. El Sumidero Canyon (Cahuare locality)	Mollusks andechinoderms *in situ* ; crabs *ex situ* housed in the MUPEPA	*Lophoranina precocious* (now *Vegaranina precocia*)	Late Cretaceous	Shallow and warm sea, with low energy; reef environment	Frost and Langenheim (1974), Feldmann *et al.* (1996)
4. Sandstone-limolite contact (Copoya)	Algae, angiosperms, protozoa, annelids, cnidarians, mollusks, crabs, echinoderms, sharks and rays *ex situ* housed in the MUPEPA	*Dardanus mexicanus, Lophoranina cristaspina*	Middle Eocene	Shallow, warm sea, very close to the coast (fluctuating coastline) and medium to high energy, with the coastline exposed to the terrestrial environment evidenced by the layers of limolite and plant fossils.	Aguilera and García (1991), Aguilera (1993); Ferrusquía-Villafranca *et al.* (1999, 2000), Vega *et al.* (2001a, 2008)
5. Fossil corals locality (Copoya)	Algae, protozoan, sponges, cnidarians, bryozoans, mollusks, echinoderms *in situ*	None so far	Late Cretaceous	Shallow sea, warm and medium to high energy, deduced by fragmented fossils	Aguilera and García (1991), Aguilera (1993), Ferrusquía-Villafranca *et al.* (1999, 2000), Jiménez-Gonzáles (2006)
6. Microfossils (El Jobo)	Protozoan, cnidarians, annelids, mollusks, brachiopods, crabs, echinoderms, sharks, rays, algae and angiosperms	*Dardanus mexicanus, Lophoranina cristaspina*	Middle Eocene	Given the proximity to emerging land, it received contributions of terrifying material and plant remains	Aguilera and García (1991), Aguilera (1993), Ferrusquía-Villafranca *et al.* (1999, 2000), Vega *et al.* (2001a), Martín Medrano (2006), Martín-Medrano and García-Barrera (2006), Vega *et al.* (2008)
7. Los Laguitos cave	Rudist and bivalves *in situ*	None so far	"Middle" Cretaceous	Shallow, warm and low energy sea, reef environment	There are no specific works, but in nearby places are: Frost and Langenheim (1974), Alencáster (1995), Pons *et al.* (2016)
8. Tzu-Tzu	Mollusks (ammonites, gastropods, innoceramids, rudists), celenterates, echinoderms *in situ* and *ex situ*	*Icriobranchiocarcinus tzutzu*	Late Cretaceous (Maastrichtian)	Shallow sea, warm, reef environment.	Pons *et al.* (2016), Gómez-Pérez *et al.* (2016), Vega *et al.* (2018), Gómez-Pérez and Moreno-Bedmar (2019)
9. El Chango quarry	Gymnosperms and angiosperms; ammonites, crustaceans and bony fishes *ex situ* housed in the MUPEPA and in Instituto de Geología, UNAM	*Archaeochiapasa mardoqueoi, Mexicania grijalvaensis, Mokaya changoensis, Pepemkay maya, Sapperichthys chiapanensis, Scombroclupea javieri* , *Tzeltalpenaeus exilichelatus, Unicachichthys multidentate, Veridagon avendanoi, Zoqueichthys carolinae, Zoquepenaeus spinirostratus*	Late Cretaceous (Cenomanian)	Shallow sea, of low energy and transparent waters that limited with relatively flat beach where there was a dominance of Cupressaceae, Podocarpaceae and Pinaceas conifers and several groups of angiosperms (Sapindales), among others	Vega *et al.* (2003), González-Ramírez *et al.* (2013), Guerrero Márquez *et al.* (2013), Alvarado-Ortega and Than- Marchese (2012, 2013), Amaral *et al.* (2013), Moreno-Bedmar *et al.* (2014), Díaz-Cruz *et al.* (2016, 2019), Guinot *et al.* (2019), Than-Marchese *et al.* (2020)
10. El Espinal quarry	Gastropods, crustaceans, insects, and bony fishes *ex situ* housed in the MUPEPA	*Protoapseudoidus espinalensis, Palinurus palaciosi*	Lower Cretaceous (Albian)	Shallow sea, of low energy and transparent waters that limited with relatively flat beach where the contribution of terrigenous sediments was poor.	Vega *et al.* (2006), Alvarado-Ortega and Ovalles-Damián (2008), Alvarado-Ortega *et al.* (2009), Heard *et al.* (in press)
11. El Cerebro sandstone-limolite contact	Rudists, bivalves, gastropods *in situ*	None so far	Late Cretaceous (Maastrichtian)	Extensive lagoon next to a large reef structure	Vega *et al.* (2001b), Pons *et al.* (2016)
12. Sima de las Cotorras	Mollusks and echinoderms *in situ*	None so far	Late Cretaceous	Shallow sea, low energy, transparent and warm waters that limited relatively flat beach where the supply of terrigens was scarce	There are no specific works, but in nearby places are: Michaud (1984), Steele and Waite (1986), Alencáster (1995), Pons *et al.* (2016)
13. La Venta Canyon (El Aguacero)	Protozoans, sponges, cnidarians, annelids, arthropods, mollusks and echinoderms *in situ*	None so far	Early Cretaceous	Shallow sea, low energy, transparent and warm waters that limited relatively flat beach where the supply of terrigens was scarce	Steele and Waite (1986)

objectives, mainly to groups of students and researchers with objectives to determine the taxonomic identity of the fossils, geological age, paleogeographic correlation and paleobiological aspects, among others (Avendaño-Gil, 2011).

6. Conclusions

The Chiapas state has an important geological and paleontological heritage that must be protected, conformed by singular geological structures and fossils with high scientific relevance. However, to date no strategies have been proposed to promote its conservation. This work lays the paleontological basis for the systematic study of paleontological interest geosites in the state of Chiapas, an initiative that will allow us to disseminate the importance of paleontological and geological resources of a state that they are rapidly being transformed by overexploitation of their natural resources and the growth of urban spots. This is in order to be used to generate scientific, didactic, recreational, and conservation activities, which will raise social awareness of the resources mentioned and support the economic development of the communities involved through different sustainable strategies (*e.g.* geotourism and geoeducation). It is a first attempt in Chiapas to bring the geological and paleontological resource closer to society privileging its natural environment and making use of the wonders they offer to society.

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