Paleontología Mexicana
Volumen 5, núm. 1, 2016, p. 1-19

New Eocene bivalves from Bateque Formation, Baja California Sur, Mexico

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Abstract

A total of 11 new mollusc bivalves are reported (*Lithophaga* sp., *Anadara*? sp., *Gryphaeostrea sanjuanicus* sp. nov., *Ostrea* sp., cf. *O. contracta amichel*, *Argopecten*? sp., *Chlamys* sp. a, *Chlamys* sp. b, *Pecten*? sp., *Tellina* sp., *Macrocallista* sp. and *Pitar* sp.), in the Bateque Formation, which includes one of the most complete fossil records for the Eocene Epoch, in Baja California Sur, Mexico. Prior to this work, existing faunal lists were reviewed, resulting in 155 macroinvertebrate species reported for the Bateque Formation. The faunal assemblage indicates an age range of early Eocene ("Capay Stage") to the late middle Eocene ("Tejon Stage"), and also it is characteristic of shallow marine water (inner shelf to outer) and tropical to subtropical climates. The abundance and diversity of macroinvertebrates previously reported and new records of molluscs contribute to the understanding of the origin of the different taxonomic groups in Baja California Sur and the Pacific Coast of North America. Most species are indicative of warm waters from the Tethys circum-global current, which created the conditions for a wide biotic exchange between marine organisms of the Atlantic, Gulf of Mexico-Caribbean, and Pacific.

Keywords: Bivalves, Bateque Formation, Eocene, Baja California Sur, Mexico.

Resumen

Se reportan 11 nuevos moluscos: bivalvos (Lithophaga sp., Anadara? sp., Gryphaeostrea sanjuanicus sp. nov., Ostrea sp., cf. O. contracta amichel, Argopecten? sp., Chlamys sp. a, Chlamys sp. b, Pecten? sp., Tellina sp., Macrocallista sp. y Pitar sp.), de la Formación Bateque, la cual representa uno de los registros fosilíferos más completos de la época del Eoceno, en Baja California Sur, México. Antes de este trabajo, se revisaron los listados faunísticos ya existentes, dando como resultado 155 especies reportadas de macroinvertebrados para la Formación Bateque. Esta fauna es indicativa de aguas poco profundas (plataforma interna a externa) y de climas tropicales a subtropicales. El conjunto faunístico indica un intervalo de edad del Eoceno temprano ("Piso Capay") al Eoceno medio superior ("Piso Tejon"). La abundancia y diversidad de los macroinvertebrados previamente reportados, así como los nuevos registros de moluscos, contribuyen en el entendimiento del origen de los diferentes grupos taxonómicos en Baja California Sur y en la costa del Pacífico de Norteamérica. La mayoría de las especies, son indicativas de aguas cálidas relacionadas con la corriente circum-tropical del Tethys, la cual creó las condiciones para un amplio intercambio biótico entre los organismos marinos del Atlántico, el Golfo de México-Caribe y el Pacífico.

Palabras clave: Bivalvos, Formación Bateque, Eoceno, Baja California Sur, México.

1. Introduction

Macroinvertebrates found in Bateque Formation represent one of the most complete fossil records of the Eocene Epoch (56 to 33.9 Ma) in Mexico. This formation is exposed on the Pacific Ocean side of the Baja California peninsula on the eastern and western shores of Laguna San Ignacio to Arroyo El Mezquital (between San Juanico and La Purisima) (Figure 1) (Squires and Demetrion, 1992, 1994a, González-Barba, 2003).

Previous listings of macroinvertebrate fauna reported 155 species for the Bateque Formation (Table I). However, in 2011, new sites were visited and 11 new records of bivalve molluscs were found: *Lithophaga* sp., *Anadara* sp., the new species *Gryphaeostrea sanjuanicus*, *Ostrea* sp., cf. *O. contracta amichel*, *Argopecten*? sp., *Chlamys* sp. a, *Chlamys* sp. b, *Pecten*? sp., *Tellina* sp., *Macrocallista* sp. and *Pitar* sp.

The phylum Mollusca is the most diverse and abundant group in the area, and is found in various formations along the Pacific Coast of North America. Most species of molluscs are attributed to an early Eocene age ("Capay Stage"), an age that is determined by the presence of *Spondylus batequensis* Squires and Demetrion, 1990, which is a diagnostic species of this stage (Squires and Demetrion, 1994a). However, several species exhibit a wider age range that extends to the late middle Eocene ("Tejon Stage"). A special case is the genus *Argopecten*?, which records show has the wider age range from Oligocene to Recent according Paleobiology Database (2013), but our specimens could extend the age range of the genus, *i.e*. from late middle Eocene ("Tejon Stage") to Recent.

The abundance and diversity of macroinvertebrates previously reported and the new records of molluscs contribute to understanding the origins of the different invertebrate groups in the state. Most species indicate a warm-water biota (tropical to subtropical) related to the

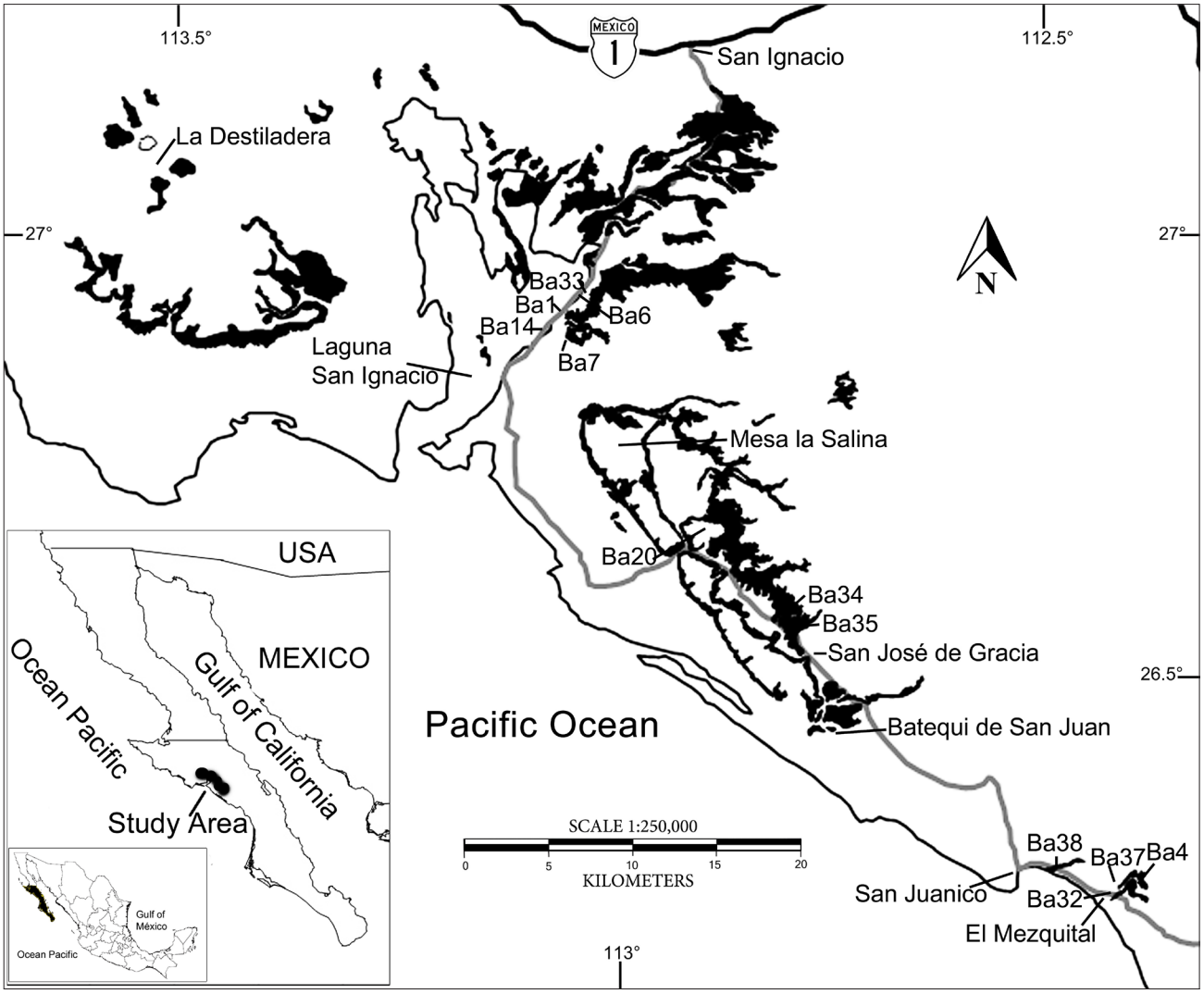

Figure 1. Index map showing the outcrops of the Bateque Formation, Baja California Sur, Mexico (Geological-Mining Letter, Baja California Sur, 2008), localities (Ba), and geographic place names. Country road continuous gray line.

Table 1. Age range of the marine invertebrates from Bateque Formation; from upper Paleocene to late middle Eocene, represented by Molluscan Stage Range of the Pacific Coast of North America; wherein: Mr = "Martinez Stage" and Me = "Meganos Stage", correspond to the upper Paleocene; Ca = "Capay Stage", Do = "Domengine Stage", Tr = "Transition Stage" and Te = "Tejon Stage", correspond to Eocene. The symbols represent: "--" = presence of the genus and/or species on the Pacific Coast of North America (from Chiapas, Mexico to Washington, United States of America). "●"=presence of the species in the formation. "?"=probably with this age range.

	Mr	Me	Ca	Do	Tr	Te	Range Reference
Protista							
Lepidocyclina sp.			●	--	--	--	Vaughan, 1933 (Lepidocyclina)
Operculina sp., aff. *O. cookie* Cushman, 1921a				●	●	●	Squires and Demetrion, 1992
Actinocyclina sp., aff. *A. aster* Woodring, 1930			●	--	--	--	Vaughan, 1933 (Actinocyclina); Squires and Demetrion, 1992
Pseudophragmina clarki (Cushman, 1920)			●	●			Squires and Demetrion, 1992
Pseudophragmina advena (Vaughan, 1929)			●	●	●	●	Squires and Demetrion, 1992
Porifera							
Elasmostoma bajaensis Squires and Demetrion, 1989			●				Squires and Demetrion, 1992; Morales-Ortega, 2010
Clionaidae?, indet.			●	●?			Squires and Demetrion, 1992
Cnidaria							
Spongiomorphidae?, indet.			●				Squires and Demetrion, 1992
Heliopora ? sp.			●	--			Frost and Langenheim, 1974; Squires and Demetrion, 1992
Parisis batequensis Squires and Demetrion, 1992			●				Squires and Demetrion, 1992
Astrocoenia dilloni Durham, 1942			●	●?			Squires and Demetrion, 1992
Stylophora chaneyi Durham, 1942			●	●?			Squires and Demetrion, 1992
Heterocoenia ? sp.			●				Squires and Demetrion, 1992
Stylosmilia ameliae Squires and Demetrion, 1992			●				Squires and Demetrion, 1992
Actinacis ? sp.			●	●?			Frost and Langenheim, 1974; Squires and Demetrion, 1992
Balanophyllia sp.			●	--			Frost and Langenheim, 1974; Morales-Ortega, 2012b
Goniopora sp., cf. *G. vaughani* Nomland, 1916			●	●?			Frost and Langenheim, 1974; Squires and Demetrion, 1992
Porites ? sp.			●				Morales-Ortega, 2012b
Colpophyllia nicholasi Squires and Demetrion, 1992			●				Squires and Demetrion, 1992
Montastrea laurae Squires and Demetrion, 1992			●	--			Frost and Langenheim, 1974; Squires and Demetrion, 1992
Antillia batequensis Squires and Demetrion, 1992			●	●			Squires and Demetrion, 1992; Squires, 2001
Stephanocyathus ? sp.			●				Squires and Demetrion, 1992
Turbinolia dickersoni Nomland, 1916	--	--	●	●			Squires and Demetrion, 1992
Placotrochus ? sp.			●				Squires and Demetrion, 1992
Bryozoa							
Stomatopora sp.			●				Squires and Demetrion, 1992 (age range: K-Rec)
Conopeum ? sp.			●			--	Morales-Ortega, 2012b; upper Eocene of Russia and United States of America (age range K-Rec)
Cellaria sp.			●				Squires and Demetrion, 1992
Annelida							
Serpula batequensis Squires and Demetrion, 1992			●				Squires y Demetrion, 1992
Rotularia sp.	--	--	●	--	--		Squires and Goedert, 1994; Morales-Ortega, 2012b
Brachiopoda							
Terebratellidae?, indet. King, 1850						●	Morales-Ortega, 2012b
Terebratulinae, indet**.** Gray, 1840						●	Morales-Ortega, 2012b
Terebratulina sp., cf. *Terebratulina louisianae* Stenzel,1940			--?	--		●	Sandy *et al* ., 1995; Squires, 2001; Morales-Ortega, 2010
Terebratalia batequia Sandy, Squires and Demetrion, 1995				--		●	Sandy *et al*., 1995; Squires, 2001
Mollusca: Scaphopoda							
Detalium stentor Anderson and Hanna, 1925				●	●	●	Squires and Demetrion, 1992
Diodora batequensis Squires and Demetrion, 1994			●				Squires and Demetrion, 1994a
Arene mcleani Squires, 1988b			●				Squires and Demetrion, 1992
Velates perversus (Gmelin, 1791)		--	●	●?			Squires, 1999
Velates batequensis Squires and Demetrion, 1990			●				Squires and Demetrion, 1992
Turritella andersoni s.s. Dickerson, 1916		--?	●				Squires and Demetrion, 1992; Squires, 1984; 2008
Turritella andersoni lawsoni Dickerson, 1916				●			Squires and Demetrion, 1992; Squires, 1984

Table 1 (Continuation).

	Mr	Me	Ca	Do	Tr	Te	Range Reference
Turritella sp., cf. *T merriami*? Dickerson, 1913			●				Squires and Demetrion, 1992
Turritella buwaldana Dickerson, 1916	--	●?	●	●	●	●	Squires, 2008
Turritella uvasana subsp.			●	●		--?	Squires, 1984; Morales-Ortega, 2012b
Vermetidae, indet.						●?	Morales-Ortega, 2012b
Tenagodus bajaensis Squires, 1990a			●				Squires and Demetrion, 1992
Acrilla? sp. Squires and Demetrion, 1992			●				Squires and Demetrion, 1992
Epitonium sp.			●				Squires and Demetrion, 1992
Cirsotrema eocenica Squires and Demetrion, 1994				●			Squires and Demetrion, 1994a
Xenophora stocki Dickerson, 1916			●	●	●	●	Squires and Demetrion, 1992
Lobatus sp., aff*., Lobatus peruvianus* (Swainson, 1823)			●				Morales-Ortega, 2012b
Platyoptera pacífica Squires and Demetrion, 1990			●	--			Squires and Demetrion, 1992; Squires, 2001
Ectinochilus (*Macilentos*) *macilentus* (White, 1889)			●	●			Squires, 2008
Ectinochilus (*Cowlitzia*) sp., aff. *E.* (*C.*) *canalifera* (Gabb, 1864)			●				Squires and Demetrion, 1992
Paraseraphs erracticus (Cooper, 1894)			●	●	●		Squires and Demetrion, 1992
Bernaya (*Protocypraea*) *grovesi* Squires and Demetrion, 1992			●				Squires and Demetrion, 1992
Megalocypraea clarki Ingram, 1940			●				Squires and Demetrion, 1994a
Eocypraea? sp.			●				Squires and Demetrion, 1992
Cypraedia sp.			●				Squires and Demetrion, 1992
Amauropsis sp.			●				Squires and Demetrion, 1992; Squires, 2008
Gyrodes? sp.			●				Squires and Demetrion, 1992
Crommium sp., cf. *C. andersoni* Dickerson 1914			●				Morales-Ortega, 2012b
Eocernina hannibali Dickerson, 1914			●	●	--		Squires and Demetrion, 1992; Squires, 2008
Pachycrommium clarki (Stewart, 1927)		--	●	●	●	●	Morales-Ortega, 2010; Squires, 2008
Galeodea sp.			●	--	--?		Squires and Demetrion, 1992; Squires, 2008
Galeodea (*Caliagaleodea*) *californica* Clark 1942			●	--			Squires and Demetrion, 1994a
Phalium (*Semicassis*) *louella* Squires and Advocate, 1986			●				Squires and Demetrion, 1994a
Olequahia domenginica (Vokes, 1939)			●	--			Squires, 1988b; Squires and Demetrion, 1992
Campanile sp.			●				Squires and Demetrion, 1992
Dirocerithium sp.				●			Squires and Demetrion, 1994a
Clavilithes tabulatus (Dickerson, 1913)			●	●			Squires and Demetrion, 1992
Olivella mathewsonii? Gabb, 1864	--	--	●	--	--	--	Squires and Demetrion, 1992; Squires, 2008
Lyria andersoni Waring, 1917			●	●			Squires and Demetrion, 1992
Lyrischapa lajollaensis (Hanna, 1927)			●	●			Squires and Demetrion, 1992
Eocithara mutica californiensis (Vokes, 1937)			●	--			Squires, 1984; Morales-Ortega, 2012b
Conus caleocius Vokes, 1939			●	●			Squires and Demetrion, 1992
Conus sp., aff. *C.* (*Lithoconus*) sp.						●	Morales-Ortega, 2010, 2012b
Terebra californica Gabb, 1869			--	--	--	●	Squires, 1984; Morales-Ortega, 2012b
Architectonica (*Stellaxis*) *cognata* Gabb, 1864			●	●			Squires, 1984; Squires and Demetrion, 1992
Architectonica (*Architectonica*) *llajasensis* Sutherland, 1966				●			Squires and Demetrion, 1994a
Retusa (*Cylichnina*) sp. = *Cylichnina tantilla*			●	●	●	●	Squires and Demetrion, 1992
Scaphander? sp.			●				Squires and Demetrion, 1992
Megistostoma gabbianum (Stoliczka, 1868)				●	●	●	Squires and Demetrion, 1992
Mollusca: Bivalvia							
Barbatia (*Barbatia*?) sp.			●				Squires and Demetrion, 1992
Barbatia (*Acar*?) sp.			●				Squires and Demetrion, 1992
Anadara? sp.						●	**Ba37**
Glycymeris (*Glycymerita*) *sagittata* (Gabb, 1864)			●	●	●	●	Squires and Demetrion, 1992
Lima kennedyi Squires and Demetrion, 1992			●				Squires and Demetrion, 1992
Lithophaga sp.							**Ba14**
Pinna llajasensis Squires, 1983			●	●			Squires and Demetrion, 1992
Nayadina (*Exputens*) *batequensis* Squires, 1990a			●				Squires, 1990a; Squires and Demetrion, 1992

Table 1 (Continuation).

	Mr	Me	Ca	Do	Tr	Te	Range Reference
Argopecten ? sp.						●	**Ba1**
Batequeus mezquitalensis Squires and Demetrion, 1990						●	Squires and Demetrion, 1990b, 1992
Chlamys sp. a						●	**Ba32**
Chlamys sp. b						●	**Ba32**
Pecten ? sp.						●	**Ba32**
Plicatula surensis Squires and Saul, 1997			●				Squires and Saul, 1997
Plicatula ? sp. b Squires and Saul, 1997			●	●	●	●	Squires and Saul, 1997
Spondylus batequensis Squires and Demetrion, 1990b			●				Squires and Demetrion, 1990b
Anomia ? sp.			●	--			Squires, 1984; Squires and Demetrion, 1992
Pycnodonte (*Phygraea*) *pacifica* Squires and Demetrion, 1990b			●	●	●	●	Squires and Demetrion, 1990b; Squires, 2001
Pycnodonte (*Phygraea*) *cuarentaensis* Squires and Demetrion, 1994			●				Squires and Demetrion, 1994a
Pycnodonte (*Pegma*) *bajaensis* Squires and Demetrion, 1990b			●	●	●	●	Squires and Demetrion, 1990b
Gryphaeostrea sanjuanicus sp. nov.			●			●	**Ba35 and 38**
Cubitostrea mezquitalensis Squires and Demetrion, 1990						●	Squires and Demetrion, 1990b
Ostrea sp., cf. *O. contracta amichel* Gardner, 1945							**Ba38**
Glyptoactis (*Claibornicardia*) *domenginica* (Vokes, 1939)			●	●	●		Squires and Demetrion, 1992
Crassatella sp.			●				Squires and Demetrion, 1992
Acanthocardia (*Agnocardia*) sp., aff. *A.* (*A.*) *sorrentoensis* (Hanna, 1927)			●	●			Squires and Demetrion, 1992; Squires, 2001
Nemocardium liteum (Conrad, 1855)		●	●	●	●	●	Squires and Demetrion, 1992; Squires, 1999
Dosinia sp.					--	●?	Squires, 2008
Fimbria pacifica Squires, 1990c			●				Squires and Demetrion, 1992
Solena (*Eosolen*) *novacularis* (Anderson and Hanna, 1928)			●	●	●	●	Squires and Demetrion, 1992
Tellina sp.			●	●	●?	●	**Ba4, 6, 14, 32 and 33**
Macrocallista sp.		--	--	--	--	●	**Ba37**
Pitar (*Lamelliconcha*) *joaquinensis* Vokes, 1939			●	●			Squires and Demetrion, 1992; Squires, 2008
Pitar sp.			●			●?	**Ba1, 6 and 7**
Pholadomya sp., cf. *P.* (*Bucardiomya*) *givensi* Zinsmeister, 1978			●	●	●	●	Squires and Demetrion, 1992
Teredinidae, indet.			●				Squires, 2008
Mollusca: Cephalopoda							
Hercoglossa ? sp.			●				Squires and Demetrion, 1992
Aturia myrlae Hanna, 1927			●	●			Squires and Demetrion, 1992
Arthropoda							
Callianassidae *sensu lato* species 1 *in* Schweitzer *et al*., 2005				●		●	Schweitzer *et al.*, 2005
Callianassidae *sensu lato* species 2 *in* Schweitzer *et al*., 2005			--	●		●	Schweitzer *et al.*, 2005
Callianassidae *sensu lato* species 3 *in* Schweitzer *et al*., 2005				●		●	Schweitzer *et al.*, 2005
Callianassidae *sensu lato* species 4 *in* Schweitzer *et al*., 2005				●		●	Schweitzer *et al.*, 2005
Callianassidae *sensu lato* species 5 *in* Schweitzer *et al*., 2005			--	●		●	Schweitzer *et al.*, 2005
Paguroidea species 1 *in* Schweitzer *et al*., 2005				●		●	Schweitzer *et al.*, 2005
Paguroidea species 2 *in* Schweitzer *et al*., 2005				●		●	Schweitzer *et al.*, 2005
Paguroidea species 3 *in* Schweitzer *et al*., 2005			--	●		●	Schweitzer *et al.*, 2005
Paguristes mexicanus (Vega *et al*., 2001)			--	●		●	Schweitzer *et al.*, 2005
Galatheinae genus and species indet. *herein*				●		●	Schweitzer *et al*., 2006
Holoma bajaensis Schweitzer *et al*., 2006				●		●	Schweitzer *et al*., 2006
Lophoranina bishopi Squires and Demetrion, 1992			●	●?		●?	Squires and Demetrion, 1992; Schweitzer *et al*., 2002
Ranina berglundi Squires and Demetrion, 1992			●	●?		●?	Squires and Demetrion, 1992; Schweitzer *et al*., 2006
Raninoides acanthocolus Schweitzer *et al*., 2006				●		●	Schweitzer *et al*., 2006
Raninoides proracanthus Schweitzer *et al.*, 2006				●		●	Schweitzer *et al*., 2006
Cyclodorippoidea: family, genus and species indet. *herein*				●		●	Schweitzer *et al*., 2006
Calappilia hondoensis Rathbun, 1930b			--	●		●	Schweitzer *et al*., 2006
Prehepatus mexicanus Schweitzer *et al*., 2006				●		●	Schweitzer *et al*., 2006
Daldorfia salina Schweitzer *et al*., 2006				●		●	Schweitzer *et al*., 2006
Anatolikos undecimspinosus Schweitzer *et al*., 2006				●		●	Schweitzer *et al*., 2006
Lobonotus mexicanus Rathbun, 1930b			--	●		●	Schweitzer *et al*., 2002; Schweitzer *et al*., 2005

Table 1 (Continuation).

	Mr	Me	Ca	Do	Tr	Te	Range Reference
Archaeotetra inornata Schweitzer, 2005				●		●	Schweitzer, 2005
Montezumella tubulata Rathbun 1930b				●		●	Schweitzer *et al*., 2006
Xanthoidea: family, genus and species indet. *herein*				●		●	Schweitzer *et al*., 2006
Paracorallicarcinus tricarinatus Schweitzer *et al* ., 2006				●		●	Schweitzer *et al*., 2006
Carcininae genus and species indet. *Herein*				●		●	Schweitzer *et al*., 2006
Echinodermata							
Cidaroida, indet. spine A			●				Squires and Demetrion, 1992
Cidaroida, indet. spine B						●	Squires and Demetrion, 1992
Cidaroida, indet. spine C						●	Squires and Demetrion, 1992
Cidaroida?, indet. spine D			●				Morales-Ortega *et al*., 2015
Cassidulus ellipticus Kew, 1920			●				Squires and Demetrion, 1995
Calilampas californiensis Squires and Demetrion, 1995			●				Squires and Demetrion, 1995
Haimea bajasurensis Squires and Demetrion, 1994			●				Squires and Demetrion, 1994b
Schizaster (*Paraster*) sp., aff. *S. lecontei* Merriam, 1899		--	●	--	--	--	Squires and Demetrion, 1992
Eupatagus batequensis Squires and Demetrion, 1992			●				Squires and Demetrion, 1992

current tropical Tethys Sea, although their centres of origin are in different parts of the world (Squires and Demetrion, 1992; Morales-Ortega, 2010, 2012a).

2. Previous works

The first authors to work with descriptions of marine invertebrates were Squires and Demetrion (1989, 1990a, 1990b, 1991, 1992, 1994a, 1994b, 1995). They described new species of gastropods and bivalves, and also echinoderms and a new form of sponge; in addition they made comparisons between the faunas of Bateque and Tepetate formations. In 1992, they were the first to make a list of marine macrofossils found in the Bateque Formation, reporting 95 species, including 63 molluscs (one scaphopod, 37 gastropods, 23 bivalves and two nautiloids).

Squires (1990a, 1990b, 1990c) made comparisons between different molluscs found in the Pacific coast of North America, *i.e*. from California (United States of America) to Baja California Sur (Mexico). Sandy *et al*. (1995) described two species of brachiopods of Middle Eocene from the uppermost part of the Bateque Formation; both species are also present in the middle part of the Tepetate Formation. Subsequently, Squires and Saul (1997) described and compared new species of genus *Plicatula*, found in Cretaceous and Cenozoic strata of California and Baja California Sur. In recent years, Schweitzer (2005) and Schweitzer *et al*. (2005, 2006) described new species of decapod (Infraorders: Thalassinidean, Anomura: Paguroidea and Brachyura) from the Bateque and Tepetate formations.

It is important to point out that the marine invertebrate fauna of the Bateque Formation indicates an age from "Capay Stage" (Early Eocene) to "Tejon Stage" (late Middle Eocene); this age range is based on the Molluscan Stages Range of the Pacific Coast of North America, informally proposed by Clark and Vokes (1936). However, the stages have been recently designate by various authors and based on the fauna of gastropods found in different formations in Washington, Oregon, California (United States of America) and Baja California Sur (Mexico). Below are listed stages in ascending order of the Paleocene and Eocene Epochs: "Martinez Stage" –Squires (1997); "Meganos Stage" –Squires (1990b); "Capay Stage" –Squires and Goedert (1994), Squires (2000); "Domengine Stage" –Squires (1984, 2000, 2001); "Transition Stage" –Squires (1999a); "Tejon Stage" –Clark and Anderson (1938), Givens and Kennedy (1979), Nesbitt (1995). It is important to mention that these stages have not yet been properly defined. Future multidisciplinary studies of palaeomagnetism and stable isotopes will be needed, as well as a review of studies of molluscan taxonomy and biostratigraphy and other fossil groups (*i.e*. foraminifera, brachiopods, or vertebrates) (Squires, 2003).

3. Depositional environments

Bateque Formation represents an age range from the middle Paleocene to Eocene (Mina-Uhink, 1956, 1957; Sorensen, 1982). Its base is not exposed and has disconformity with volcanic and sedimentary rocks, with age ranges from Upper Eocene to Holocene (Squires and Demetrion, 1992). Also, Sandy *et al*. (1995) mention that in the southern outcrops of the Bateque Formation (between San Juanico and La Purisima) it shows a discordant stratigraphic relation with Isidro Formation (Miocene).

Moreover, the fossil records are characteristic of deep marine deposits and shelf environments during the Early Eocene, and also deep environments the Middle Eocene, this generated by transgressive seas and the global circulation of the warm current of Tethys (Squires and Demetrion, 1992; González-Barba *et al*., 2002).

4. Stratigraphic and faunal correlation

Cenozoic history of Baja California Sur begins with the deposition of marine rocks of the Tepetate and Bateque formations, which are important in the geological record, especially in the North American Pacific region, as they may represent one of the most complete fossil and palaeoceanographic records of the Paleogene period (66 to 23.03 Ma) (Morales-Ortega, 2012a).

Tepetate Formation has been originally described as a package of sandstone 1000 meters thick and suggests the existence of deep environments at least from the Maastrichtian (Upper Cretaceous) to late early Eocene in some localities, while in platform environments the formation only records the Early Eocene to the Middle Eocene (Heim, 1922; Schwennicke *et al*., 2004; Miranda-Martínez and Carreño, 2008). New data supports the idea of a "concordant" sequence, *i.e*. that older deposits are found at the bottom and the newest at the top, with regressive-transgressive marine sequences interspersed throughout the formation (Morales-Ortega, 2012b).

In the Bateque Formation deep marine and shelf environments during the Early Eocene, and also deep environments in the Middle Eocene have been reported (Squires and Demetrion, 1992). All this was generated by transgressive seas in the continental masses and the circulation of Tethys (Squires and Demetrion, 1992; González-Barba, 2003). This formation has an inclination of 3 degrees northwest, where the oldest deposits are found in the northwest and the youngest deposits in the southeast. The combining this regional slope favoured the wash, which prevents observation of the oldest outcrops in the southern part of the formation, between Batequi San Juan and San Juanico (Squires and Demetrion, 1992).

Previous studies, based on invertebrate faunal associations in both formations, suggest that they possess a similar age range. The fossils of the Tepetate Formation indicate an age range equivalent to the Molluscan Stage Range of the Pacific Coast of North America, from "Martinez Stage" (Selandian and Thanetian) to the "Tejon Stage" (Lutetian, Bartonian, and lower part of the Priabonian?) (Morales-Ortega, 2010). The invertebrates found in the Bateque Formation show an age range of "Capay Stage" (Ypresian) to "Tejon Stage" (Lutetian and Bartonian) (Squires and Demetrion, 1992).

The litho- and biostratigraphic data are consistent when both formations are compared, *i.e*. the fossils found in the middle part of the Tepetate Formation coincide with those present in the middle of the Bateque Formation, which proves that both formations are equivalent in time, corresponding to the "Capay Stage" (Ypresian). The depositional environments found in most localities of both formations are of the inner to outer shelf. In addition, the type of materials in of both formations is a yellow sandstone, which helps preserve the fossils, although they are mostly internal moulds or mineralized shells (Squires, 1992; Squires and Demetrion, 1992; González-Barba *et al*., 2002; Schwennicke *et al*., 2004; Morales-Ortega, 2010, 2012b).

The abundance and diversity of marine invertebrate species is due primarily to the circum-tropical Tethys current, which created the conditions for a wide biotic exchange between the Atlantic, Gulf of Mexico, Caribbean and Pacific. All this coincides with a rise in the sea level which was recorded globally, possibly associated with greenhouse gases without forming polar ice during most of the Eocene. Actually, this fauna correlates with the faunal records of Europe (France, United Kingdom, and Italy), the Middle East, Caribbean (Cuba and Jamaica) and the North Pacific from Washington, United States to Chiapas, Mexico. The abundance and diversity of species is due primarily to circum-tropical currents of Tethys, which caused a wide biotic exchange between the Atlantic, Gulf of Mexico, Caribbean and Pacific Oceans (Squires, 1992; Schweitzer *et al*., 2002; Morales-Ortega-2010, 2012a).

5. Localities

All localities are in the Bateque Formation. They are indicated in the Mexican government topographic quadrangle map (Instituto Nacional de Estadística, Geografía e Informática (INEGI), scale 1:50000) (Figure 1). The stratigraphic section of the locality Mesas San Ramón is shown in Figure 2. Below are listed the localities visited during this work.

- MHN-UABCS Ba1. Mesa San Ramón (La Rinconada), at Lat. N. 26°58.6', Long. W 113°01.6', Mexican government topographic quadrangle map (1:50000) of Laguna San Ignacio (G12A53-INEGI, 2003), Baja California Sur, Mexico.
- MHN-UABCS Ba4. Rancho Malbar (southern Arroyo Mezquital), at Lat. N. 26°13.1, Long. W 112°18.2', Mexican government topographic quadrangle map (1:50000) of San Isidro (G12A86-INEGI, 2004), Baja California Sur, Mexico.
- MHN-UABCS Ba6. Hill A North, at Lat. N. 26°56.1', Long. W 113°04.7', Mexican government topographic quadrangle map (1:50000) of Laguna San Ignacio (G12A53 INEGI, 2003), Baja California Sur, Mexico.
- MHN-UABCS Ba7. Mesa La Salina, at Lat. N. 26°45.8', Long. W 113°01.1', Mexican government topographic quadrangle map (1:50000) of Laguna San Ignacio (G12A53 INEGI, 2003), Baja California Sur, Mexico.
- MHN-UABCS Ba14. Locality 1219, Squires and Demetrion (1992), at Lat. N. 26°55.9' Long. W 113°04.8', Mexican government topographic quadrangle map (1:50000) of Laguna San Ignacio (G12A53-INEGI, 2003), Baja California Sur, Mexico.

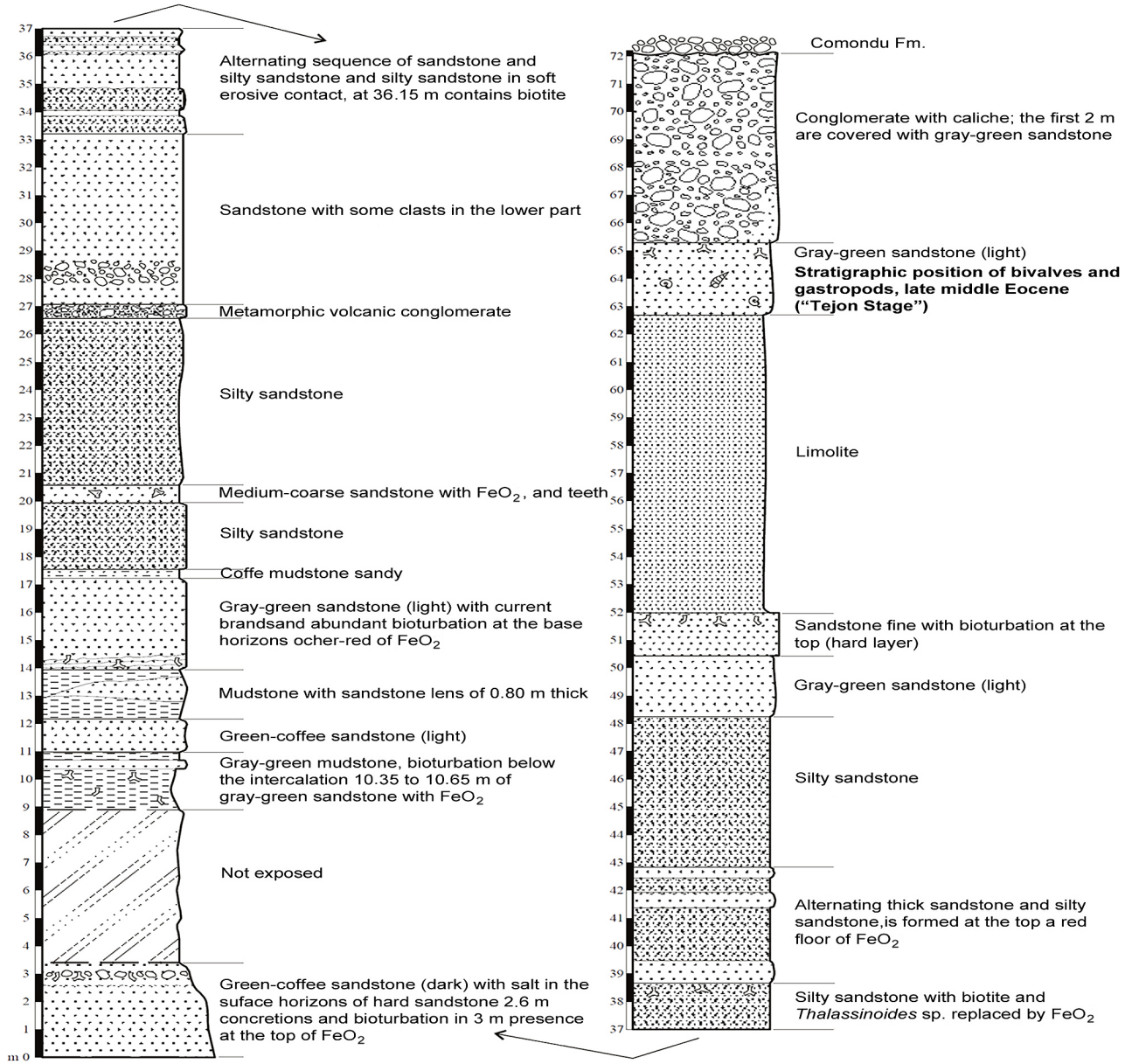

Figure 2. Composite section of the Mesa San Ramon locality showing stratigraphic position of some macrofossil localities (late Middle Eocene, "Tejon Stage") (modified section of González-Barba, 2003).

- MHN-UABCS Ba20: Arroyo Cantil Blanco (southeast of Mesa La Ladera to El Bule), at Lat. N. 26°40.1', Long. W 112°52.4', Mexican government topographic quadrangle map (1:50000) of San José de Gracia (G12A64-INEGI, 2003), Baja California Sur, Mexico.
- MHN-UABCS Ba32. Mesa El Mezquital, at Lat. N. 26°14.7', Long. W 112°21.7', Mexican government topographic quadrangle map (1:50000) of Punta Pequeña (G12A85-INEGI, 2004), Baja California Sur, Mexico.
- MHN-UABCS Ba33. Near the locality 1219, Squires and Demetrion (1992), at Lat. N. 26°58.8', Long. W 113°01.3', Mexican government topographic quadrangle map (1:50000) of Laguna San Ignacio (G12A53-INEGI, 2003), Baja California Sur, Mexico.
- MHN-UABCS Ba34. San Juan Basin-Mesa Azufrera, at Lat. N. 26°33.6', Long. W 112°46.4', Mexican government topographic quadrangle map (1:50000) of San José de Gracia (G12A64-INEGI, 2003), Baja California Sur, Mexico.

- MHN-UABCS Ba35. Southern Mesa Copalar, at Lat. N. 26°33.4', Long. W 112°45.8', Mexican government topographic quadrangle map (1:50000) of San José de Gracia (G12A64-INEGI, 2003), Baja California Sur, Mexico.
- MHN-UABCS Ba37. Arroyo El Mezquital, at Lat. N. 26°13.2', Long. W 112°21.3', Mexican government topographic quadrangle map (1:50000) of San José de Gracia (1:50000) of San Juanico (G12A75-INEGI, 2004), Baja California Sur, Mexico.
- MHN-UABCS Ba38. Punta Ostra, at Lat. N. 26°16.8', Long. W 112°24.6', Mexican government topographic quadrangle map (1:50000) of San José de Gracia (1:50000) of San Juanico (G12A75-INEGI, 2004), Baja California Sur, Mexico.

6. Systematic palaeontology

We follow the classification system for bivalves that was proposed by Coan and Valentich-Scott (2012) to the genus level, except for the case of the extinct genus *Gryphaeostrea*, in which Stenzel (1971) was used. The specimens studied have been deposited in the Colección de Referencia Paleontológica de Invertebrados, Museo de Historia Natural de la Universidad Autónoma de Baja California Sur (MHN- UABCS).

Class Bivalvia Linnaeus, 1758
Subclass Protobranchia Pelseneer, 1889
Order Mytilida Férussac, 1822
Superfamily Mytiloidea Rafinesque, 1815
Family Mytilidae Rafinesque, 1815
Subfamily Lithophaginae Adams and Adams, 1857

Genus *Lithophaga* Röding, 1798

Type species. *Lithophaga mytiloides* Röding, 1798, p. 156 (=*Mytilus lithophagus* Linnaeus, 1758); designation by monotype. Recent, Mediterranean.

Diagnosis. Shell elongate and cylindrical. Sculpture absent or of weak oblique striae; posterior slope frequently with ridges or radial riblet. Umbones anterior; ligament external, elongate usually sunken into groove and attached to resilial ridge.

Lithophaga sp.
(Figure 3.1)

Description. The specimen has a thin cylindrical shell that tapers towards the rear. Sculpture is weak, with oblique striae. Umbones anterior.

Material. One specimen, MHN-UABCS Ba14/33/32; 30 mm in length by 13,5 mm in height.

Occurrence. Locality 1219, Squires and Demetrion (1992).

Age. Early Eocene ("Capay Stage").

Discussion. The specimen was embedded in a sandstone rock, apparently *in situ*, because these bivalves drilled rocks, coral heads and even other shells, in order to create a burrow.

Lithophaga is a genus with wide age range and a cosmopolitan distribution. However, this is the first report in the state of Baja California Sur, which would further extend its known distribution range.

Order Arcida Gray, 1854
Superfamily Arcoidea Lamarck, 1809
Family Arcidae Lamarck, 1809
Subfamily Anadarinae Reinhart, 1935

Genus *Anadara* Gray, 1847

Type species. *Arca antiquata* Linnaeus, 1758; original designation. Recent, Indian Ocean.

Diagnosis. Shell inequivalve of subquadrate oval or trapezoidal shape and generally longer than high. Umbo is prominent, usually ahead of the midline but symmetric in the cardinal area. Outer surface has numerous radial ribs and with radial striated interspaces. Elongated flap more or less straight to slightly curved with numerous transverse teeth.

Anadara? sp.
(Figure 3.2)

Description. One internal mould with poor preservation and incomplete. The shell shape is slightly longer than tall. The mould only retains a very prominent umbo. Radial ribs on the surface observed, although not completely checked. The shape of the flap is flat or slightly arched.

Material. One specimen, MHN-UABCS Ba37/44/388; with a height of 26 mm, with a length of 33 mm.

Occurrence. Arroyo El Mezquital.

Age. Late Middle Eocene ("Tejon Stage").

Discussion. The specimen was classified within the family Arcidae mainly by the shape of the hinge, as it is straight and this is one of the main characteristics of the family. The form of the shell is the main criterion to assign to the genus *Anadara* (Poutiers, 1995; Coan *et al*., 2000), because several species of this genus have a similar form to the specimen found.

Order Ostreida Férussac, 1822
Superfamily Ostreoidea Rafinesque 1815
Family Gryphaeidae Vyalov, 1936
Subfamily Exogyrinae Vyalov, 1936

Genus *Gryphaeostrea* Conrad, 1865

Type species. *Gryphaea eversa* Melleville, 1843, p. 87. Eocene, France.

Diagnosis. Valve left convex, with a well-developed

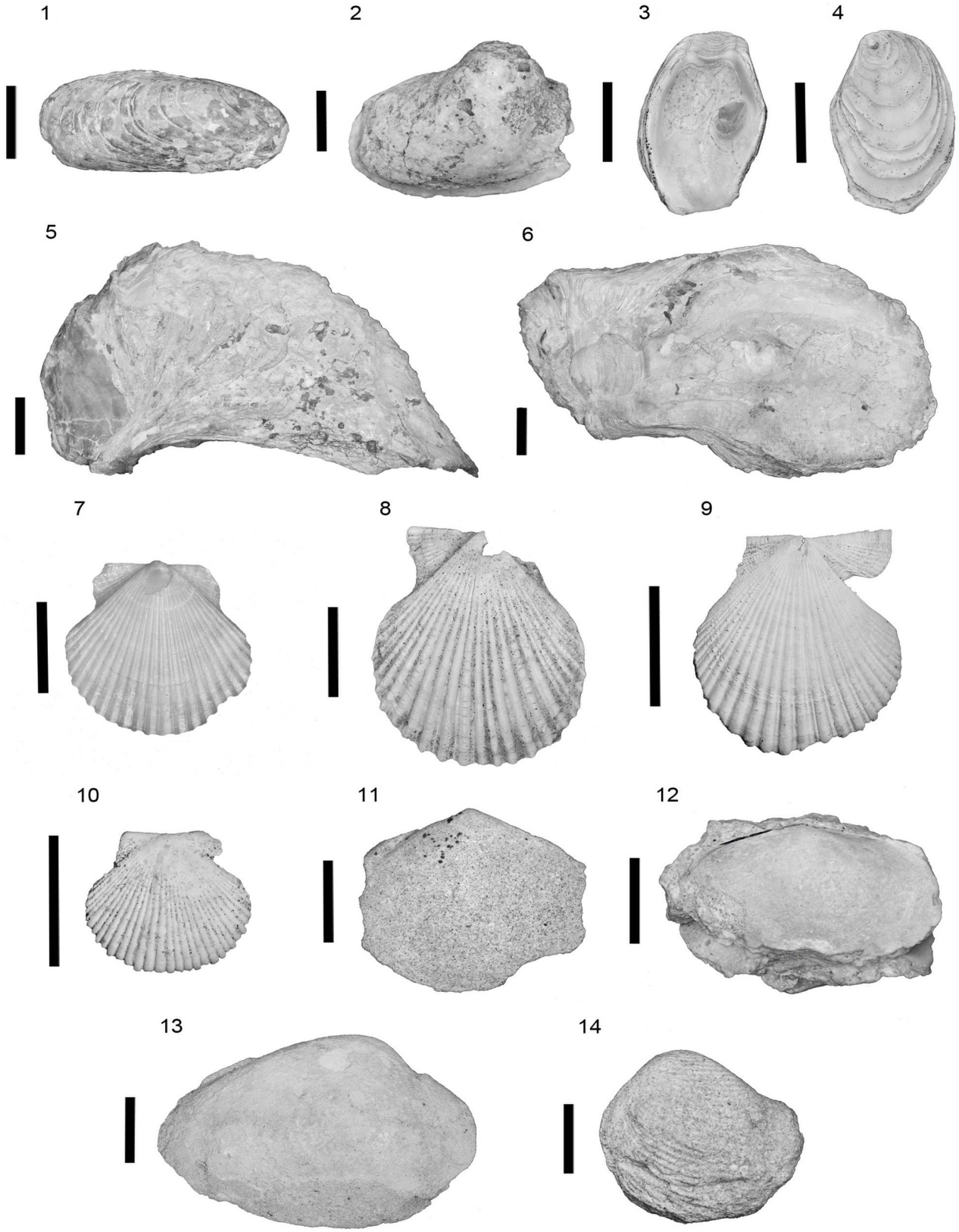

Figure 3. 1, *Lithophaga* sp., MHN-UABCS Ba14/33/32, right valve; 2, *Anadara*? sp., MHN-UABCS Ba37/44/388, right valve; 3–4, *Gryphaeostrea sanjuanicus* sp. nov., MHN-UABCS Ba38/45/80, right valve (holotype); 5–6, *Ostrea* sp., cf. *O. contracta amichel*, MHN-UABCS Ba38/45/39, right valve (5, external lateral view and 6, interior view); 7, *Argopecten*? sp., MHN-UABCS Ba1/9/52, right valve; 8, *Chlamys* sp. a, MHN-UABCS Ba32/36/76, left valve; 9, *Chlamys* sp. b, MHN-UABCS Ba32/36/82, right valve; 10. *Pecten*? sp., MHN-UABCS Ba32/36/84, right valve; 11–12, *Tellina* sp., MHN-UABCS Ba32/36/98, left valve (11), and MHN-UABCS Ba33/39/123, right valve (12); 13. *Macrocallista* sp., MHN-UABCS Ba37/44/969, right valve; 14. *Pitar* sp., MHN-UABCS Ba6/23/33, right valve. Scales to 10 mm, except *Ostrea* sp., cf. *O. contracta amichel* to 20 mm.

area without commissural chomata deep umbonal cavity dominated by the hinge area; fixing large area in many species, but small in others, this position posterior or posterodorsal margin of the valve, as they may be inclined roughly between 45° to 90° in an anteroposterior direction. Right valve flat oval to triangular and lacking chomata, is considerably smaller than the left valve, leaving a bare margin of up to seven millimetres in the left valve. Both valves are deep, narrow and spiral growth displaying a ligamental area that expands and straightens sharply near the end of the shell growth. External sculpture of both valves with numerous concentric growth lines and regularly spaced, strongly folded and elevated.

Gryphaeostrea sanjuanicus sp. nov.
(Figures 3.3–4, and Figure 4)

Etymology. The nearest town to the locality where the specimens were collected is San Juanico.

Description. Original shells in a good state of preservation, 12 right valves and eight fragments with poor preservation. Shell small, slightly flat with an oval or quadrate contour, with a deep umbonal cavity, the valve surface with numerous concentric growth lines and regularly spaced, tightly folded and raised over the entire surface of the shell; the adductor scar have a sub-circular to oval shaped, near to the posterior margin and approximately half the height of the valve. Ligamental area has a deep fossa, with two lateral areas thickening. Hinge lacking teeth.

Type. Holotype, MHN-UABCS Ba38/45/80; and eight paratypes, MHN-UABCS Ba38/45/66-73.

Material. 20 specimens, MHN-UABCS Ba35/42/31 and MHN-UABCS Ba38/45/66-84. 12 right valves and eight fragments.

Measurement. At different stages of growth, maximum height 39 mm, while minimum height 12 mm.

Type locality. Punta Ostra, near the town of San Juanico, Baja California Sur, Mexico.

Occurrence. Ba35, south of Mesa Copalar; and Ba38, Punta Ostra.

Age. Early Eocene ("Capay Stage") and late Middle Eocene ("Tejon Stage").

Discussion. The specimens found in Bateque Formation are considered a new species on the Pacific Coast of North America, since to date these are the only original shells described. Previously, Moore (1987) mentioned *G. aviculiformis* Anderson (1905, p 194-195, pl. 13, figs. 3-5) from the Domengine Formation, California, in his comments indicate that the right valve have a similar form to a operculum, as *G. sanjuanicus*, however, the description is limited and is based on shell fragment. The original description by Anderson is a similar to *G. sanjuanicus*, but the holotype is broke, and the comparison is difficult.

Several authors have reported the genus *Gryphaeostrea* in different parts of the world since the age range is from the Cretaceous to the Miocene. The Eocene species reported are *G. vomer* Morton, 1834, New Jersey and North Carolina, United States of America and parts of Europe; *G. trachyoptera* White, 1887, Brazil; *G. eversa* (Melleville, 1843) of the Paris Basin; *G. plicatella* (Morton, 1834) United States of America; *G. aviculiformis* (Anderson, 1905) of Domengine Formation, California. *G. callophyla* (Ihering, 1903) for the Danian Stage, Paleocene in Argentina (Moore, 1987; Casadío, 1998).

Despite the wide age range and its wide distribution, especially in the Atlantic Coast, the new species *Gryphaeostrea sanjuanicus* provides new data for understanding the paleobiogeography and the evolutionary history of the genus on the Pacific Coast of North America.

Family Ostreidae Rafinesque, 1815
Subfamily Ostreinae Rafinesque, 1815

Genus *Ostrea* Linnaeus, 1758

Type species. *Ostrea edulis* Linnaeus, 1758; by subsequent designation. Recent, England.

Ostrea sp., cf. *O. contracta amichel* Gardner, 1945
(Figures 3.5–6)

Description. Specimens were abundant, but only found in one locality. In this site, valves were found, both right and left, but no articulated specimen. The original shell is large, thick, oval, elongated, and inequivalve. The left valve is slightly convex, while the right is almost flat. Surface sculpture has numerous concentric sheets and growth lines. The ventral margin is rounded, while the lateral margins are almost straight, with numerous longitudinal strips. The ligament area is large with concentric grooves. Imprint of the adductor muscle is relatively small and oval.

Material. 17 specimens, MHN-UABCS Ba38/45/39-55.

Measurement(s). 200 mm maximum height found, common between 140 to 180 mm, 150 mm maximum length, common between 70 to 130 mm.

Occurrence. Punta Ostra.

Age. Late Middle Eocene ("Tejon Stage").

Discussion. *Ostrea* is one of the most abundant fossil records around the world, as it is a cosmopolitan genus. Despite this, identification of species is difficult since in some cases it is difficult to differentiate between left and right valves. This is because these oysters have an extensive and irregular shell, which makes the observation of certain characters difficult (Poutiers, 1995).

Taking into account the characteristics of the specimens found in the Bateque Formation, the specific determination of the genus *Ostrea* is somewhat complicated. So far, there is only one species described from the middle Eocene in Mier Basin, Tamaulipas, which matches the characteristics of *Ostrea* sp., this species is *O. contracta amichel* Gardner (1945). However, this species is similar to *O. contracta*, but this has a long and narrow shell (Perrilliat, 1963).

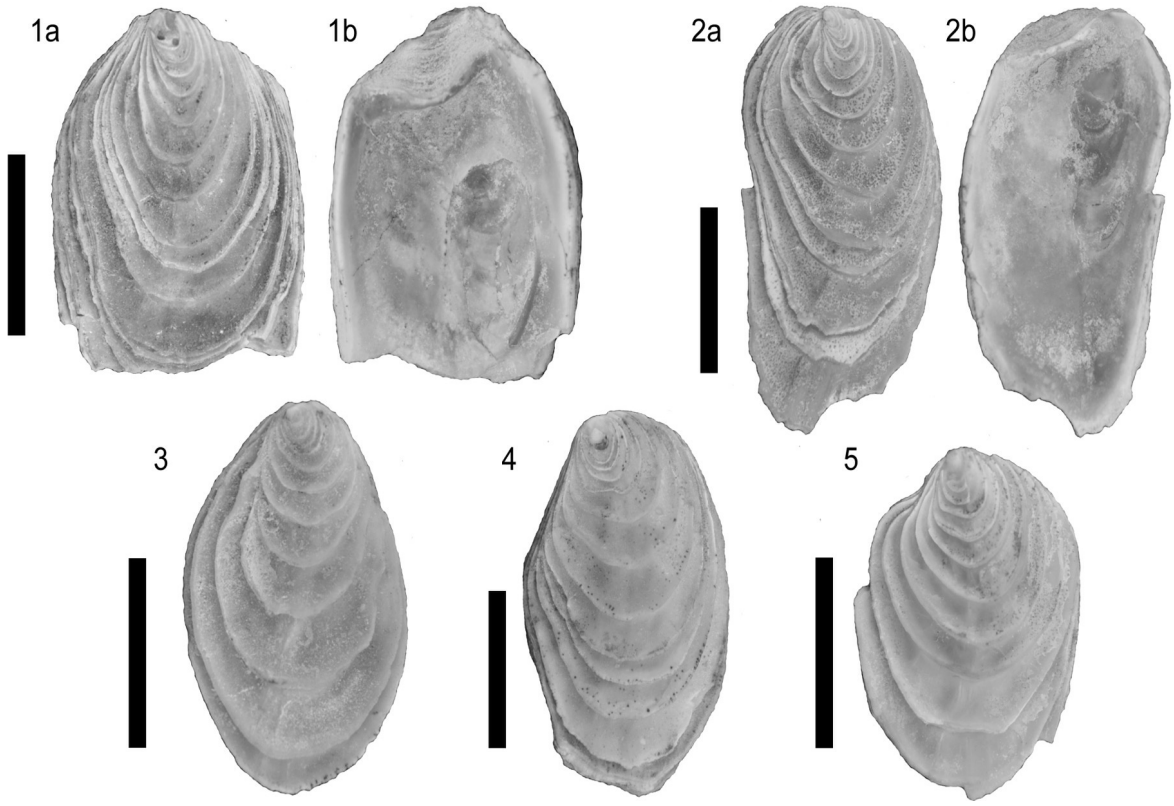

Figure 4. *Gryphaeostrea sanjuanicus* sp. nov., right valves paratypes. 1, MHN-UABCS Ba38/45/66 (1a, external view, and 1b, interior view); 2, MHN-UABCS Ba38/45/67 (2a, external view, and 2b, interior view); 3–5, MHN-UABCS Ba38/45/68-70 (external view). Scales to 10 mm.

O. contracta is probably a descendant of the subspecies *amichel*, although for many years it was known with the name of *O. alabamiensis* Lea (1833). All the specimens there have been reported in the eastern or the western Mexico Gulf (Gardner, 1945).

The specimens from Mier Basin in Tamaulipas and those found in Bateque Formation, Baja California Sur, are the only records we have of this genus and/or species in Mexico. The affinity between the specimens is remarkable and for this reason, the specific determination should be respected.

Order Pectinida (Gray, 1854)
Superfamily Pectinoidea Rafinesque, 1815
Family Pectinidae Rafinesque, 1815
Subfamily Chlamydinae Teppner, 1922

Genus *Argopecten* Monterosato, 1889

Type species. *Pecten solidulus* Reeve, 1853 (=*Pecten ventricosus* G. B. Sowerby, 1842), by subsequent designation (Monterosato, 1889, p 193). Holocene, from southern California to Peru.

Diagnosis. Shell convex, thin, usually subcircular. Both valves with numerous imbricated, strong and broad radial ribs, interspaces overlain by fine commarginal lamellae. Anterior and posterior ears, long and uneven.

Argopecten? sp.
(Figure 3.7)

Description. Only three original shells with good preservation, including two complete, one right and one left. All valves are of small size; despite this, the shell is thicker and sub-circular in shape, moderately convex. External carving has 24 square radial ribs separated by and flat bottom interspaces slightly narrower than the ribs. On the surface, concentric growth lines are also observed. The anterior and posterior ears of both valves (left and right), presented six radial ribs crossed by growth lines. The hinge only contains faint marginal reliefs (toothless).

Material. Complete original shells; MHN-UABCS Ba1/9/52 20 mm in height by 19 mm in length; MHN-UABCS Ba1/9/53, 11 mm in height by 10,5 mm in length.

Occurrence. Mesa San Ramón (La Rinconada).

Age. Late Middle Eocene ("Tejon Stage").

Geological range. The age range reported for the genus ranges from the Oligocene to Recent.

Discussion. Up until now, the genus *Argopecten* had not been reported in the Eocene Epoch, so this would be the first record for this period and for the Pacific Coast of North America. However, the specific determination can raise questions about the material found in the Bateque

Formation, as this is very similar to *A. cristobalensis*, differing only in the size and number of ribs in the auricles of the left valve (with eight or nine ribs and a slight indentation in the anterior ear). *A. cristobalensis*' geological range is Pliocene, being reported in the Almejas Formation with a geographical distribution from Cedros Island to Turtle Bay in Baja California.

Due to its characteristics, the material found can generate some doubt, as the Almejas and Bateque formations are closely together, but specimens were obtained from a locality named Mesa San Ramón (La Rinconada) which have been attributed to late Middle Eocene age (González-Barba, 2003). The idea of extending the age range of *Argopecten* cannot be conclusive because the fossils could have been transported in some way, or it could just be a new species. However, we need to find new specimens in other localities of the Bateque Formation, which could confirm this hypothesis, but the information presented herein should be considered.

Genus *Chlamys* Röding, 1798

Type species. "*Pecten islandicus* Linnaeus" (=*Ostrea islandica* Gmelin, *Pecten islandicus* Müller); by subsequent designation (Herrmannsen, 1847–49, p. 231). Recent, North Atlantic from Norway to Iceland, Greenland, and south to Cape Cod.

Diagnosis. Shell small subcircular in form, generally higher than long and often oblique. Radial shape with numerous primary and secondary ribs. Presents a concentric figure consisting of small flakes which gives the ribs a rough texture (rough or uneven). Unequal atria, *i.e*. longer than the anterior posterior. The anterior ear feature byssal notch, and usually with a ctenolium with four to six teeth.

Discussion. Both generic and specific determination are complicated, since the specimens found have quite poor preservation and most are incomplete. The genus *Chlamys*, despite having a wide age range (from the Permian to Recent), is virtually unknown in the Pacific Coast of North America with Eocene age. The specific determination can be argued; however, as reported here, it should be considered for future ecological and biogeographic interpretations of the genus.

Chlamys sp. a
(Figure 3.8)

Description. Original shells with good preservation, although no complete shell. Two left valves were found, while the rest are indistinguishable. Shell of medium size, compressed and thin, more height than length. The anterior and posterior margins are straight. Both valves show almost the same convexity. The outer surface has between 22 to 24 radial ribs, rounded. The ribs show protuberances in the form of small spines and small scales, particularly well developed in the ventral and lateral margin ribs, and numerous concentric grooves. The density and size of the scales and spines vary considerably between individuals. The anterior and posterior auricles of the left valve between seven and ten have perfectly smooth ribs; no spines or flakes are observed on these.

Material. Six specimens, MHN-UABCS Ba32/36/76-81. Specimen with key MHN UABCS Ba32/36/76, height of 27 mm by 22 mm in length; remaining are incomplete specimens.

Occurrence. Mesa El Mezquital.

Age. Late Middle Eocene ("Tejon Stage").

Discussion. There are several species of the genus *Chlamys* reported in the Eocene Epoch in different parts of the world. The only record of this genus in the Pacific Coast of North America is reported by Nilsen in 1987, where it is mentioned that Nilsen and Addicott (1971) collected fragments *Chlamys*? sp. in San Emigdio, Kern County, California, United States of America, with an age range of "Tejon Stage"; however, there is no description of the material.

The specimens found in Bateque Formation, have some affinities with *Chlamys varia* (=*Mimachlamys varia*), but this species has an age range from Miocene to Recent, and has only been reported in different European localities.

So far, *Chlamys* sp. a represents the first species reported from the Pacific Coast of North America with an Upper Eocene age; however, more and better-preserved specimens are needed to better determine the species. Furthermore, this record should be taken into account for future paleobiogeographic interpretations.

Chlamys sp. b
(Figure 3.9)

Description. Original thin and fragile shells but with good preservation. Of the six valves, three are right, one is left, and two are incomplete fragments. The shell is of small size, and slightly equilateral convex, is higher than long. The anterior and posterior margins are straight. Rights valves have bifurcated radial ribs, which appear towards the middle, between two ribs, a thinner rib, a total of between 38 to 42 ribs, the interspaces are narrow and smooth. The above atrium six to eight shows radial ribs and concentric lamellae, which pass above and through the ribs, while the atrium is smaller after six radial ribs. Straight hinge line with a byssal notch and ctenolium.

Material. Six valves (MHN- UABCS Ba32/36/82-87), of which only three right valves rights are complete. MHN-UABCS Ba32/36/82, height 19,5 mm, length 16,5 mm, hinge length 11,5 mm; MHN- UABCS Ba32/36/83, height 24 mm, length 21,5 mm, hinge length 14 mm; MHN-UABCS Ba32/36/84, height 15 mm, length 13,5 mm, hinge length 9 mm.

Occurrence. Mesa El Mezquital.

Age. Late Middle Eocene ("Tejon Stage").

Discussion. *Chlamys* sp. b confirms the presence of

the genus in Bateque Formation; however, the specific determination remains controversial. This species has some affinity with *C. opuntia*; both species are very similar, the only differences being the "size" and the number of ribs in the ear (12 ribs), plus the age range, Pliocene to Pleistocene for this species (Quiroz-Barroso and Perrilliat, 1989; Powell and Stevens, 2000).

So far there is no complete shell, *i.e*. right and left, making it even more difficult to describe the species. Nevertheless, similar to *Chlamys* sp. a, this record should be taken into account for further works.

Subfamily Pectininae Wilkes, 1810

Genus *Pecten* Müller, 1776

Type species. *Ostrea maxima* Linnaeus, 1758, p. 824; by subsequent designation (Schmidt, 1818). Recent, Atlantic Ocean.

Diagnosis. Shell subcircular with well-developed radial ribs, usually with grooves or slots on the ribs. Concavity present in many shells on the umbonal area of the right valve.

Pecten? sp.
(Figure 3.10)

Description. Only two original valves, with good preservation were found, and they are small and fragile. The shape of the shell is subcircular. Both valves are right and the ornamentation consists of 32–34 rounded radial ribs, separated by narrow slightly rounded interspaces and concentric growth lines are also observed. Poor preservation of the ears does not allow the observation of the ribs but lighter grooves are observed. The hinge lacks teeth, and contains only faint marginal relief.

Material. Only two specimens; MHN- UABCS Ba32/36/74, 11,5 mm high by 12 mm long and hinge length, 8 mm; MHN- UABCS Ba32/36/75, 10 mm high by 10 mm long and hinge length, 4,5 mm.

Occurrence. Mesa El Mezquital.

Age. Late Middle Eocene ("Tejon Stage").

Discussion. *Pecten*? sp. exhibits some affinity with *Pecten* (*Plagioctenium*) *evermanni* Jordan and Hertlein, 1926 (synonyms: *P.* (*Aequipecten*) *evermanni* in Grant and Gale, 1931 and *Argopecten evermanni* in Moore, 1984) reported on the Almejas Formation, Baja California, Mexico, with the Pliocene species. However, the right valve of *P.* (*Pl.*) *evermanni* has 30–31 radial ribs, and the anterior ear have four radial ribs including a very thick on the base, while the posterior ear is similar but without the thick rib (Jordan and Hertlein, 1926; Puffett, 1974; Moore, 1984; CAS, 2012).

The genus *Pecten* is known in the Eocene Epoch and in the Pacific Coast of North America, but these specimens represent the first record in the Bateque Formation.

Superorder Heterochonchia Gray, 1854
Order Venerida Gray, 1854
Superfamily Tellinoidea Blainville, 1814
Family Tellinidae Blainville, 1814

Genus *Tellina* Linnaeus, 1758

Type species. *Tellina radiata* Linnaeus, 1758; by subsequent designation (Children, 1823). Recent, Caribbean.

Diagnosis. Shell elongated and compressed. Hinge with two cardinal teeth in each valve, and a lateral tooth in one or both valves. The division of the genus *Tellina* in subgenus is inconsistent until now and there are most likely numerous morphological convergences.

Tellina sp.
(Figures 3.11–12)

Description. All specimens found are internal moulds or impressions of shells, some with good preservation, and others incomplete. Various forms, but most elongated-oval and with compressed shell. A deep mantle is observed in some specimens. The outer surface of all specimens is extremely smooth.

Material. 11 specimens, MHN-UABCS Ba4/47/11, MHN-UABCS Ba6/23/42-45, MHN-UABCS Ba14/33/39, MHN-UABCS Ba32/36/98 and MHN-UABCS Ba33/39/123-126. Moulds with different stages of growth, maximum height 30 mm, minimum 13 mm; 47 mm maximum length, minimum 23 mm.

Occurrence. Ba4 Rancho Malbar (south of Arroyo Mezquital); Ba6, Hill A Norte; Ba14 locality 1219, Squires and Demetrion (1992); Ba32, Mesa El Mezquital and Ba33, near locality 1219, Squires and Demetrion (1992).

Age. Early Eocene ("Capay Stage") and late Middle Eocene ("Tejon Stage").

Discussion. The evolutionary history of the family Tellinidae reveals diversification in different ocean basins, which seems to have resulted in many parallel forms. A clear example is the genus *Tellina*, which features a large number of subgenera and species that have generated a lot of contradictions when identifying and classifying (Moore, 1969a).

The specimens found in the Bateque Formation certainly belong to the genus *Tellina*; however, they have different contours, which means that they may belong to different subgenera. For example, it is possible that the specimens of the Locality 1219, Squires and Demetrion (1992) (Ba14 and Ba33) have affinity to *T.* (*Tellina*) (Moore, 1969b, p. N614, figs 11a, b) (Figure 3.12, MHN-UABCS Ba33/39/123) since the shape is more elongated, however the poor preservation of specimens makes a subgeneric and specific determination difficult.

Superfamily Veneroidea Rafinesque, 1815
Family Veneridae Rafinesque, 1815

Genus *Macrocallista* Meek, 1876

Type species. *Venus gigantea* Gmelin, 1791, p. 3282 (=*Venus nimbosa* Lightfoot, 1786, p. 175); designated by monotype. Recent, Caribbean.

Macrocallista sp.
(Figure 3.13)

Description. Only one complete internal mould was found, the remaining specimens are incomplete and are poorly preserved. Shape oval-elongated, slightly flattened and completely smooth shell. It has a moderately deep pallial sinus.

Material. Complete internal mould, MHN-UABCS Ba37/44/469, 40 mm tall and 60 mm in length; and other specimens with key MHN-UABCS Ba37/44/470-472.

Occurrence. Arroyo El Mezquital.

Age. Late Middle Eocene ("Tejon Stage").

Discussion. Three species of the genus *Macrocallista* are reported in the Pacific Coast of North America: *M.*? *packi* Dickerson (1914), *M. horni* (Gabb) Stewart (1930), and *M. meganosensis* Clark and Woodford (1927), all of the Eocene Epoch, found in strata of California, United States of America (Dickerson, 1914; Moore, 1968).

The poor preservation of specimens makes comparison with previously reported species difficult, since the descriptions are made with original shells and not with internal moulds. *Macrocallista* sp. of the Bateque Formation represents the first record of the genus in Baja California Sur, Mexico, therefore the geographical distribution should be extended.

Genus *Pitar* Römer, 1857

Type species. *Venus tumens* Gmelin, 1791, selected by a recent monotype. West Africa.

Diagnosis. Oval shell, orbicular, or subtriangular, usually with prominent umbones, located in the midline of valve or in front of the axis. Lunule usually present. External sculpture with numerous concentric ribs and/or a radial component.

Pitar sp.
(Figure 3.14)

Description. Internal moulds with poor preservation. Shell has sloping posterior margin, a concave anterior ventral margin, and an oval contour. Slightly elongated oval shell with prominent features which are umbones, prosogyrates, and anteriorly incurved. Sculpture with high external concentric ribs, each with different thickness, covering the entire shell. No internal structure is observed.

Material. Three specimens MHN- UABCS Ba1/38/38, MHN-UABCS Ba6/23/33, and MHN-UABCS Ba7/24/72. Average height 22 mm, average length 28 mm.

Occurrence. Ba1, Mesa San Ramón (La Rinconada); Ba6, Hill A Norte; and Ba7, Mesa La Salina.

Age. Early Eocene ("Capay Stage").

Discussion. *Pitar* is a very common genus in the Eocene Epoch, however it has many synonyms or simply several species of the genus have been reassigned to other genus of the family Veneridae, hence allocation of this genus is truly complicated and even more so when there are no complete specimens.

The specimens found are very similar to the specimens reported by Weaver and Van Winkle-Palmer (1922) in his "Fauna from the Eocene of Washington", where they describe two new species of the genus *Pitaria*. The first is *P. eocenica*, while the second is *P. stocki*, both very similar, and very similar to the internal moulds found, although only certain external characters are comparable.

Both species are very similar, *i.e.*, the shape of the shell is almost equal showing differences in the shape of the anterior and posterior margin, while the position of the umbo is perhaps one of the biggest differences between them. The umbo of *P. stocki* is positioned at an angle of 35° of the anterior margin, while the umbo of *P. eocenica* is one third of the distance from the anterior margin. Similarly, both species have an outer surface having numerous concentric ribs; however, the interspaces are wider in *P. eocenica* than *P. stocki* (Weaver and Van Winkle-Palmer, 1922).

Because of the resemblance, it is truly difficult to distinguish the species, and, in addition, currently the genus *Pitaria* is obsolete and their species have mainly been allocated to the genus *Pitar*.

On the other hand, there are several species of genus *Pitar* reported in the Pacific Coast of North America, in the Eocene Epoch, which are: *P.* (*Calpitaria*) *uvasanus* (Conrad, 1855); *P.* (*Lamelliconcha*) *joaquinensisk* Vokes, 1939; and *P. uvasana coquillensis* Turner, 1938, but none of these species were found in the Bateque Formation (Squires and Demetrion, 1992; Squires, 1984, 1999, 2001).

Although the generic and specific designation is still a question for specimens found in Bateque Formation, it is highly likely that the genus *Pitar* had a wide distribution and extends in to part of Baja California Sur, during the Eocene.

7. Conclusions

Marine invertebrates found in the Bateque Formation indicate a warm-water biota related to the tropical Tethys Sea current, which created the conditions for a wide biotic exchange between marine organisms of the Atlantic, Gulf of Mexico-Caribbean, and Pacific.

The fossil fauna indicates an age range of the "Capay Stage" (Early Eocene: Ypresian) to the "Tejon Stage" (late Middle Eocene: Bartonian). The problem lies in the limits of "Tejon Stage", because this stage includes part of the Middle Eocene (upper part Lutetian and the whole

Bartonian), and a small portion of the Upper Eocene (lower part of Priabonian). Thus, studies of magnetic stratigraphy, biostratigraphy, and stable isotopes are needed in order to obtain a more precise age-calibration.

The age previously suggested by Mina-Uhink (1956, 1957) and Sorensen (1982) for the Bateque Formation is the middle Paleocene, based on small foraminifera faunal; however, this cannot be corroborated by the results of this study, since no invertebrate or locality indicated this age.

The litho- and biostratigraphic data are consistent when the comparison between both formations is carried out, *i.e*. the fossils found in the middle part of the Tepetate Formation coincide with those present in the middle of the Bateque Formation, which proves that both formations are partially contemporaneous and correspond to the "Capay Stage" (early Eocene: Ypresian). Depositional environments that prevail during the Eocene correspond to inner to outer shelf, according to the faunal associations found in the majority of the localities.

Finally, this study represents the acquisition of new data, whose interpretations provide foundation knowledge for palaeontologic, stratigraphic correlation and evolutionary history of species in the Pacific region of North America

Acknowledgements

We are grateful to the Programa Institucional de Formación de Investigadores, Instituto Politécnico Nacional (PIFI-IPN, 2011), and Consejo Nacional de Ciencia y Tecnología (CONACYT) that provided a scholarship to make this work.

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Manuscript received: March 8, 2016.
Corrected manuscript received: April 18, 2016.
Manuscript accepted: April 21, 2016.