ABOUT AN OUTCROP WITH FAUNA OF THE *VENERICARDIA PLANICOSTA* GROUP IN THE WESTERN BURGOS PROVINCE, NE MEXICO

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Resumen

El presente estudio trata sobre el afloramiento "El 7", que se encuentra en el Embalse del Río Grande, al oeste de la provincia de Burgos, en el distrito "China", formado por estratos sedimentarios del Mesozoico Tardío y Paleoceno. Este afloramiento se encuentra en el anticlinal de Vaquerías (sistema Higueras-Vaquerías), conocido desde 1946. Se muestrearon varios ejemplares del grupo *Venericardia planicosta* Lamarck. Tras comparar la morfología de la concha así como el rango estratigráfico de estos fósiles con holo-, co- e, hipotipos de diferentes publicaciones, una parte de las conchas descritas pueden asignarse a la especie *Venericardia (Venericor) diga*.

Palabras claves

Provincia de Burgos, Cuenca de Burgos, Bahía de Río Grande (Río Bravo), Paleógeno, Paleoceno, Eoceno, Formación Wilcox, Formación Midway, Grupo *Venericardia planicosta* Lamarck, *Venericardia (Venericor) zaptai*, *Venericardia (Venericor) diga*

Abstract

The present study deals with the outcrop “El 7”, which is in the Rio Grande Embayment, western Burgos province, in the "China" district, formed by sedimentary strata from the late Mesozoic and Paleocene. This outcrop is located on the Vaquerías anticline (Higueras-Vaquerías system), known since 1946. Various specimens of the *Venericardia planicosta* Lamarck group were sampled. After comparing the shell morphology as well as the stratigraphic range of these fossils with holo-, co- and, hypotypes from different publications, a part of the described shells can be assigned to the species *Venericardia (Venericor) diga*.

Keywords

Burgos Province, Burgos Basin, Rio Grande Embayment, Paleogene, Paleocene, Eocene; Midway Formation, Wilcox Formation, *Venericardia planicosta* Lamarck group, *Venericardia (Venericor) zaptai*, *Venericardia (Venericor) diga*

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Introduction

Although the Burgos Basin has a supr-regional geological and economic importance, it has numerous natural resources (uranium, coal, hydrocarbons, etc.); there are few published studies on the surface geology due to the specific morphological conditions as part of the Gulf of Mexico Coastal Plain compared to the adjacent Sabinas and La Popa basins, as well as the Sierra Madre Oriental is underrepresented. Although Petróleos Mexicanos (Pemex) has conducted intensive exploration work in this basin, much of this data remains in unpublished archives (Eguiluz de Antuñano, 2011a).

The outcrop I would like to refer to in this paper is the point labeled "EL 7" by Hernández-Ocaña et al. (2018) at 25.469113° N and 99.283854°W. These are poorly exposed strata west of the Highway 35 Terán - China (see Figure 1). This outcrop has been used for paleontological field work for some time, as a rich Venericardia fauna can be found there. Stratigraphically, the "El 7" outcrop is in the Midway Formation (Carta Geológica [1:250000]; Río Bravo; Herrera-Monreal et al., 2008) on the eastern flank of an anticline of the Higueras-Vaquerías system.

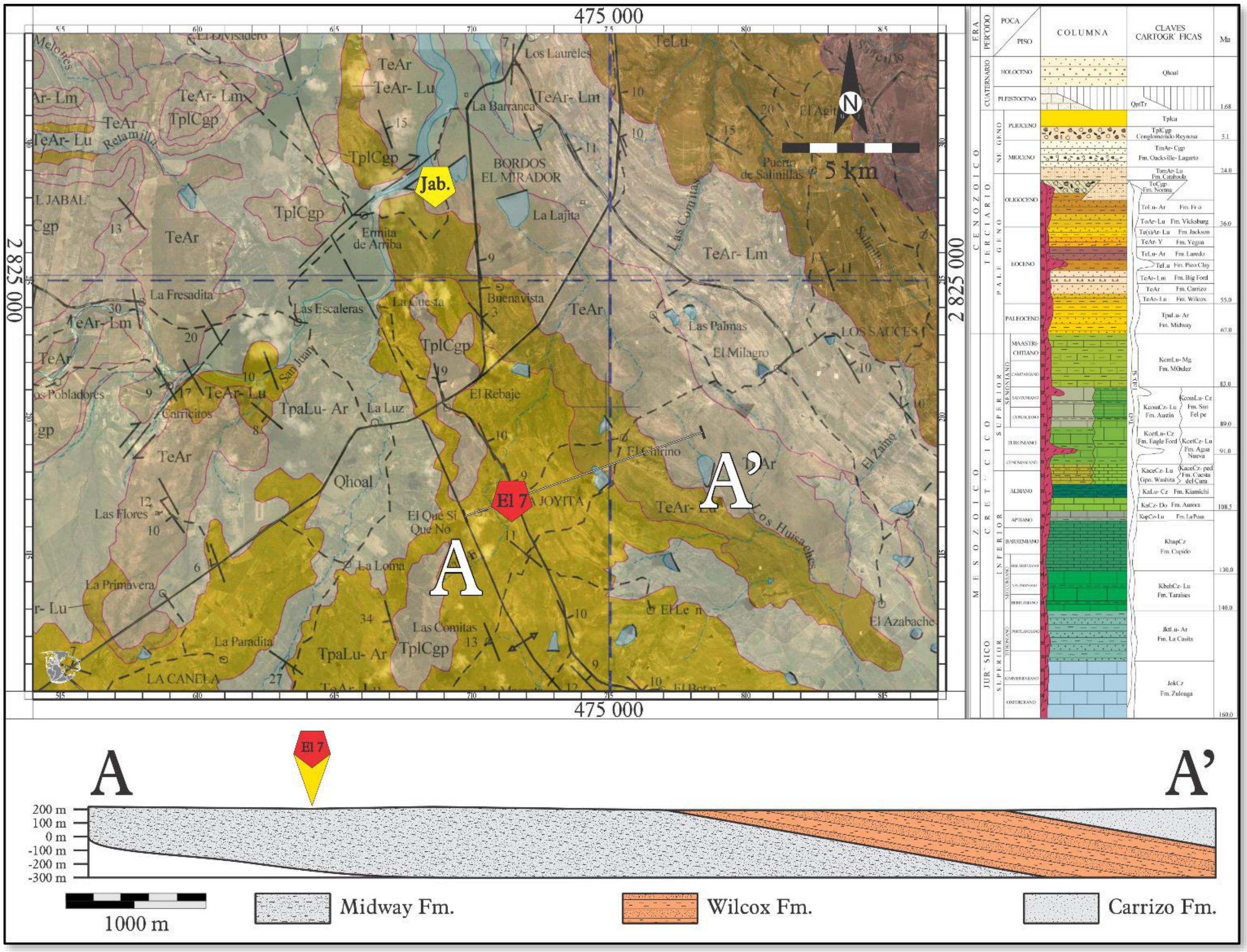

Figure 1: Above left: Geological map from the Mexican Geological Service (SGM, 2008) projected onto the Google Earth image. Above right: stratigraphic column from Herrera-Monreal et al. (2008). The section described in the paper fits into the Midway Formation Below: schematic cross-section from A, the anticline axis to A', the Carrizo Formation, showing that the real position of the section described in the paper is located 273 m under the Midway/Wilcox boundary. The overall length of section A–A' is 8,250 m (modified from Jenchen, 2019).

I want to take the opportunity to enrich the information published so far on the outcrop with a summary of generally available information and my observations on the topic. These are in detail (1) the geographic and stratigraphic position of the outcrop to the Burgos Basin; (2) the structural geology of the western part of the Burgos Province; (3) the stratigraphic evolution of the western Burgos Province in the Paleogene; (4) and observations of the lamellibranchiate in the working area with reference to the *Venericardoa planicosta* Lamarck Group in the Paleocene strata of the Midway Formation. This manuscript is divided into two parts: the first part deals with the stratigraphic and geographic position of the outcrop in the Burgos Province (Part I: About the Burgos Province). The second part deals with problems in describing, identifying, and stratigraphically classifying the occurring Venericardia fauna (Part II: The Venericardia problem).

About the Burgos Province

Although this section consists of a compilation of known literature, it is crucial to understand the geological situation of the Burgos Province.

Geographical/geological boundaries of the Burgos Province

The stratigraphic and structural development of NE Mexico begins with the fragmentation of Pangea in the late Triassic to the middle Jurassic. It led to the Gulf of Mexico's subsequent opening and developed a passive continental margin in the Late Cretaceous (Goldhammer & Johnson, 2001).

The early Cenozoic culminated in the Laramide foreland's deformation (Mexican orogen; see Fitz-Díaz et al., 2018). The structural core of northeastern Mexico consists of fault blocks from the Triassic and Lower Jurassic, which partly reflect Proterozoic and Late Paleozoic orogenic patterns of metamorphosis and igneous intrusions (Ramírez-Fernández & Jenchen, 2016; Torres-Sánchez et al., 2016, 2017; Alemán-Gallardo et al., 2019a,b, 2020; Casas-Peña et al., 2021; Ramírez-Fernández et al., 2021; Torres-Sánchez et al., 2021). The Coahuila Block, Burro Salado Arch, and Tamaulipas Arch testify to the initial segmentation of Pangea as highs. Sabinas Basin and the Monterrey Trough form the lows (see Figure 2). These early Mesozoic fault blocks, in turn, controlled the stratigraphic patterns of the late Jurassic and Cretaceous. These blocks strongly influenced the Laramide Orogeny's structural patterns and the deposition of the associated foreland basins (see also: Buffler & Sawyer, 1985; Pindell, 1985; Pindell & Barrett, 1990; Martini & Ortega-Gutierrez, 2016).

According to Hernández-Mendoza et al. (2008), the Burgos Basin (Echánove-Echánove, 1986 speaks of the Burgos Province) is a Cenozoic coastal basin in Eastern Mexico, which represents the southern extension of the Texas Rio Grande Embayment. The Burgos Province is located on the northeast coast of Mexico, east of the Sabinas Basin in northern Mexico, south of the extended Texas Gulf Coast Province, and north of the Laguna Madre-Tuxpan area. This area also includes the Cenozoic Tampico-Misantla Basin. The deepest part of the Burgos Basin lies northeast of the covered Mesozoic carbonate shelf (Tuxpan Platform), originally built as a structural high during the Jurassic opening of the Gulf of Mexico (e.g., Goldhammer, 1999; Galloway et al., 2000). The structural framework of the Burgos Province appears to be a transition zone between the gravitational collapse in Mexican offshore basins in the south (Wawrzyniec et al., 2003) and the salt-induced raft tectonics of the Gulf Coast in southern Texas (Al-Ghamdi & Watkins, 1996). The Burro Salado Arch and Tamaulipas Arch form the western boundary of Burgos Province.

Filling of the Mesozoic basins

An influx of clastic sediments marks the beginning of the deformation of the Mexican Orogen in the Sierra Madre Oriental into the foreland region around the Turonian/Coniacian limit (de Cserna, 1956; Baker, 1970; McBride et al., 1974; Padilla y Sánchez, 1982; Eguiluz de Antuñano, 1984; Soegaard et al., 2003; Gray et al., 2001). These sediments coming from the north and west filled the western basins up to the Maastrichtian, for example, the Parras Basin and the Monterrey Trough (Baker, 1970; McBride et al., 1974; Eguiluz de Antuñano, 2001) as well as the La Popa Subbasin during Paleocene-Eocene (Suter, 1984; Bitter 1986, 1993; Rehrmann et al., 2012). Lawton et al. (2020) give a summary of these events.

This beginning of Laramide Orogeny at the end of the Cretaceous period led to the elevation of the Sierra Madre Oriental and Sabinas basins west of the Burgos province, which initiated the deposition of a thick siliciclastic series to the east (Winker, 1984; Galloway et al., 1991, 2000; Hernández-Mendoza et al., 2008). The first significant inflow of sediments on the continental shelf of Burgos Province occurred during a transgression to the west, which led to the deposition of the mudstone-dominated Midway series in the early Paleocene, which was particularly dominant in the depocenter.

Overall, the clastic entry into Burgos Province was still relatively low at the beginning of the Cenozoic, as part of the sediments was enclosed in the considerable, locally actively accumulating Mayrán Basin (Amezcua et al., 2012; Gray et al., 2020). Once the contraction of the Laramide Orogeny ended, the area was uplifted and eroded. This complete inversion sent large amounts of eastward sediment, exceeding the Burro-Salado and Tamaulipas arches and the Tuxpan platform. This rapid accumulation causes growth faulting, downslope sliding, and folding of sediments along the entire eastern Gulf of Mexico (see Gray et al., 2020; Pérez-Cruz, 1993; Hudec et al., 2019). The western part of Burgos Province was no longer a deposition area. Echánove-Echánove (1986) described the shift of the nondeposition and deposition areas from west to east. This mobilization of sediments covers the Jurassic evaporites, which led to deformations. Finally, from the late Oligocene to the most recent times, thick sequences of siliciclastic sequences developed towards the Gulf of Mexico, favored by growth faulting and diapirism from Jurassic clay and salt deposits (Rodríguez-Martínez et al., 2020).

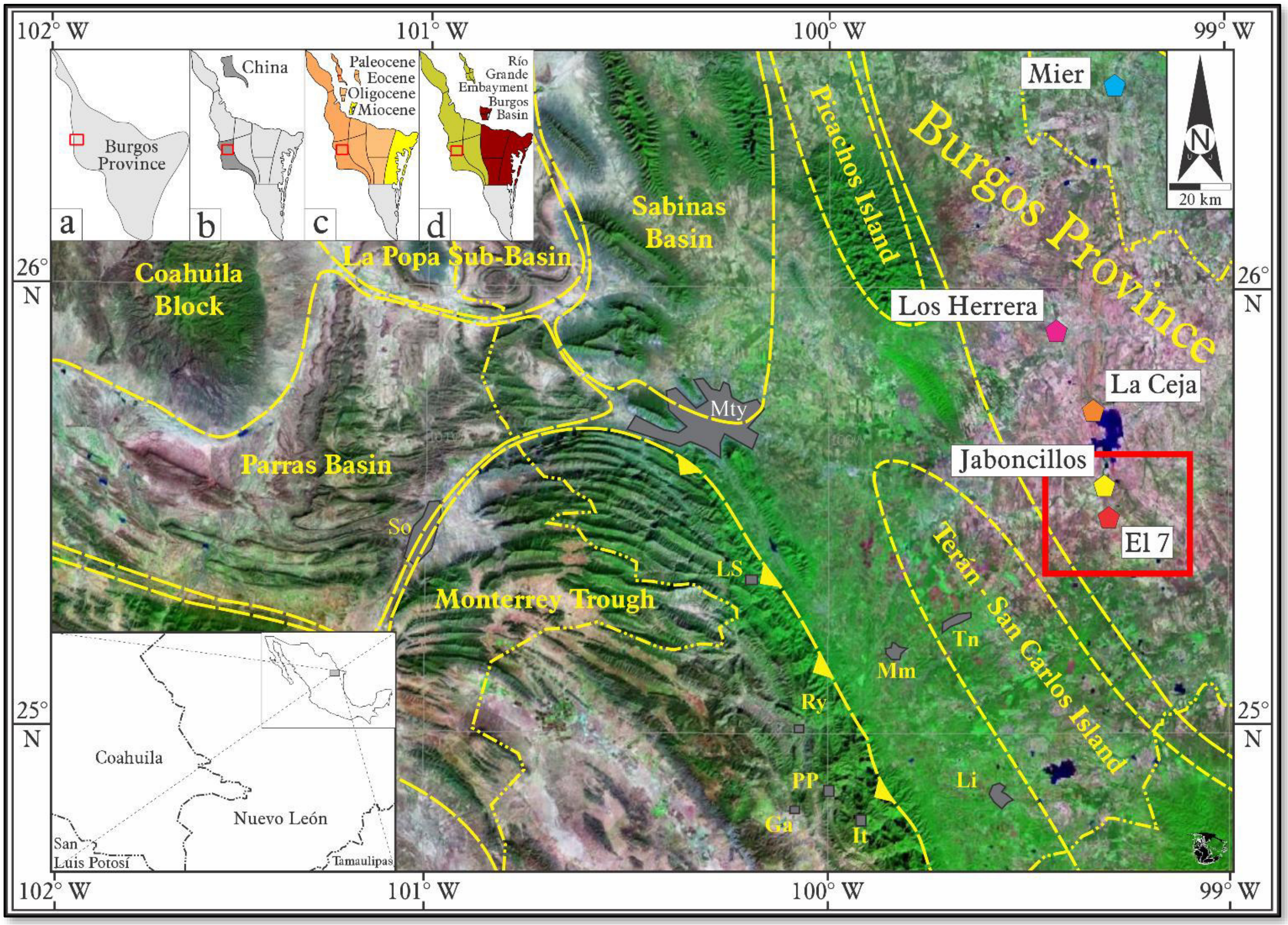

Figure 2: Mosaic of Mesozoic basins and heights in NE Mexico (modified from Jenchen, 2007). Inlets: a) Extension of the Burgos Province according to Muñoz-Cisneros et al. (2013); b) regions according to Echánove-Echánove (1986); c) segments with predominantly Paleocene, Eocene, Oligocene, and Miocene sediments (after Echánove-Echánove, 1986); d) Foothills of the Río Grande Depression and location of the actual Burgos Basin according to Gray et al. (2020) based on Echánove-Echanavoe (1986). Locations: Mty - Monterrey, Li – Linares, It – Iturbide, Ga – Galeana, PP – Potrero Prieto, Ry – Rayones, LS – Laguna de Sánchez, Tn – General Terán, So – Saltillo. Location of the outcrops: Jaboncillos, La Ceja, Los Herrera, and Mier from Perrilliat-Montoya (1963). The working area with the outcrop "El 7" is marked with a red frame.

During this uplift, anticlines developed, e.g., the great Higueras-Vaquerías system (Rodríguez-Cabo, 1946; Pérez-Cruz, 1993; Horbury et al., 2003). Typical of this is the development of Bathonian-Oxfordian sediments, including the evaporites deposited in half-grabens that have inverted into severely deformed, narrow folds, possibly an effect of a "fore bulge" associated with the foreland basins of the Mexican Orogen. The Higueras-Vaquerías system is an inverted former half-graben with a thick, late Jurassic filling (Horbury et al., 2003). The Vaquerías- and Papagayos folds strike northwest-southeast: the basement fault and inversion events of both dates from the middle Eocene. As the youngest unit, the Queen City Formation is involved in deformation and partly eroded. The discordant late Eocene Yegua Formation then shows an onlap onto the deformation zone and a progression away from it (see Figures 3 and 4) (Horbury et al., 2003).

The other developments in the western and eastern part of Burgos Province, according to Echánove-Echánove (1986), a general name for the region as the "Burgos Basin," make it appear problematic. Gray et al. (2020) go so far as to identify the western part of Burgos Province as the southern branch of the Rio Grande Embayment (comparable to the districts: Laredo, W

Presa Falcón, Camargo, General Bravo, and China according to Echánove-Echánove, 1986) the depocenter as the actual Burgos Basin with the districts: Reynosa, San Fernando and Matamoros (Figure 3).

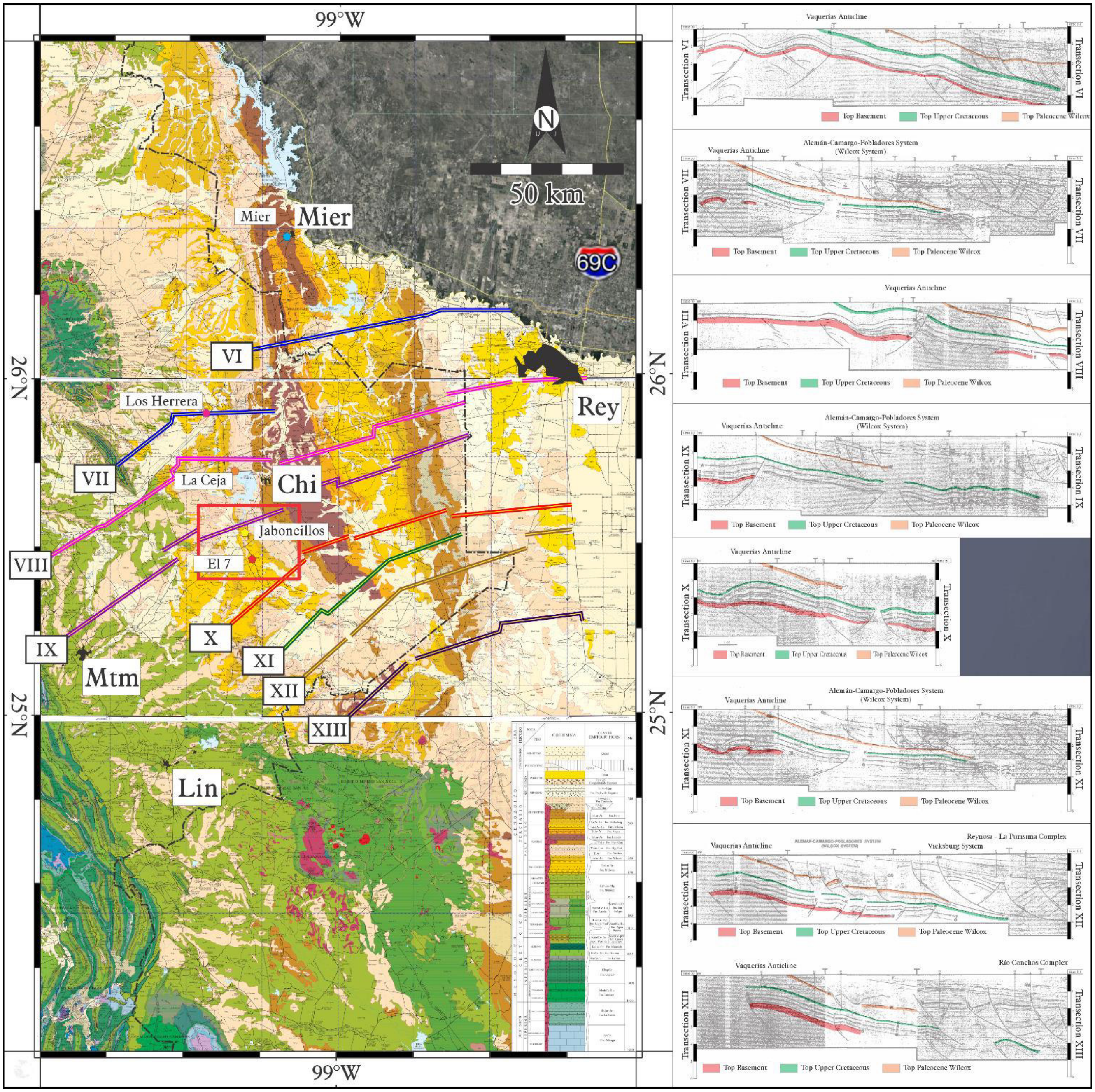

Figure 3: Mosaic of geological maps of the "Servicio Geológico Mexicano" (Mexican Geological Service, SGM) on a scale of 1: 250,000 (left) compared with the seismic sections VI-XIII from Pérez-Cruz (1993; right). Bottom-up: G14-11 Linares (Loaerza-García et al., 2008); G14-8 Río Bravo (Herrera-Monreal et al., 2008) and G14-5 Reynosa (Ramírez-Gutiérrez et al., 2008). Locations: Li – Linares, Mtm. – Montemorelos, Rey – Reynosa, Mier - Cd. Mier. Location of the outcrops: Jaboncillos, La Ceja, Los Herrera, and Mier from Perrilliat-Montoya (1963). The study area with the outcrop "El 7" is marked with a red frame.

Finally, it remains to be added that the working area discussed here is located on the Burgos Province's western limit (district of China, according to Echánove-Echánove, 1986). Its distance is small to Picacho Island (Burro-Salado Arch) and San Carlos Island (Tamaulipas Arch). The work area is crossed almost in the middle by the Vaquerías Anticline (see Figure 1 and Figure 3). In Figure 3, which is a combination of the geological maps of the "Servicio Geológico Mexicano" with the seismic sections from Pérez-Cruz (1993), its sections IX and X run through the upper and lower edge of the working area and leave no doubt about its structural geological situation arises.

Stratigraphic correlation

The Burgos Province's western area belongs to the relics of the Gulf of Mexico's opening, including the Tamaulipas Arch and the Burro-Salado Arch. The Burro-Salado Arch extends far up to Texas (Laredo Region). This arch and the adjacent areas have been covered mainly with sediments since the Upper Cretaceous. However, they continue to play an essential role as a paleo element, especially concerning the Laramide Orogeny; the discordant Yegua Formation illustrates this (see also Eguiluz de Antuñano, 2009, 2011b).

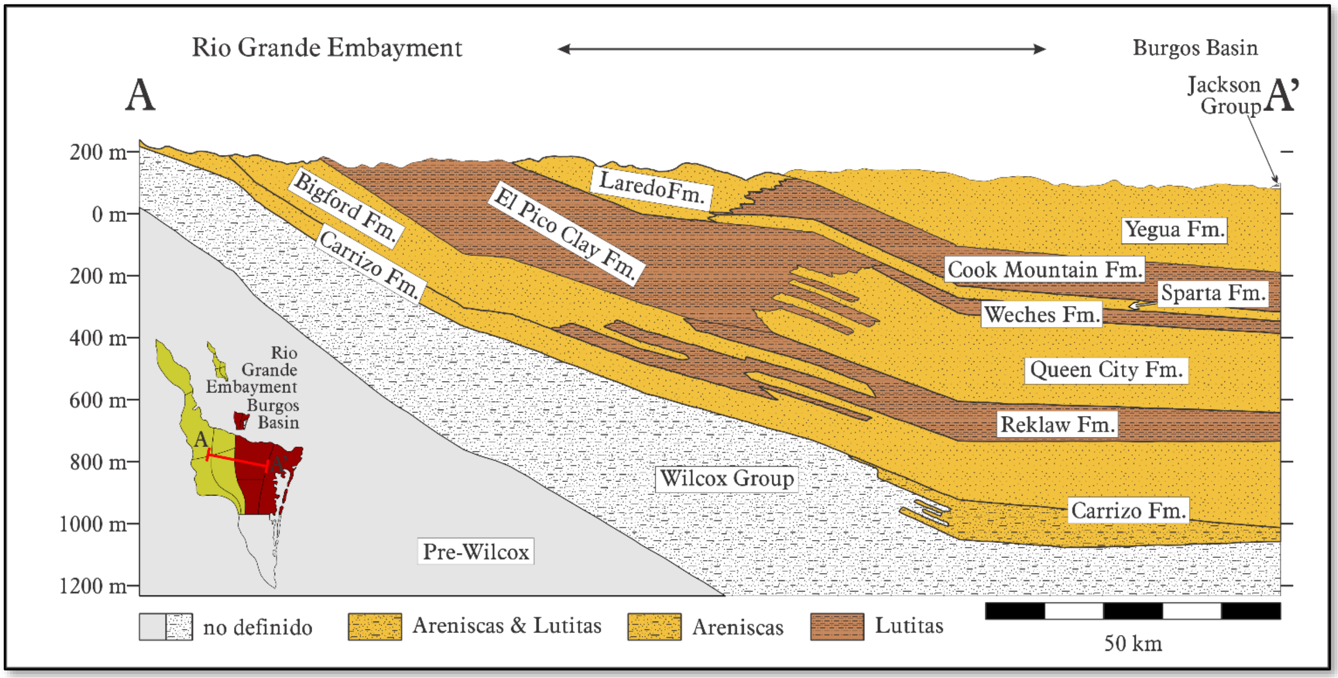

Figure 4: Conceptual geological section extending from the Rio Grande Embayment to the Burgos Basin (modified from Eargle, 1968). Here, the Carrizo Sands (Carrizo Formation) form an independent unit.

Therefore, Burgos Province's western area formed the uplift area, and the eastern region formed the depocenter, which absorbed the main sediment load. Accordingly, the facies distribution also follows the predominantly north-south striking structures. Consequently, it changes towards the depocentres of Burgos Province and the Rio Grande Embayment. An excellent example of this, provided by Eargle (1968), illustrates a W-E section from the Rio Grande Embayment to the Burgos Basin central area (Figure 4). These geological units shown in the figure can be lithostratigraphically correlated, following the Burro-Salado Arch to the south. The facies shift over the relatively short distance of <100 km towards the depocenter is also noticeable (Figure 4). It is possible to trace the lithostratigraphic units from Texas to the south and thus along the western edge of Burgos Province. In detail, I would like to point out the formation descriptions that are important for this correlation: Midway Formation (Juárez-Arriaga & López-Palomino, 2012); Wilcox Group/Formation (Amezcua, 2006); Claiborne Group (López-Palomino, 2010); Carrizo Formation (Palma-Ramírez & López-Palomino, 2019); Bigford Formation (Sáenz-Pita & López-Palomino, 2017); Reklaw Formation (Sáenz-Pita & López-Palomino, 2018); Queen City Formation (Sáenz-Pita et al., 2015); El Pico Clay Formation (Remigio-Morales & López-Palomino, 2014); Weches Formation (Contreras-Cruz & López-Palomino, 2014); Laredo Formation; (Juarez-Arriaga, 2010a); Yegua Formation (Juárez-Arriaga, 2010b); Jackson Formation (Juárez-Arriaga; 2010c); Vicksburg Formation (Juárez-Arriaga, 2010d); and Frío Formation (Juárez-Arriaga, 2010e).

Suppose the listed formations are correlated with the above-mentioned geological units of the Río Grande Embayment; the following stratigraphic table results (see Figure 5). It can be used to classify the Paleogene Venericardia fauna stratigraphically. As the figure shows, there is no single or reliable stratigraphic table for southern Texas and the Burgos Basin, but each table reflects its respective scope.

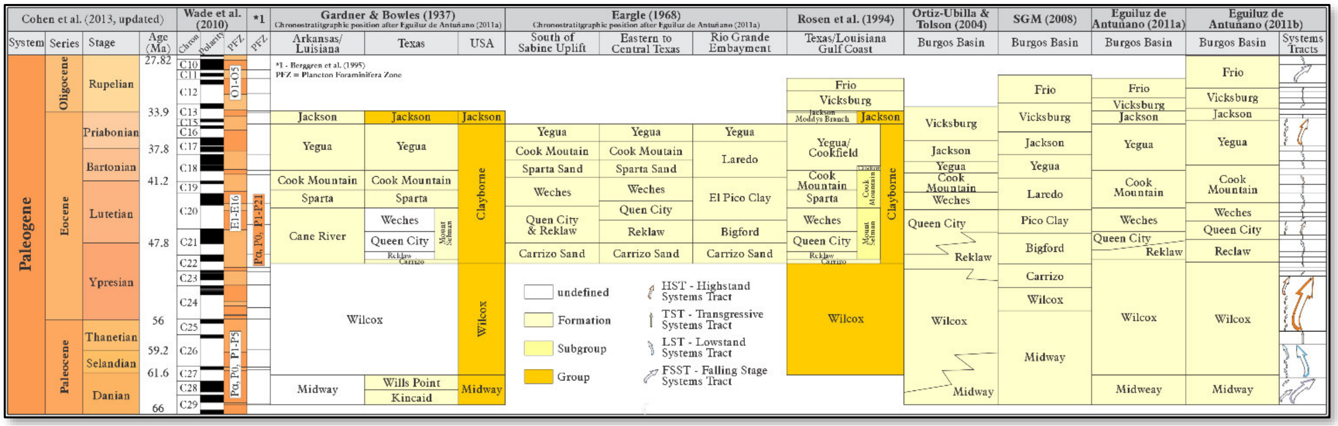

Figure 5: Stratigraphic table of parts of the Paleocene, Eocene, and the Lower Oligocene in Texas and the Burgos Province. Also, chronostratigraphic, magnetostratigraphic, and biostratigraphic zones are shown (Cohen et al., 2013; Wade et al., 2011; Berggren et al., 1995), as well as sequence stratigraphic interpretations according to Eguiluz de Antuñano (2011a) are included. Lithostratigraphic correlation based on Wade et al., 2011; Berggren et al., 1995; Gardner & Bowles, 1937; Eargle, 1968; Rosen et al., 1994; Ortíz-Ubilla & Tolson, 2004; Herrera-Monreal et al., 2008; and Eguiluz de Antuñano, 2009, 2011a, b).

The Venericardia Problem

Methodology

In this work 28 fossils were documented and compared with Hernández-Ocaña et al (2018) with 17 samples and the the study of Perriliat-Montoya (1963) from the "Jaboncillos" outcrop located a few kilometers north of "El 7" with 71 individuals. Both studies are used as comparison groups. In the "Laboratorio de Geopreparación, Facultad de Ciencias de la Tierra," the fossils were mechanically cleaned of coarse contamination, treated with hydrogen peroxide for several days, and mechanically cleaned again and again in the meantime.

The fossils were photographed with a SONY-NEX-7 camera, an 18-200 mm SEL18200 lens, and a black background under natural and artificial light. As far as possible, the left and right valves, front and back (anterior, posterior), and dorsal and ventral views were documented (see Figure 6). The better images from both series were scaled to the original size with Corel Draw and processed further with Adobe Photoshop: the objects were cut out, white balancing, exposure corrections were made, and a conversion to grayscale was carried out. The photographs from Gardner & Bowles (1937), Perrilliat-Montoya (1963), and Hernández-Ocaña et al. (2018) used in the following figures have been scaled to the original size and cut out. Images from Gardner & Bowles (1937) were then inserted on a colored background corresponding to their stratigraphic position (Cohen et al., 2013). The illustrations of Gardner & Bowles (1937) are not scaled, so I used the sizes of holo- and cotypes mentioned in the text and scaled the photographs of the hypotypes (without dimensions) to the average size of the individual species. Since the photographs published in Perrilliat-Montoya (1963) are of insufficient quality and not to scale, the photographs provided by UNAM (Alvarado et al., 2015a-d), which are of excellent quality, were used instead. These photographs show the same individuals, albeit with a slightly modified collection key. Furthermore, the individuals in my collection were measured, and, as far as possible, their ribs were counted.

Really *Venericardia (Venericor) zapatai*?

Figure 6 and Table 1 show that the bivalves collected in "El 7" are very diverse. They differ in size, shape, and number of ribs (Table 1). The morphological descriptions of the valves are based on McMahon & Bogan (2001), Gaspar et al. (2002), Kosnik et al. (2006), Carter et al. (2012), Silantiev et al. (2018), El Mekawy et al. (2019) among others.

Table 1: Morphological data of the examined individuals. Abbreviations: BV - Both Valves, RV - Right Valve; LV - Left Valve; F - Fragment.

Sample	Description	Height	Length	Convexity	Height/Length	Height/Convex	Rips
UJe-17.02.2020-01	(F-LV)	39.3	42.6		0.9		
UJe-17.02.2020-02	(F-RV)	52.0	51.0		1.0		20

Sample	Description	Height	Length	Convexity	Height/Length	Height/Convex	Rips
UJe-17.02.2020-03	(F-LV)	38.5	49.8		0.8		20
UJe-17.02.2020-04	(F-BV)	54.0	62.2	42.5	0.9	1.3	23
UJe-17.02.2020-05							
UJe-17.02.2020-06	(BV)	57.6	58.5		1.0		23
UJe-17.02.2020-07	(RV)	51.7	42.3		1.2		
UJe-17.02.2020-08	(BV)	73.0	66.1	39.2	1.1	1.9	18
UJe-17.02.2020-09	(RV)	65.7	62.3		1.1		18
UJe-17.02.2020-10	(F-RV)	47.0	44.1		1.1		
UJe-17.02.2020-10	(F-LV)	41.1	41.1		1.0		
UJe-17.02.2020-11	(BV)	60.2	70.6	40.9	0.9	1.5	21
UJe-17.02.2020-12	(RV)	45.0	49.4		0.9		25
UJe-17.02.2020-13	(LV)	44.2	43.0		1.0		19
UJe-17.02.2020-14	(BV)	69.6	62.1		1.1		20
UJe-17.02.2020-15	(BV)	58.8	52.8	32.4	1.1	1.8	21
UJe-17.02.2020-16	(RV)	39.6	37.4		1.1		14
UJe-17.02.2020-17	(F)		65.8		0.0		23
UJe-17.02.2020-18	(BV)	62.3	65.9	42.9	0.9	1.5	21
UJe-17.02.2020-19	(RV)	35.4	41.9		0.8		25
UJe-17.02.2020-20	(F-LV)	53.4					18
UJe-17.02.2020-21	(BV)	59.8	64.3	36.3	0.9	1.6	25
UJe-17.02.2020-22	(BV)	61.6	62.1	41.0	1.0	1.5	25

The shells of the individuals found are often large, heavy, and transversely oval-trigonal in outline, rather heavily inflated in the umbonal area but flattened towards the edges, especially towards the posterior ventral edge. The umbos are low, directed to the anterior. The valves are moderately elongated towards the anterior area. Common to the individuals are small and not very noticeable lunules and escutcheons. There are different shell shapes, such as inflated-cordate, transversely ovate-trigonal, and obliquely trigonal to ovate-trigonal.

Table 2: Stratigraphic Range and morphologic data from selected *Venericardia planicosta* Lamarck Group species.

	Length (mm)	Height (mm)	Rips	Age (Ma)	Range (Ma)	Stratigraphic position	See further
¿ *Venericardia (Venericor) zapatai* ? **(Gardner & Bowles, 1937)**							
Maximum	68	70	26	57.55	22.8	Cook Mountain Formation, Yegua Formation, Lowest Wilcox Formation	Gardner & Bowles (1937), Perrilliat-Montoya (1963), Alvarado et al. (2015c,d); Hernández-Ocaña et al. (2018, 2019)
Minimum	52	55	24	34.75			
Venericardia (Venericor) hijuana **(Gardner & Bowles, 1937)**							
Maximum	50	50	16	65	1.2	Cook Mountain Formation, Yegua Formation, Lowest Wilcox Formation	Gardner & Bowles (1937), Harnik (2009)
Minimum	50	50	15	63.8			

	Length (mm)	**Height (mm)**	**Rips**	**Age (Ma)**	**Range (Ma)**	**Stratigraphic position**	**See further**
Venericardia (Venericor) jewelli **(Gardner, 1935; in Gardner & Bowles, 1937)**							
Maximum	70	67	20	66	2.58	Kincaid Formation, Midway Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	63	60	18	63.42			
Venericardia (Venericor) mediaplata **(Gardner & Bowles, 1937)**							
Maximum	60	58	31	64.82	3.13	Midway Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	35	34	29	61.69			
Venericardia (Venericor) smithii **(Aldrich, 1894)**							
Maximum	56	53	36	64.82	3.93	Midway Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	43	40	25	60.89			
Venericardia (Venericor) aposmithii **(Gardner & Bowles, 1937)**							
Maximum	113	117	36	59.89	4.93	Wilcox Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	64	70	28	54.96			
Venericardia (Venericor) diga **(Gardner & Bowles, 1937)**							
Maximum	58	63	27	55.8	7.2	Wilcox Grp.	Gardner & Bowles (1937), Alvarado et al. (2015c,d), Perrilliat-Montoya (1963)
Minimum	51	59	24	48.6			
Venericardia (Venericor) hatcheplata **(Gardner & Bowles, 1937)**							
Maximum	78	85	32	55.15	2.70	Wilcox Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	59	59	27	52.45			
Venericardia (Venericor) bashiplata **(Gardner & Bowles, 1937)**							
Maximum	76	79	31	54.39	0.57	Wilcox Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	56	58	24	53.82			
Venericardia (Venericor) pilsbryi **(Stewart, 1930)**							
Maximum	103	93	38	54.39	0.57	Wilcox Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	82	83	32	53.82			
Venericardia (Venericor) horatiana **(Gardner, 1935)**							
Maximum	86	90	25	54.39	0.57	Wilcox Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	60	63	21	53.82			
Venericardia (Venericor) claiboplata **(Gardner & Bowles, 1937)**							
Maximum	72	78	32	50.35	12.86	Mount Selman Formation, Claiborne Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	55	55	29	37.49			
Venericardia (Venericor) densata **(Conrad, 1845)**							
Maximum	49	47	29	48.81	11.32		

	Length (mm)	**Height (mm)**	**Rips**	**Age (Ma)**	**Range (Ma)**	**Stratigraphic position**	**See further**
Minimum	21	21	23	37.49		Mount Selman Formation, Claiborne Grp.	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Venericardia (Venericor) cacamai **(Gardner & Bowles, 1937)**							
Maximum	65	70	32	48.81	11.32	Mount Selman Formation, Claiborne Grp.	Gardner & Bowles (1937), McClure (2009), McClure & Lockwood (2015)
Minimum	55	55	27	37.49			
Venericardia (Venericor) zapatai **(Gardner & Bowles, 1937)**							
Maximum	68	70	26	44.25	4.17	Cook Mountain Formation, Yegua Formation	Gardner & Bowles (1937), Harnik (2009)
Minimum	52	55	24	40.08			
Venericardia (Venericor) cookei **(Gardner & Bowles, 1937)**							
Maximum	41	40	40	34.15	4.33	Jackson Formation	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	39	37	37	38.48			
Venericardia (Venericor) apodensata **(Gardner & Bowles, 1937)**							
Maximum	70	71	37	44.25	4.33	Jackson Formation	Gardner & Bowles (1937), McClure (2009), Harnik (2009), McClure & Lockwood (2015)
Minimum	45	45	34	40.08			

Some individuals have a compact shape (height/length ratio > 1) or more elongated shapes with a height/length ratio <1. The number of ribs varies regardless. However, an individual (Uje-17022020-16) has a significantly reduced number of ribs. The individuals (Uje-17022020-08 and -09) also have fewer but broader ribs. All forms show relatively strong forward-inclined umbos, reflected by the poorly preserved tooth caves' inclination. Comparing the proportions of the three studies mentioned (Perrilliat-Montoya, 1963; Hernández-Ocaña et al., 2018: and this study), it becomes apparent that the three comparison groups appear similar at first glance (Figures 7 and 8). The comparison group from Perriliat-Montoya (1963) shows the most significant number of individuals. Their height/length ratio is higher than 1. The shell size distribution showed an overall approximately Gaussian distribution with a positive skew. It is noticeable that the individual "IGL:IGM:1174" (1174-1-P-IGM: Perrilliat-Montoya, 1963), published in Alvarado et al. (2015c), does not match any of the sizes given by Perriliat-Montoya (1963) (Figure 7b). The individuals from Hernández-Ocaña et al. (2018) were distributed over several clusters with different regression lines (Jenchen, 2019). The individuals collected for this study are divided into two groups, and in contrast to the previous groups, the majority show a negative height/length ratio (Figure 7c).

Only the individual (Figure 8g) shows a certain similarity with the hypotype, according to Perriliat-Montoya (1963). Thus, the individuals (Figure 8a) and (Figure 8b) show a more rounded shell shape, the individuals (Figure 8c, d, e, and f) show oval shells elongated to the front and with forwardly inclined umbos, and only that individual (Figure 8g) has a trigonal form comparable to the individual depicted by Perriliat-Montoya (1963). Individuals (Figure 8e) show strongly pronounced ribs associated with a lower number, unlike the others. Comparing the interior view of the individual (Figure 8a) with the form (Figure 8j) of Perrilliat-Montoya (1963) shown as *Venericardia (Venericor) zapatai*, the form (Figure 8j) possesses vertical and much more pronounced teeth caves, also the anterior adductor impressions are different and the inclination of the umbos.

However, since a similarity with the holotype (Figure 8o,p) published by Gardner & Bowles (1937) is far more critical, it must be mentioned here that only individual (Figure 8b) has a certain degree of comparability; all others in shape and ribs vary greatly. A comparison of the tooth hollows is not possible because there are no images of the holotype.

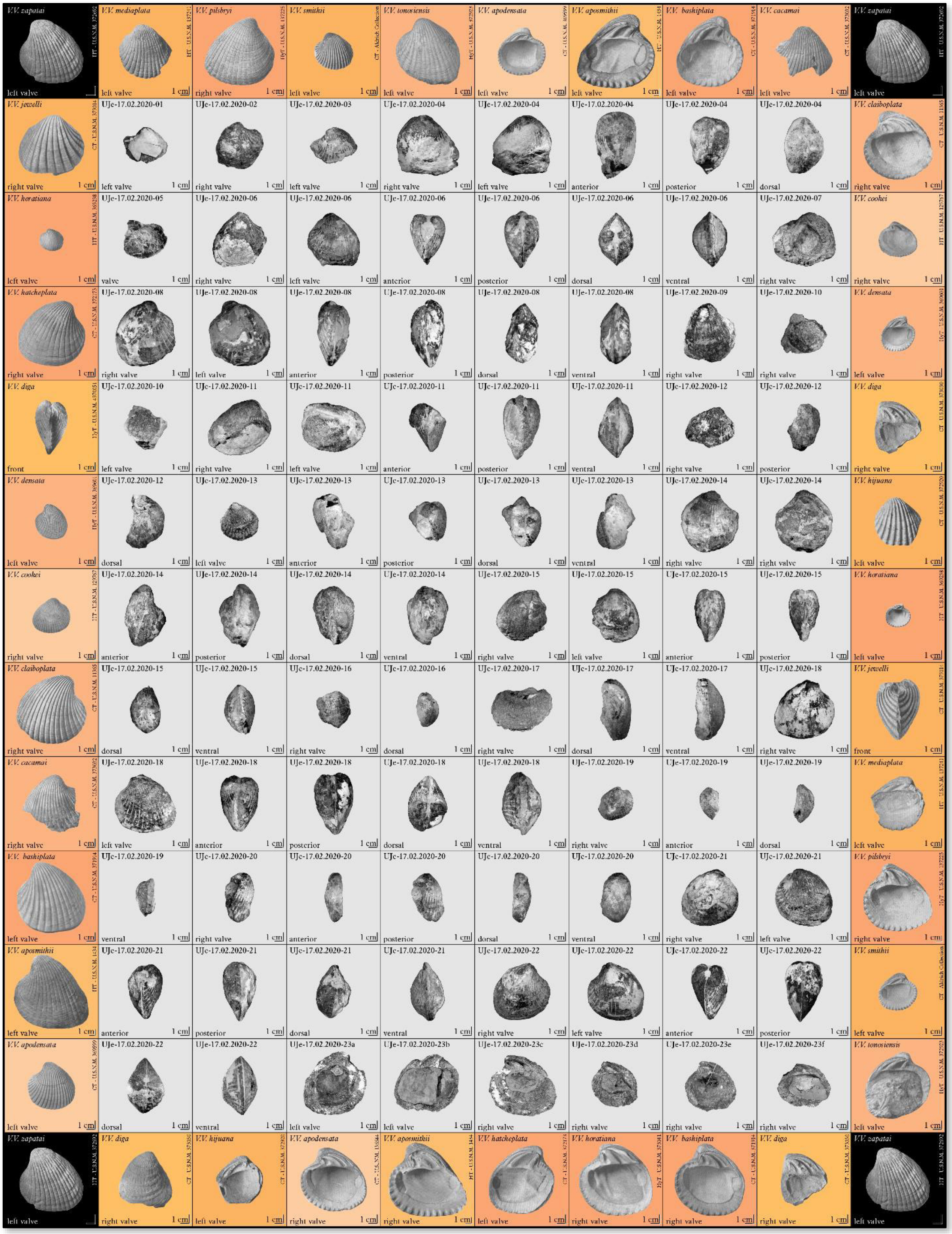

Figure 6: Variety of the bivalves sampled on February 17th, 2020: (gray background): sampled bivalves; (colored background): selected specimens from Gardner & Bowles (1937). Colored backgrounds correspond to the stratigraphic position of the species (after Cohen et al., 2013). The only secured photograph of *Venericardia (Venericor) zapatai* has a black background.

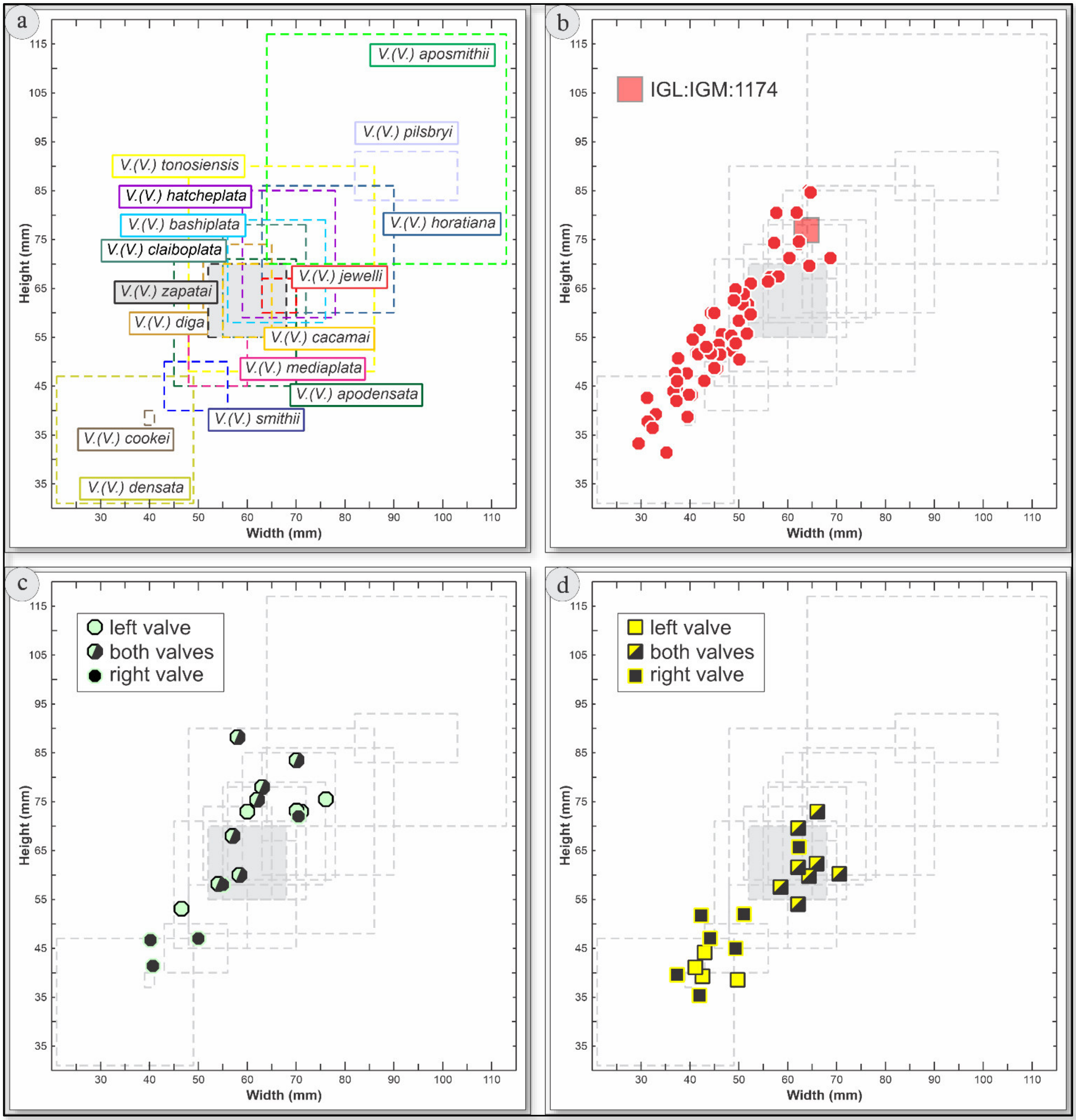

Figure 7: Comparison of the proportions of Paleogene Veneridcardia species: (a): see Table 2; (b): individuals published *as Venericardia (Venericor) zapatai* by Perrilliat-Montoya (1963). (c): Individuals published as *Venericardia (Venericor) zapatai* by Hernández-Ocaña et al. (2018); and (d) the individuals found in the outcrop "El 7".

However, since a similarity with the holotype (Figure 8o,p) published by Gardner & Bowles (1937) is far more critical, it must be mentioned here that only individual (Figure 8b) has a certain degree of comparability; all others in shape and ribs vary greatly. A comparison of the tooth hollows is not possible because there are no images of the holotype.

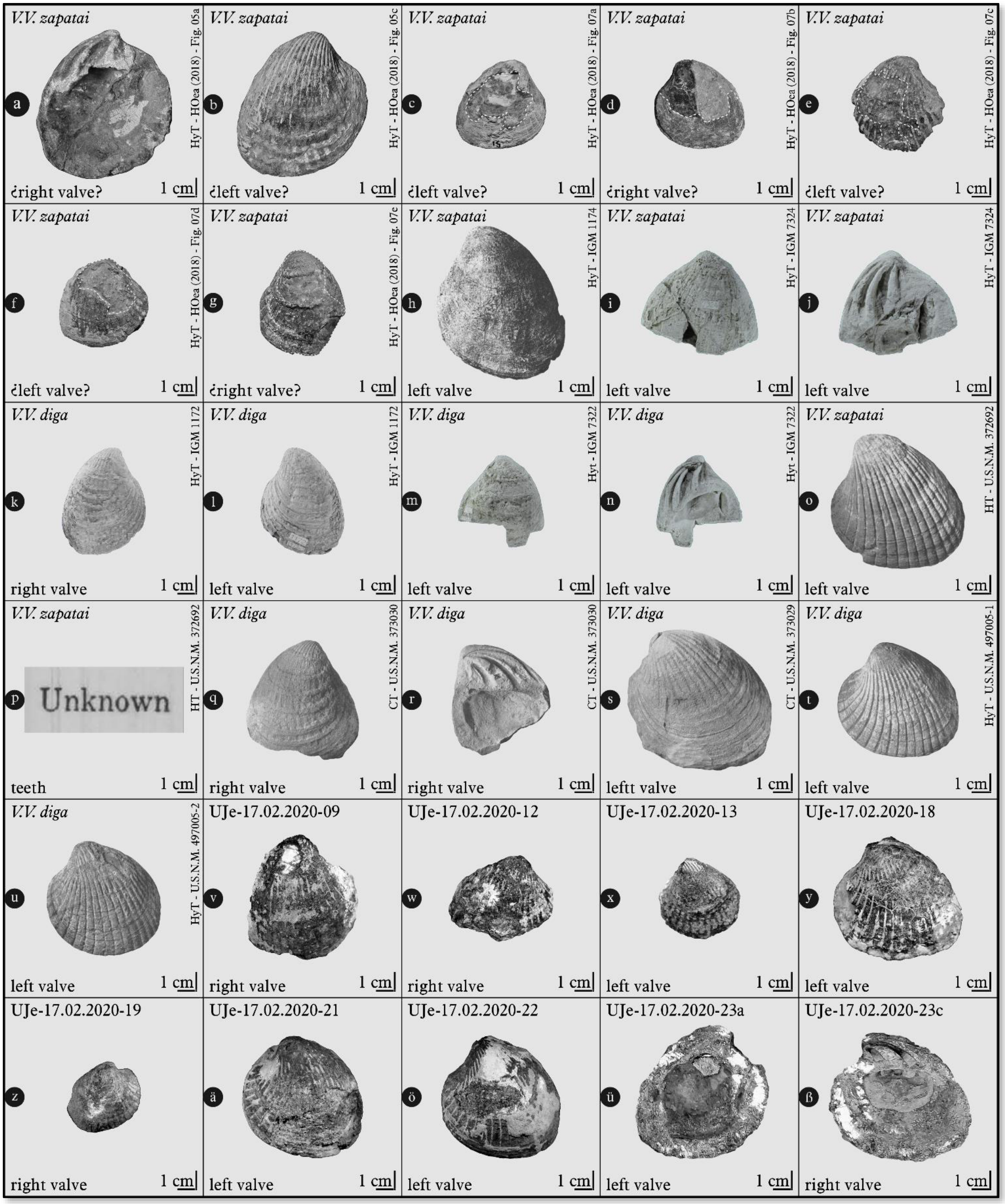

Figure 8: Comparison of different bivalves that should represent in the majority Venericardia (Venericor) zapatai: (a-g) Hypotypes of *Venericardia (Venericor) zapatai* (Hernández-Ocaña et al., 2018 [HOea (2018)]); (h-j) hypotypes of *Venericardia (Venericor) zapatai* (Perillita-Montoya, 1963); (h-j) Hypotypes of *Venericardia (Venericor) diga* (Perillita-Montoya, 1963; see Alvarado et al., 2015a-d); (o-p) holotypes of *Venericardia (Venericor) zapatai* (Gardner & Bowles, 1937); (q-u) co- and hypotypes of *Venericardia (Venericor) diga* (Gardner & Bowles, 1937); (v-ß) individuals collected on 02/17/2020 see Figure 6.

The fact mentioned above was probably also known in 1963. Therefore, the determination of Perrilliat-Montoya (1963) appears to be quite interesting, although there is no morphological similarity between the holotype and the hypotype. Primarily, it seems that the hypotype shown is a heavily eroded individual. However, the pronounced concentric growth stripes are recognizable. The individuals (Figure 8h-j) are, however, very similar to the *Venericardia (Venericor) diga*, also described by Perrilliat-Montoya (1963). Shell structure, growth stripes, ribs, the inclination of the umbo, and hinges are almost identical. The similarity also exists to the cotypes of the *Venericardia (Venericor) diga* (Gardner & Bowles, 1937), on which the pronounced concentric growth stripes are also recognizable. The hinges are comparable (Figure 8q-s). The hypotypes presented in Gardner & Bowles (1937) resemble some individuals (Figures 8b, c, d, and f) from Hernández-Ocaña et al. (2018). At the same time, individual Figure 8 is very similar to the cotype from Gardner & Bowles (1937) (Figure 8q)

It seems that the forms called *Venericardia (Venericor) zapatai* by Perrilliat-Montoya (1963) and some individuals from Hernández-Ocaña et al. (2018) are far more similar to the *Venericardia (Venericor) diga* described by Gardner & Bowles (1937) as belonging to *Venericardia (Venericor) zapatai*.

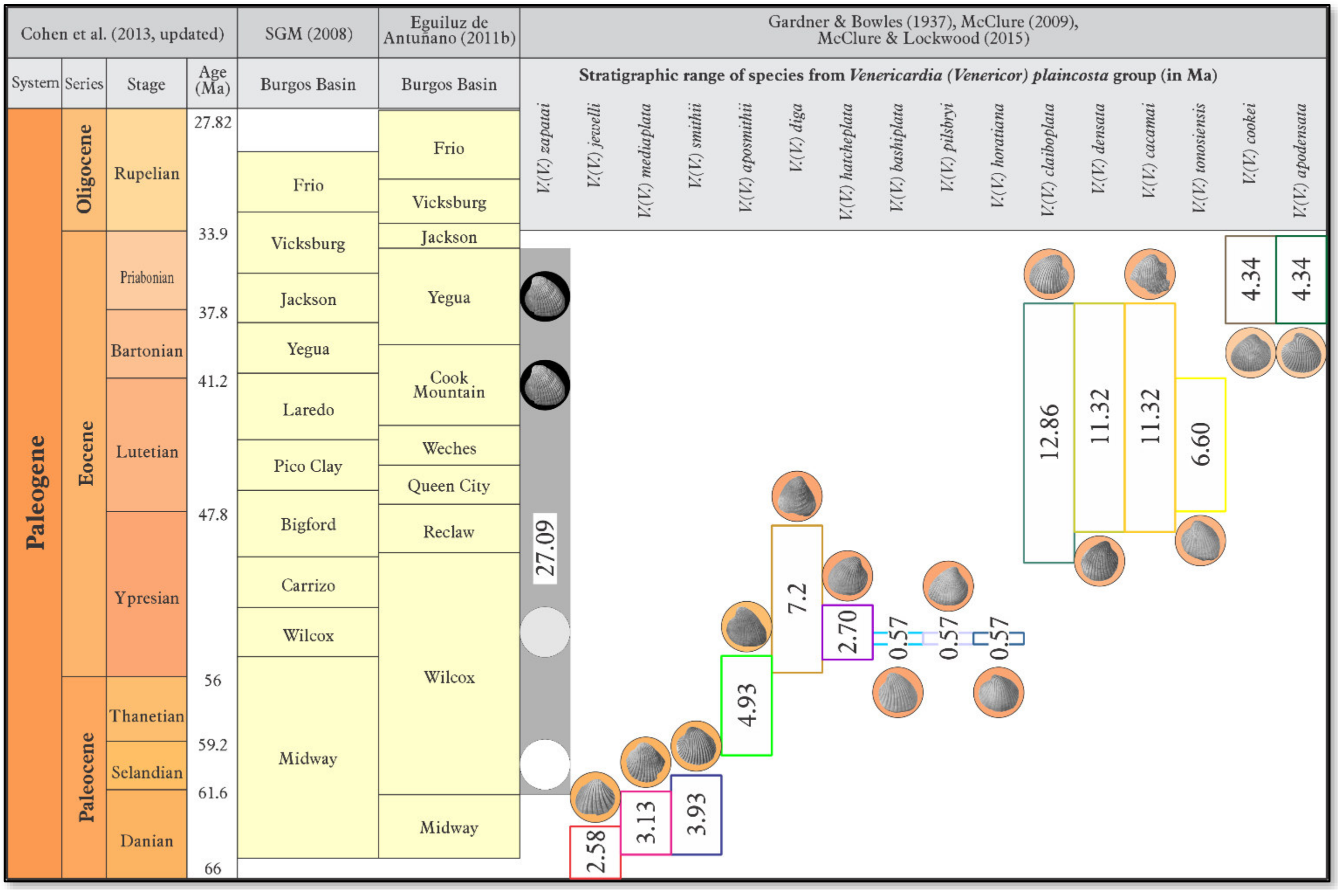

Figure 9: Stratigraphic ranges of the Venericardia species in Ma (see also Table 2). The photos attached to the bars are not to scale. The gray bars offer the alleged and accurate range of *Venericardia (Venericor) zapatai*. Marked with a white background: the stratigraphic position of the specimens from Hernández-Ocaña et al. (2018); with a gray background: the stratigraphic position of the specimens by Perrilliat-Montoya (1963) and with a black background: position according to Gardner & Bowles (1937).

The individuals also show no similarity to *Venericardia (Venericor) zapatai*, and only the individuals (Figure 8v,ä,ö) offer certain comparability to *Venericardia (Venericor) diga*. Thus, a diverse species number in outcrop “EL 7” is given or even proven. Furthermore, an exclusive or only partial assignment to the species *Venericardia (Venericor) zapatai* is highly unlikely. The assignment of the individuals represented by Perriliat-Montoya (1963) (Figure 8h,i,j) to the same species is highly questionable; an assignment to *Venericardia (Venericor) diga* should be considered if the collection is to be revised.

The stratigraphic position of the Venericardia

. Comparing the chronostratigraphic positions of *Venereicardia (Venericor) zapatai*, then in Gardner & Bowles (1937), it is located both in the Cook Mountain Formation (Claiborne Group) and in the Yegua Formation; by Perrilliat-Montoya (1963) in the Mount Selman Formation (location: „Los Jaboncillos"), actually Wilcox Formation (see Figure 1 and Figure 3). With this, the stratigraphic range of the Venercardia (Venericor) zapatai increases indirectly from approx. 4.17 Ma (Gardner & Bowles, 1937) to approx. 14.8 Ma (Yegua, Cook Mountain, and Mount Selman formations), as in Perrilliat-Montoya (1963) postulated. Including the stratigraphic position of the outcrop "El 7" in this calculation, it is likely to be in the upper Midway Formation (according to Herrera-Monreal et al., 2008), the alleged stratigraphic range of the *Venericardia (Venericor) zapatai* increases to approx. 22.8 Ma (Figure 9). It would thus be about twice to four times as high as the other species mentioned in Figure 9. However, it is far more likely that the individuals described in Perrilliat-Montoya (1963) can belong to the species *Venericardia (Venericor) diga*.

It is also noticeable that the discovery site Mier for the species Venericardia (Venericor) diga in the Yegua Formation (Perriliat-Montoya, 1963) in the current geological map (Ramírez-Gutiérrez et al., 2008) located in the Laredo Formation would almost double the stratigraphic range of the *Venericardia (Venericor) diga* towards the hanging wall (14.8 Ma). It indicates that revising the collection formed by Perrilliat-Montoya (1963) would make sense.

Conclusions

The working area is located in the Paleocene Midway in the Mesozoic-Paleocene China-District, according to Echánove-Echánove (1986), at the eastern flank of the Vaquerías Anticline of the Rio Grande Embayment, western Burgos Province. The fossils described do not belong to the species *Venericardia (Venericor) zapatai*; the appearance of *Venericardia (Venericor) diga*, among other still not determined species, is more likely. In conclusion, the fossils of the *Venericardia planicosta* Group are awaiting detailed study in NE Mexico. Both the classification of the fossils and further questions, such as paleoecology or sexual dimorphism, are still unanswered.

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