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Ammonoids from the Maastrichtian (Late Cretaceous) at El Zancudo, Nuevo Laredo, Tamaulipas, Mexico

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Abstract

A small assemblage of Maastrichtian ammonoids was collected at El Zancudo, south of Nuevo Laredo, Mexico, on the border with Texas. They are preserved as goethitic internal moulds of the innermost whorls. Nine taxa are described in abbreviated form. Eight taxa have been recorded from northeastern Mexico before: *Baculites ovatus*, *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes, 1846), *Diplomoceras cylindraceum*, *Fresvillia* sp. indet., *Gaudryceras kayei*, *Hypophylloceras* (*Neophylloceras*) cf. *H*. (*N*.) *surya*, *Phyllopachyceras forbesianum*, and *Tetragonites superstes*. The genus *Discoscaphites* was recorded and described for the first time in this region. The assemblage indicates an early late Maastrichtian age and is compared to other ammonoid assemblages from Texas and northeastern Mexico. It provides an important level marker for long-distance correlation into the deltaic sediments of northeastern Mexico, known as the Difunta Group.

Keywords: ammonoids, biostratigraphy, Cretaceous, Maastrichtian, Mexico, paleobiogeography, systematic description.

Resumen

Se describe una pequeña asociación de amonites del Maastrichtiano hallada en la localidad de El Zancudo, al sur de Nuevo Laredo y cerca de la frontera con Texas. Sólo fueron preservadas las vueltas internas de los fósiles como moldes interiores de goethita. Se describen nueve especies de manera breve. Ocho de ellos ya han sido registrados para el noreste de México: Baculites ovatus, Brahmaites (Anabrahmaites) vishnu, Diplomoceras cylindraceum, Fresvillia sp. indet., Gaudryceras kayei, Hypophylloceras (Neophylloceras) cf. H. (N.) surya, Phyllopachyceras forbesianum, y Tetragonites superstes. El género Discoscaphites se registra y se describe por primera vez para esta región. Esta asociación indica una edad que corresponde a la parte temprana del Maastrichtiano tardío y se compara con otras asociaciones coetáneas de amonites de Texas y de México. El horizonte fosilífero representa un importante nivel de correlación de larga distancia hacia los sedimentos deltaicos del noreste de México, conocidos como el Grupo Difunta.

Palabras Clave: ammonoides, bioestratigrafía, Cretácico, descripción sistemática, Maastrichtiano, México, paleobiogeografía.

1. Introduction

Localities containing Maastrichtian ammonite assemblages are scarce in northeastern Mexico. In recent years, a series of publications have dealt with assemblages from new sites. The assemblages described show a strong bathymetric specialization for either explicitly shallow (Ifrim *et al*., 2005; Ifrim and Stinnesbeck, 2010) or deep water conditions (Ifrim *et al*., 2004, 2010).

Shallow water associations occur widely in the deltaic Difunta Group, a foreland basin to the uplifting Sierra Madre Oriental which covers most of eastern Chihuahua, Coahuila, and northwestern Coahuila. *Sphenodiscus*, *Coahuilites* and *Baculites* are present in this area and apparently were adapted to shallow coastal to marginally marine environments with reduced and changing salinities, temperature and agitated water (*e.g*. Ifrim *et al*., 2005; Ifrim and Stinnesbeck, 2010). In the Difunta Group, ammonoids other than the above described genera are extremely rare and only occur during sea level highstands in thin intervals of the succession. Occasionally, however, hemipelagic cephalopod assemblages and associated planktonic foraminifers are also present in the Difunta Group and in the transition to the coeval Mendez Formation. Recently, a diverse and abundant assemblage was discovered at La Parra, at approximately 20 km north of Saltillo, in the eastern Parras basin, and was assigned to the early Maastrichtian planktonic foraminiferal zone CF 5. This horizon provided an important level marker for correlation of the lower Difunta Group (Ifrim *et al*., 2010). East and south of Monterrey, in the states of Nuevo León and Tamaulipas, the Mendez Formation is coeval to the Difunta Group, and marls and shales in this area were deposited under open marine conditions. Faunal assemblages of the Mendez formation are hemipelagic and include abundant planktonic foraminifers, indicating water depths of over 100 m existed in the area of Cerralvo, 40 km east of Monterrey in the state of Nuevo Leon, and greater than 300 m east of Linares (Ifrim et al., 2004; Figure 1). The assemblage from Cerralvo is diverse (23 species referred to 18 genera) and indicates deposition in a pelagic environment during the early Maastrichtian biozone CF 7 of Li and Keller (1998a, 1998b), between 70.39 and 69.56 Ma; *Sphenodiscus*

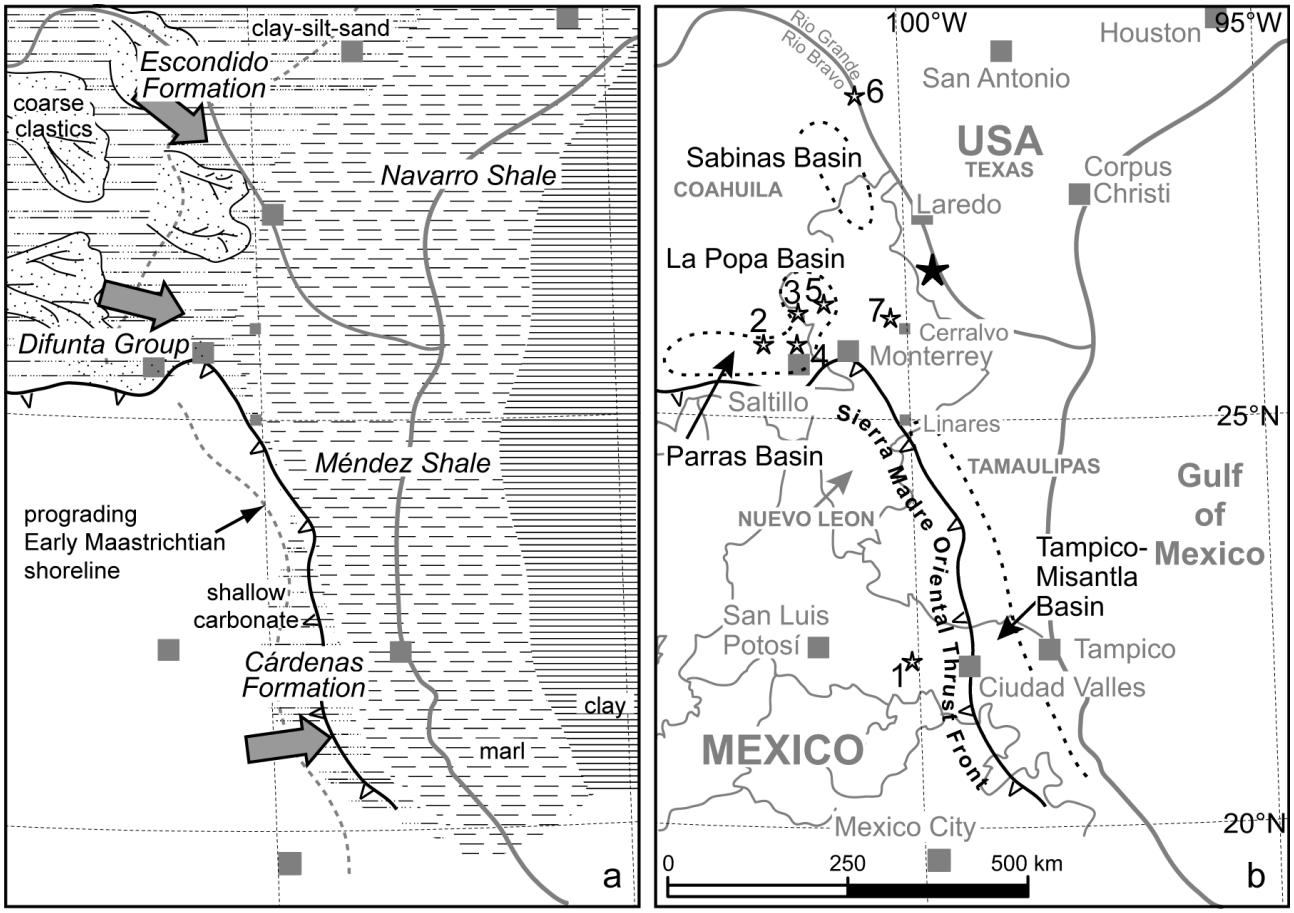

Figure 1. a: Paleogeographic lithofacies map of northeastern Mexico (modified after Goldhammer and Johnson, 2001; Soegaard *et al*., 2003) with coastline prograding from the northeast and east (after Weidie *et al*., 1972). b: Same map with geographic locations and paleogeographic elements, and northeastern Mexican ammonoid localities. 1: Cárdenas, San Luis Potosí; 2: Rincón Colorado, Coahuila, Parras Basin; 3: Reata, Coahuila, Parras Basin; 4: La Parra, Coahuila, Parras Basin; 5: Mina, NuevoLeón, Parras Basin; 6: Eagle Pass, Texas, Rio Grande Embayment; 7: Loma Los Martinitos, near Cerralvo, Nuevo León, open shelf; 8: El Zancudo, Tamaulipas.

and *Coahuilites* are characteristically absent.

Here we report on a new ammonite assemblage which was discovered at El Zancudo, near Nuevo Laredo, Tamaulipas, in sediments of the proximal Mendez Formation. This assemblage is here interpreted in the context of the former data. It provides further insight into the many changes which occurred on the shelves of the western Gulf of Mexico during the Maastrichtian.

2. The El Zancudo locality

The fossil-bearing locality was discovered in the late 1980s by geology student Humberto Garza García of the Facultad de Ciencias de la Tierra, Universidad Autónoma de Nuevo León at Linares, during field mapping for his *licenciatura* thesis in the area. He collected the ammonites in a single shale horizon within the Campanian-Maastrichtian Mendez Formation and donated the material to one of us (WS). According to his information, the fossil site, called "El Zancudo", is located approximately 70 kilometers south of Nuevo Laredo, Tamaulipas. It can be reached following Federal Highway 2 from Nuevo Laredo to Reynosa. Then a dirt roads lead towards the site west of the road, which is near 26° 56' 46.2" N, 99° 32' 29.1" W. The lithology is marly and corresponds to the shales of the Mendez Formation.

Ammonites from El Zancudo are minute and reach maximum diameters of 18.1 millimeters (mm). All specimens are phragmocones preserved as goethitized internal moulds. Pyritization produced a thin coat on the shells, which completely filled the chambers of small diameters. Pyrite was later oxidized by weathering.

During pyritization, larger chambers were left hollow and may have collapsed under lithologic overburden, thus explaining the absence of larger specimens and crushing of some shells with diameters greater than 10 mm. The small sizes of El Zancudo ammonites apparently result from a preservational bias. This interpretation is supported by the fact that body chambers are not observed in El Zancudo ammonoids. A similar preservation was earlier observed in cephalopods from the Mendez Formation (Ifrim *et al*., 2004), 200 km to the southeast of El Zancudo, at Loma Los Martinitos, near Cerralvo (Figure 1), and 50 km north of Saltillo, at La Parra (Ifrim *et al*., 2010).

3. Systematic Paleontology

Ammonite assemblages of comparable size and their degree of preservation are known from northeastern Mexico in the Campanian-Maastrichtian Mendez Formation. These assemblages were described in detail by Ifrim et al. (2004, 2010). For taxa documented from these localities, we here refer to those publications regarding detailed species descriptions, synonymy lists and occurrences. Remarks are only added where necessary.

All 34 specimens collected at El Zancudo are registered and available at the *Colección de Paleontología de Coahuila* (CPC) at the *Museo del Desierto*, Saltillo, Coahuila, Mexico.

Linear dimensions are given in millimeters (mm). Uncertain values due to deformation of the specimen and relations resulting from uncertain measurements are marked with an asterisk. Values in brackets refer to the proportion of the particular dimension to the whorl diameter. Abbreviations: D, diameter; WB, whorl width; WH, whorl height; U, umbilical diameter; L, length between two measurements.

Systematic nomenclature of ammonoids follows the Treatise of Invertebrate Paleontology (Wright, 1996) to subspecies level, except for the genus *Gaudryceras* and the subgenus *Anabrahmaites*, for reasons discussed by Ifrim *et al*. (2004).

Order Ammonoidea von Zittel, 1884
Suborder Phylloceratina Arkell, 1950
Superfamily Phylloceratoidea von Zittel, 1884
Family Phylloceratidae von Zittel, 1884
Subfamily Phylloceratinae von Zittel, 1884
Genus *Hypophylloceras* Salfeld, 1924
Subgenus *Hypohylloceras* (*Neophylloceras*) Shimizu, 1934

Hypophylloceras (*Neophylloceras*) cf. *H*. (*N*.) *surya* (Forbes, 1846)
Figures 2.1, 3a

2004 *Hypophylloceras* (*Neophylloceras*) cf. *H*. (*N*.) *surya* (Forbes); Ifrim *et al*., p. 1580, fig. 2c, 2d, 2e, 3a

Dimensions. CPC-585. D: 7.1, WB: 2.5 (0.35), WH 3.1 (0.44), WB/WH: 0.81, U: 1.5 (0.21)

Occurrence. *Hypophylloceras* (*Neophylloceras*) *surya* (Forbes) is a Maastrichtian species, with records from Madagascar (Collignon, 1956), South Africa (Kennedy and Klinger, 1976), Alaska, California, Japan (Ward and Kennedy, 1993), possibly the lower Maastrichtian of Mexico (Ifrim *et al*., 2004), and the upper Maastrichtian of southern India (Kennedy and Henderson, 1992), western Australia (Henderson and McNamara, 1985), the Biscay region (Ward and Kennedy, 1993), Denmark (Birkelund, 1993), Pakistan (Fatmi and Kennedy, 1999) and Chile (Stinnesbeck, 1986; Salazar *et al*., 2010).

Genus *Phyllopachyceras* Spath, 1927
Phyllopachyceras forbesianum (d'Orbigny, 1850)
Figures 2.2, 2.3, 3b, 3c

1846 *Ammonites royanus* Forbes, p. 108, pl. 8, fig. 6

1895 *Phylloceras forbesianum* (d'Orbigny), Kossmat, p. 109, pl. 15, fig. 1a, 1b, 1c (therein)

1970 *Phyllopachyceras forbesianum* (d'Orbigny), Henderson, p. 7, pl. 1, fig. 2, 4, 5 (with additional synonymy)

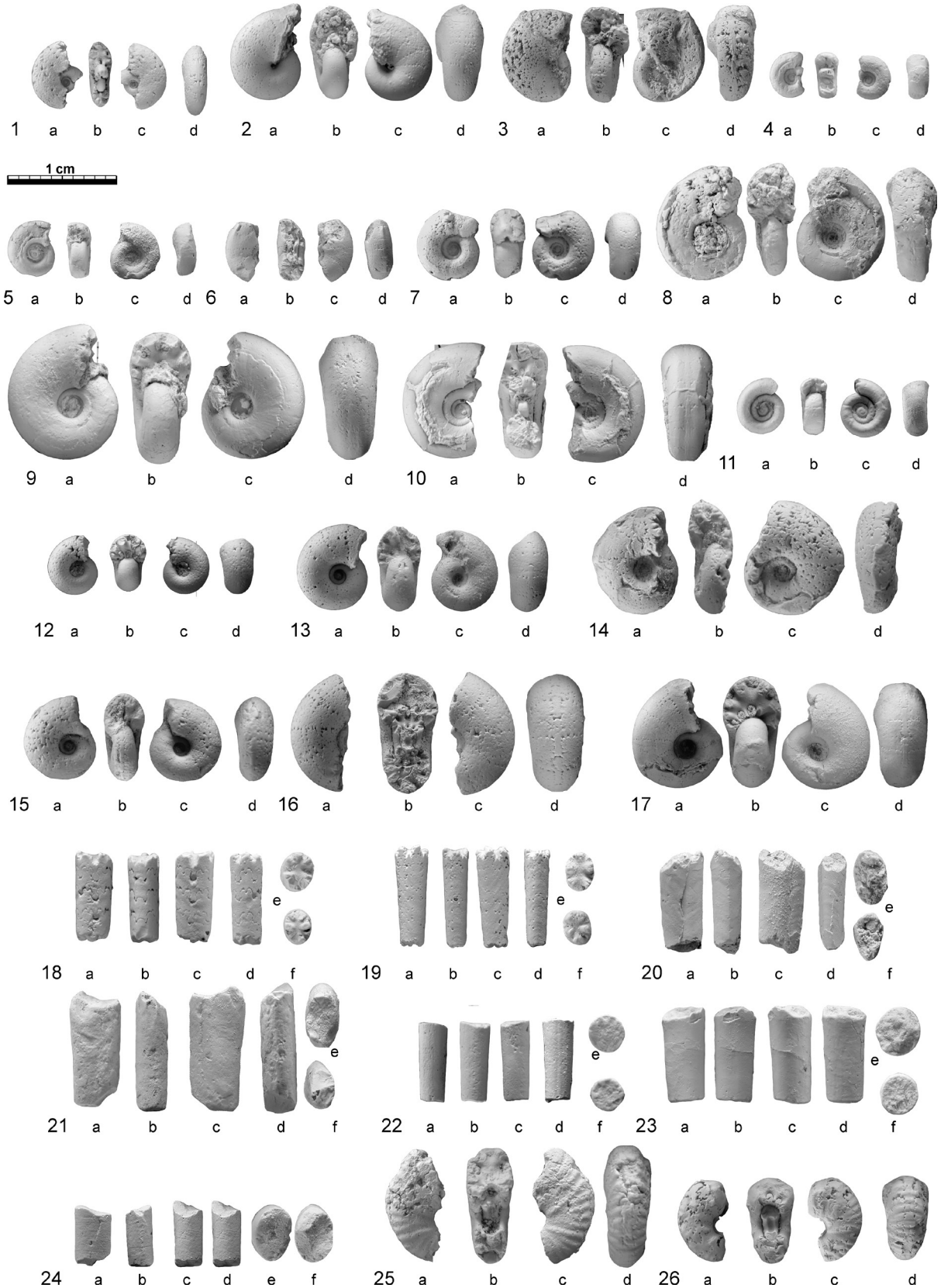

Figure 2. Ammonoids from El Zancudo. 1: *Hypophylloceras* (*Neophylloceras*) *hetonaiense* (CPC-585); 2-3: *Phyllopachyceras forbesianum* (2: CPC-586, 3: CPC-587); 4-10: *Tetragonites superstes* (4: CPC-589, 5: CPC-590, 6: CPC-591, 7: CPC-592, 8: CPC-593, 9: CPC-594, 10: CPC-595); 11: *Gaudryceras kayei* (CPC-588); 12-17: *Brahmaites* (*Anabrahmaites*) *vishnu* (12: CPC-596, 13: CPC-597, 14: CPC-598, 15: CPC-599, 16: CPC-640, 17: CPC-641); 18-21: *Baculites ovatus* (18: CPC-656; 19: CPC-654, 20: CPC-655, 21: CPC-657); 22-23: *Fresvillia* sp. (22: CPC-644, 23: CPC-647); 24: *Diplomoceras cylindraceum* (CPC-588); 25-26 *Discoscaphites* juv. sp. (25: CPC-642, 26: CPC-643).All x2.

1992 *Phyllopachyceras forbesianum* (d'Orbigny), Kennedy and Henderson, p. 394; pl. 2, fig. 1-12; text-fig. 3c (with additional synonymy)

2004 *Phyllopachyceras forbesianum* (d'Orbigny), Ifrim *et al*., p. 1583; pl. 1, fig. 1-4; text-fig. 3b, 3c

2010 *Phyllopachyceras forbesianum* (d'Orbigny), Ifrim *et al*., p. 601; fig. 4r-y, 5c-d

Dimensions.

	D	WB	WH	WB/WH	U
CPC-586	10	5.0 (0.50)	6.7 (0.67)	0.75	0.6 (0.06)
CPC-587	18.1	*7.0 (*0.39)	10.6 (0.59)	*0.66	1.1 (0.06)

Occurrence. *Phyllopachyceras forbesianum* is a cosmopolitan species and was recorded from the Santonian of Madagascar and the early Campanian of Spain. Records of Campanian-Maastrichtian ages are known from all latitudes (Alaska to the Antarctic Peninsula); this is the most widespread among the species described herein.

Suborder Lytoceratina Hyatt, 1900
Superfamily Tetragonitoidea Hyatt, 1900
Family Tetragonitidae Hyatt, 1900
Subfamily Tetragonitinae Hyatt, 1900
Genus *Tetragonites* Kossmat, 1895

Tetragonites superstes van Hoepen, 1921
Figures 2.4-2.10, 3d-3j

1921 *Tetragonites superstes* van Hoepen, p. 10; pl. 2, fig. 17-20; fig. 6

1977 *Tetragonites superstes* van Hoepen; Kennedy and Klinger, p. 162, fig. 7a-7d, 7h-7j, 8, 12a-12c

2004 *Tetragonites superstes* van Hoepen; Ifrim *et al*., p. 1584, pl. 1, fig. 5-8; Figures 3e-g

2010 *Tetragonites superstes* van Hoepen; Ifrim *et al*., p. 602, fig. 4z-4kk

Dimensions.

	D	WB	WH	WB/WH	U
CPC-589	4.7	2.3 (0.49)	1.8 (0.38)	1.28	1.4 (0.30)
CPC-590	*5.6	*2.4 (0.43)	*2.5 (0.45)	0.96	2.0 (0.36)
CPC-591	*8.5	*3.4 (0.40)	*4.0 (0.47)	0.85	-
CPC-592	6.6	3.3 (0.50)	3.5 (0.53)	0.94	1.8 (0.27)
CPC-593	9.2	4.3 (0.47)	*4.7 (0.51)	0.91	2.4 (0.26)
CPC-594	13	6.0 (0.46)	5.8 (0.45)	1.03	2.5 (0.19)
CPC-595	12.4	6.6 (0.53)	5.3 (0.43)	1.25	3.1 (0.25)

Occurrence. *Tetragonites superstes* van Hoepen is known from the late Santonian or early Campanian of South Africa (Kennedy and Klinger, 1977), the early to middle Campanian of Madagascar (Collignon, 1956), and the early Maastrichtian of north-eastern Mexico (Ifrim *et al*., 2004, 2010).

Family Gaudryceratidae Spath, 1927
Genus *Gaudryceras* de Grossouvre, 1894

Gaudryceras kayei (Forbes, 1846)
Figure 2.11

1846 *Ammonites kayei* Forbes, p. 101; pl. 8, fig. 3

1906 *Gaudryceras kayei* (Forbes), Woods, p. 335; pl. 41, fig. 8; pl. 42, fig. 1

1979 *Vertebrites kayei* (Forbes), Kennedy and Klinger, p. 160; fig. 5; pl. 14, fig. 2 (with full synonymy)

1985 *Gaudryceras kayei* (Forbes), Henderson and McNamara, p. 46; pl. 1, fig. 9,10; text-fig. 4d

2004 *Gaudryceras kayei* (Forbes), Ifrim *et al*., p. 1589; fig. 3l-3n, 5d, 6a-6c, 6h

2010 *Gaudryceras kayei* (Forbes), Ifrim *et al*., p. 603; fig. 4tt-4aaa, 5g, 5h

Dimensions. CPC-588. D: 5.3, WB: 2.5 (0.47), WH: 1.6 (0.30), WB/WH: 1.56, U: 2.3 (0.43).

Occurrence. The species is known from Santonian to Maastrichtian strata, and has been described from South Africa (Woods, 1906; Kennedy and Klinger, 1979), Tunisia (Pervinquière, 1907), the Biscay region (Ward and Kennedy, 1993), Pakistan (Fatmi and Kennedy, 1999), southern India (Kennedy and Henderson, 1992), western Australia (Henderson and McNamara, 1985), Chile (Stinnesbeck, 1986), California (Matsumoto, 1959), and Madagascar (Collignon, 1956), among other localities. The Santonian record of Böse (1928) from north-eastern Mexico was put into doubt by Ifrim *et al*. (2004), but these authors described specimens from the early (2004) and middle (2010) Maastrichtian of this region.

Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea Zittel, 1895
Family Kossmaticeratidae Spath, 1922
Subfamily Kossmaticeratinae Spath, 1922
Genus *Brahmaites* Kossmat, 1897
Subgenus *Brahmaites* (*Anabrahmaites*) Yabe and Shimizu, 1924

Brahmaites (*Anabrahmaites*) *vishnu* (Forbes, 1846)
Figures 2.12-2.17, 3k-3p

1846 *Ammonites vishnu* Forbes, 1846, p. 100; pl. 7, fig. 9

1992 *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes, 1846); Kennedy and Henderson, p. 418; pl. 6, fig. 25, 26; pl. 9, fig. 5-7, 17-20; pl. 10, fig. 5; pl. 17, fig. 8, 10, 11 (with full synonymy)

1993 *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes 1846), Kennedy and Hancock, p. 580; pl. 1, fig. 5, 6

2004 *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes 1846), Ifrim *et al*., p. 1600; fig. 8a, 8b, 9a-9d

2010 *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes 1846), Ifrim *et al*., p. 607; fig. 5n-5p, 7iii-7xxx, 9

Material. Six internal moulds of juveniles.

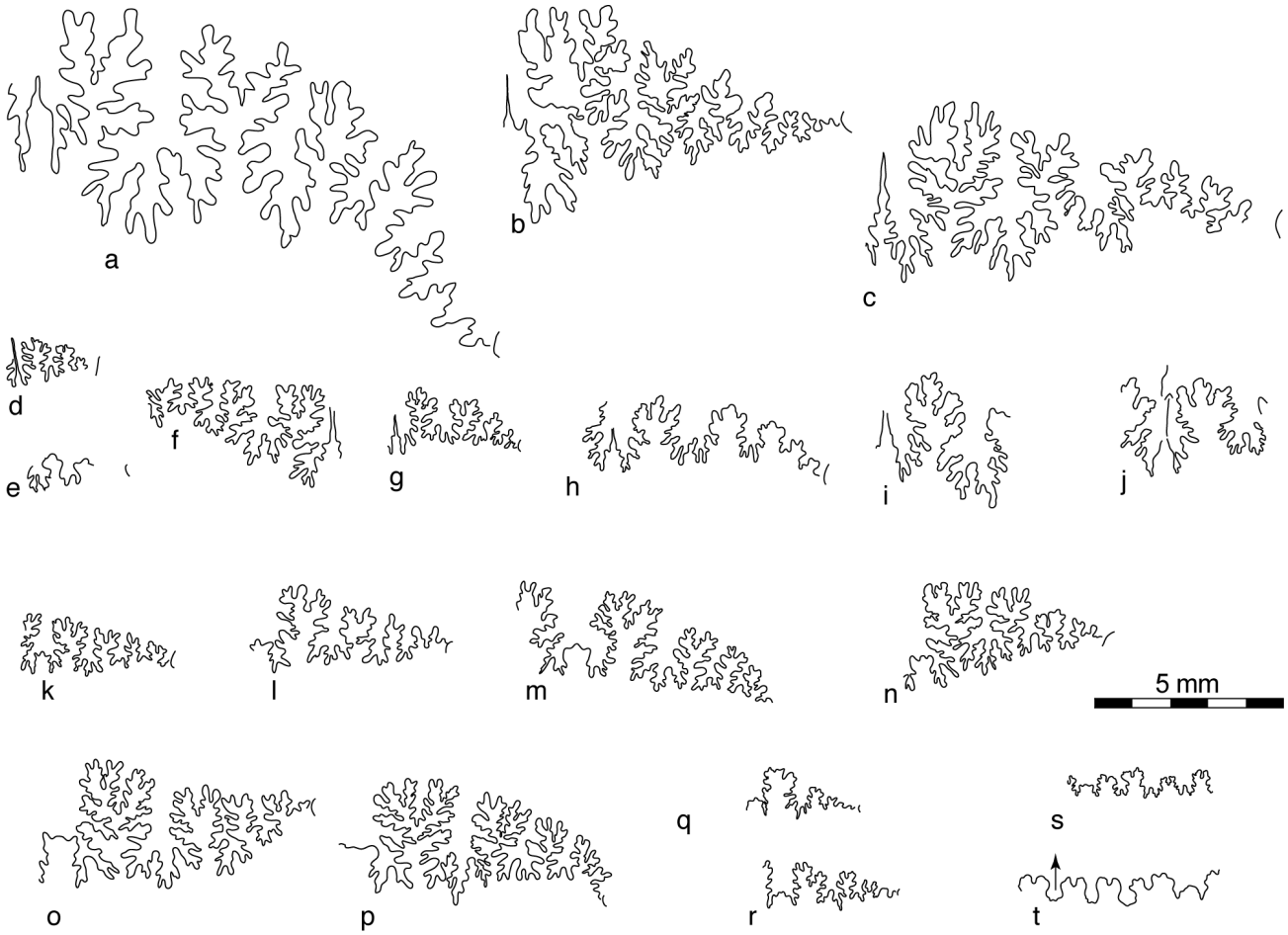

Figure 3. Suture lines of ammonoids from El Zancudo. a: *Hypophylloceras* (*Neophylloceras*) *surya* (CPC-585); b-c: *Phyllopachyceras forbesianum* (b: CPC-586, c: CPC-587); d-j: *Tetragonites superstes* (d: CPC-588, e: CPC-589o590, f: CPC-591, g: CPC-592, h: CPC-593, i: CPC-594, j: CPC-595); k-p: *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes, 1846) (k: CPC-596, l: CPC-597, m: CPC-598, n: CPC-599, o: CPC-640, p: CPC-641); q-r: *Discoscaphites* juv. sp. (q: CPC-642, r: CPC-643); s-t: *Baculites* (s: CPC-654. t: CPC-656). All x5.

Dimensions.

	D	WB	WH	WB/WH	U
CPC-596	5.5	3.5 (0.64)	2.8 (0.51)	1.25	1.2 (0.22)
CPC-597	8	*3.6 (*0.45)	4.2 (0.53)	*0.86	1.7 (0.21)
CPC-598	8.9	4.4 (0.49)	4.4 (0.49)	1	2.0 (0.22)
CPC-599	9.1	*2.6 (*0.29)	*3.0 (*0.33)	*0.87	2.2 (0.24)
CPC-640	12	6.0 (0.50)	5.3 (0.44)	1.13	*2.2 (*0.18)
CPC-641	11.3	6.0 (0.53)	5.6 (0.50)	1.07	2.6 (0.23)

Occurrence. *Brahmaites* (*Anabrahmaites*) *vishnu* (Forbes, 1846), occurs in the Maastrichtian of southern India (Kennedy and Henderson, 1992), Armenia (Atabekian and Akopian, 1970), Madagascar (Collignon, 1938), south-western France and northern Spain (Ward and Kennedy, 1993). In the Gulf of Mexico area, the genus *Brahmaites* was first described by Cobban and Kennedy (1991) from the Nacatotch Sand, Arkansas, but these specimens have not been determined to species level. In contrast, Ifrim *et al*. (2004, 2010) documented abundant *B*. (*A*.) *vishnu* from the early and early-late Maastrichtian of north-eastern Mexico.

Suborder Ancyloceratina Wiedmann, 1966
Superfamily Turrilitoidea Gill, 1871
Family Baculitidae Gill, 1871
Genus *Baculites* Lamarck, 1799

Baculites ovatus Say, 1820
Figures 2.18-2.21, 3s, 3t

1820 *Baculites ovata* Say, p. 41

1974 *Baculites ovatus* Say, Cobban, p. 3; pl. 1, fig. 1-31; pl. 2, fig. 1-14; pl. 3, fig. 1-6, 9-11; text-fig. 4 (with full synonymy)

2004 *Baculites ovatus* Say, Ifrim *et al*., p. 1601; pl. 3, fig. 1-3; text-fig. 11a-11e, 12a-12d

2005 *Baculites ovatus* Say, Ifrim *et al*., p. 58; fig. 5i, 5j, 9d-9l

2010 *Baculites ovatus* Say, Ifrim *et al*., p. 608; fig. 5y, 5z, 10a-10v

Occurrence. *Baculites ovatus* Say is known to occur in the late Campanian of New Jersey (Cobban, 1974), the

Maastrichtian of Arkansas (Kennedy and Cobban, 1993a) and Mexico (Ifrim *et al*., 2004; Ifrim *et al*., 2005; Ifrim and Stinnesbeck, 2010; Ifrim *et al*., 2010). Records may also exist from Palestine and Egypt.

Genus *Fresvillia* Kennedy, 1986b

Fresvillia sp. indet.
Figure 2.24-2.29

Dimensions.

	WB	WH	WB/WH	L
CPC-646	2.1	2.2	0.95	7.1
	2.7	2.7	1	
CPC-645	2.4	2.4	1	7.2
	3	3.1	0.97	
CPC-649	2.4	2.5	0.96	8.9
	3.2	3	1.07	
CPC-644	2.5	2.6	0.96	7.4
	3	3	1	
CPC-650	2.8	2.9	0.97	8
	3.7	3.4	1.09	
CPC-651	3.1	3.3	0.94	6.4
	3.9	4.2	0.93	
CPC-648	3.3	3.5	0.94	5.6
	3.5	3.9	0.9	
CPC-647	4.1	4	1.03	7.4
	4.7	4.5	1.04	

Remarks. The circular whorl section and the simple suture line with triangular elements of similar height and shape distinguish *Fresvillia* from *Baculites*. Specimens described here have completely smooth surfaces lacking the distant constrictions of *F. constricta. Fresvillia teres* (Forbes) differs from *F. constricta* in the presence of faint annular to ventrally prorsiradiate ribs which are equally strong around the shell, whereas the constrictions in *F. constricta* are most pronounced dorsally. No ornament is preserved, and the specimens thus cannot be related to any of the two species.

Occurrence. *Fresvillia* is a rare Maastrichtian genus, with records from France, South Africa, India, western Australia, Alaska, Mexico, and California (Wright, 1996; Ifrim *et al*., 2004, 2010).

Family Diplomoceratidae Spath, 1926
Subfamily Diplomoceratinae Spath, 1926
Genus *Diplomoceras* Hyatt, 1900

Type species. *Baculites cylindraceus* Defrance (1816, p. 160), by original designation. For a description of the genus see Olivero and Zinsmeister (1989), for occurrence see Kennedy (1986a).

Diplomoceras cylindraceum (Defrance, 1816)
Figure 2.30

1816 *Baculites cylindracea* Defrance, p. 160

1986a *Diplomoceras cylindraceum* (Defrance), Kennedy, p. 181; pl. 17, fig. 3; pl. 18, fig. 5; pl. 21, fig. 2, 3, 5, 6; pl. 22, fig. 6; pl. 23, fig. 1,2; pl. 24, fig. 1-3; pl. 25, fig. 1-8; pl. 26, fig. 18; pl. 33, fig. 16; pl. 36, fig. 6; text-fig. 9, 10 (with full synonymy)

1986b *Diplomoceras cylindraceum* (Defrance), Kennedy, p. 51; pl. 4, fig. 1, 2; pl. 9, fig. 8-10; pl. 10; text-fig. 3i-3l, 6, 7g-7m (with full synonymy)

2004 *Diplomoceras cylindraceum* (Defrance), Ifrim *et al*., p. 1607; text-fig. 13g, 13h, 14e

2010 *Diplomoceras cylindraceum* (Defrance), Ifrim *et al*., p. 610, fig. 10uu-10zz

Dimensions. CPC-658. WB: 4.7, WH: 6.5, WB/WH: 0.72, L: 4.9. WB: 4.6, WH: 6.7, WB/WH: 0.69.

Occurrence. *Diplomoceras cylindraceum* was recorded throughout the Maastrichtian and is known in all latitudes from Alaska to Antarctica.

Superfamily Scaphitoidea Gill, 1871
Family Scaphitidae Gill, 1871
Subfamily Scaphitinae Spath, 1926
Genus *Discoscaphites* Meek, 1871

Type species. *Ammonites conradi* Morton (Morton, 1834, p. 39), by original designation.

Discoscaphites juv. sp.
Figures 2.25, 2.26, 3q, 3r

Material. Two juvenile specimens, CPC-642 and CPC-643.

Description. Moderately involute, with moderate expansion rate. Whorl section is rounded to slightly compressed. The umbilicus is small and deep. The umbilical wall is narrowly rounded and grades into widely rounded convergent flanks. Maximum whorl breadth is near the umbilicolateral part of the flank. Ventrolaterally, rounding is more narrow and a shoulder is formed, which transits into a widely rounded, almost flat venter. Three primary ribs per half whorl arise from the umbilicus. They are straight and slightly prorsiradiate. In CPC-643, the larger specimen, they thicken ventrolaterally to form low tubercles, which are absent in the smaller specimen CPC-642. Three to four secondary ribs arise laterally between two primaries; they are parallel to the primaries and form ventrolateral tubercles in the same position than the tubercles on the primary ribs. In both specimens, the ribs cross the venter in a straight line. The suture line is moderately incised, with U/L being asymmetrically bifid, and L asymmetrically trifid.

Dimensions.

	D	WB	WH	WB/WH	U
CPC-642	8.6	5.0 (0.58)	*4.8 (*0.56)	*1.04	1.8 (0.21)
CPC-643	*12.0	5.0 (*0.42)	6.6 (*0.55)	0.76	1.9 (*0.16)

Remarks. The present juvenile Scaphitinae are difficult to determine. This is due to the fact that many of the specimens figured in the current literature are too large to be compared with our material, but it is also a result of

the important changes in shell morphology during early ontogeny. Five ontogenetic growth stages are documented for genera of Maastrichtian Scaphitinae. The most detailed study was carried out by Landman and Waage (1993), who documented specimens of several genera and species with diameters comparable to our material. At these small diameters, tuberculation is occasionally present, but not fully developed yet. The ribs of *Jeletzkytes* are much coarser than in our individuals, and sigmoidal instead of straight. More primary and less secondary ribs are present. Moreover, the umbilicus of *Jeletzkytes* is much larger at comparable growth stages. In juvenile *Hoploscaphites* the umbilicus is also much larger. In addition, more primary and less secondary ribs are developed than in our individuals, and the ribs bend forward to cross the venter in a wide arch. The whorl relations and ribbing pattern of juvenile *Discoscaphites* are closest to our specimens. However, the shell in *D. conradi* is more compressed than in our specimens, whereas *D. gulosus* and *D. rossi* have coarser and finer ribs, respectively. Our material compares well with juveniles of *D. iris* (compare *e.g*. Kennedy and Cobban, 2000, pl.3, fig. 33; Landman *et al*., 2004a, fig. 34a-d, s). and *D. minardi* (Kennedy and Cobban, 2000, pl. 1, fig. 2-4), but precise determination of the species is not possible at the moment.

Occurrence. The genus *Discoscaphites* is present in North America from the middle to the upper Maastrichtian (Landman *et al*., 2004b) and is known from the Western Interior Seaway, the northern Gulf of Mexico and the Atlantic Coast. Records outside North America are from the upper Maastrichtian, *e.g*. an isolated specimen of *D. iris* was recorded from the uppermost Maastrichtian of Libya (Machalski *et al*., 2009); an undeterminable specimen of *Discoscaphites* of late Maastrichtian age, but unknown stratigraphic origin, from South Africa (Klinger and Kennedy, 2005); *Discoscaphites gulosus* from Bulgaria; and *Discoscaphite*s sp. indet. from Denmark and Sweden (Machalski *et al*., 2007).

4. Interpretation of the cephalopod assemblage from El Zancudo

4.1. Biostratigraphy

Phyllopachyceras forbesianum, *Tetragonites superstes* and *Gaudryceras kayei* are long-lasting, conservative species which are known from at least the Campanian and Maastrichtian.

Hypophylloceras (*Neophylloceras*) *surya* is an exclusively Maastrichtian species, with most records restricted to the late Maastrichtian. The specimens assigned to *Fresvillia* cannot be determined further, but the genus is also restricted to the Maastrichtian. *Baculites ovatus* already exists in the late Campanian, but not in northeastern Mexico, to which it immigrated during the early Maastrichtian (Ifrim and Stinnesbeck, 2010; Ifrim *et al*., 2010). *Diplomoceras cylindraceum* was recorded throughout the Maastrichtian and is known in all latitudes from Alaska to Antarctica. *Discoscaphites*, now documented for the first time for Mexico, restricts the age of the assemblage to the lower-upper, or upper Maastrichtian.

The age of the El Zancudo ammonite association can be further restricted by comparing the faunal composition to other assemblages described from northeastern Mexico. The species of these other assemblages are listed in Table 1 for comparison. For instance, the Zancudo fauna differs from the early Maastrichtian Cerralvo fauna in the absence of *Nostoceras*. Nostoceratids became extinct during the middle Maastrichtian (Goolaerts, 2010).

The similarity of the El Zancudo ammonite assemblage with that of La Parra, Coahuila, leads to the interpretation that they are of similar age. The Zancudo fauna include the cold-water species *Tetragonites superstes*, which immigrated from the southern hemisphere during a Maastrichtian cooling event in the late early Maastrichtian (biozone CF 7, Ifrim *et al*., 2004). In addition, *Nostoceras* is missing, showing that the assemblage formed after the extinction of this genus in the middle Maastrichtian. Ammonoids declined considerably during the late Maastrichtian in Mexico, as summarized by Stinnesbeck *et al*. (2012), but this is not recognized in the El Zancudo assemblage. We therefore conclude that this assemblage must be slightly older and the fauna is of early-late Maastrichtian age.

4.2. Stratigraphic implications

Correlations within the Late Cretaceous part of the Difunta Group are mostly isolated and tentative, including correlation with other coeval deep water and marginal marine deposits within Mexico (*e.g*., Cárdenas Formation in central-eastern Mexico, Schafhauser *et al*., 2007; Mendez Formation in eastern Mexico, Stinnesbeck *et al*., 1996), and with global sea-level changes (Lawton *et al*., 2001; Soegaard *et al*., 2003; Aschoff and Giles, 2005) as a result of the near-absence of age-diagnostic fossils in this deltaic complex. The ammonite assemblage collected at El Zancudo in the Mendez Formation thus opens a rare opportunity for correlation between shallow and deep water regimes in the region.

The Maastrichtian assemblages from Texas formerly described differ significantly in their composition compared to the El Zancudo assemblage, but also from each other. A shallow water assemblage, composed of *Sphenodiscus* and *Coahuilites*, has been described from the siliciclastic complex of the Escondido Formation (Cooper, 1970). This can be explained by the deltaic facies in which the assemblage was found. Another assemblage from northeastern Texas comprises the species *Baculites columna*, *Discoscaphites conradi*, *Eubaculites carinatus*, *Glyptoxoceras*, *Jeletzkytes*, *Nostoceras major*, *Sphenodiscus lobatus*, *S. pleurisepta*, and *Trachyscaphites yorkensis* (Kennedy and Cobban,

1993b). This assemblage is early Maastrichtian in age, which partially explains the different composition of the fauna. Another Texan assemblage was described from the K/Pg boundary sediments near Brazos. It is composed of *Discoscaphites* cf. *gulosus*, *D. sphaeroidalis*, *Eubaculites carinatus*, *Pachydiscus* cf. *jacquoti* and *Glyptoxoceras* cf. *rugatum*. These are the last ammonites found below the K/Pg boundary, *i.e*. this assemblage is younger and includes the youngest ammonites found in Texas (Kennedy *et al*., 2001). Correlation of sedimentary units in Mexico is thus problematic. The similarity of the El Zancudo assemblage to the Mexican deep-water faunas now provides a further stratigraphic level marker.

4.3. Paleobiogeographical interpretation

The definition of provincialism follows that of Ifrim *et al*. (2004). The Zancudo assemblage contains faunal elements of three distinct paleobiogeographical provinces.

a) Tethyan elements sensu latu, including boreal and the southern mid-latitude species, are recognized in *Tetragonites superstes* and *Baculites ovatus* (see Ifrim *et al*., 2010, for discussion).

b) Cosmopolitan species *Gaudryceras kayei*, *Diplomoceras cylindraceum* and *Phyllopachyceras forbesianum* are known to have a worldwide distribution.

c) Cold water species. They occur in the southern high latitudes, including the Antarctic shelf, and in the northern Pacific. *Neophylloceras* (*Hypophylloceras*) *surya* is a member of this group.

In their description of a slightly older assemblage from the Mendez Formation near Cerralvo, Ifrim *et al*. (2004) distinguished a fourth group of "species endemic to North America". This group contained three species of *Nostoceras*, not present at El Zancudo.

The two fragments of *Discoscaphites* juv. sp. are difficult to classify. The genus was only known from North America until the description of an isolated fragment form the uppermost Maastrichtian of Libya (Machalski *et al*., 2009), Bulgaria, Denmark and Sweden (Machalski *et al*., 2007). However, these records differ in age and are scattered. In addition, our specimens are not determined to species level. *Discoscaphites* juv. sp. is thus left out of the palaeogeographic interpretation.

Table 1. Distribution of species in north-eastern Mexican cephalopod assemblages. Numbers are specimens registered at the site. Question marks indicate species in open nomenclature. Specimens from shallow water environments are from different localities, each of which contained too few specimens for quantitative analysis. They are C: Cárdenas, San Luis Potosí; EP: Escondido Formation, near Eagle Pass, Texas; M: Mina, Nuevo León; R: Reata, Coahuila; RC; Rincón Colorado, Coahuila; S: Saltillo, Coahuila. These localities are presented in Figure 1. Data outside El Zancudo from Ifrim *et al*. (2004, 2005, 2010).

		locality	**El Zancudo**	**Cerralvo**	**La Parra**	**near coast**
		facies	pelagic-neritic	pelagic	deep neritic	shallow water
North America	*Coahuilites sheltoni*		-	-	-	C M S
	Nostoceras (*N.*) *alternatum*		-	108	-	-
	N. (*N.*) *colubriformis*		-	108	-	-
	N. (*N.*) *rugosum*		-	66	-	-
	Sphenodiscus lobatus		-	-	-	RC
	Sphenodiscus pleurisepta		-	-	-	C EP R
Tethyan and Boreal	*Baculites ovatus*		?6	167	**137**	M
	Brahmaites (*Anabr.*) *vishnu*		6	83	**127**	-
	Fresvillia constricta			22	**10**	-
	Hauericeras rembda		-	35	**2**	-
	Pachydiscus (*P.*) *neubergicus*		-	? 60	**? 30**	C
	Solenoceras reesidei		-	15	**3**	-
	Solenoceras texanum		-	13	-	-
	Tetragonites superstes		7	27	**? 15**	-
cosmopolitan	*Anagaudryceras politissimum*		-	27	**3**	-
	Desmophyllites diphylloides		-	18	**17**	-
	Diplomoceras cylindraceum		1	3	**3**	-
	Gaudryceras kayei		1	53	**68**	-
	Phyllopachyceras forbesianum		2	104	**40**	-
	Pseudophyllites indra		-	9	**9**	-
cold water	*Fresvillia teres*		8	? 8	**10**	-
	Hypophylloceras (*Neophylloceras*) *surya*		1	? 6	**? 4**	-
	H. (*N.*) *hetonaiense*		-	20	**6**	-
	Naefia neogaeia		-	4	-	-
	Pachydiscus (*P.*) *egertoni*		-	-	**? 79**	-
	Zelandites varuna		-	9	-	-
undefined	*Eutrephoceras* sp.		-	-	**1**	-
	Menuites juv. sp.		-	42	**36**	-
	Saghalinites cala		-	1	-	-
	Discoscaphites juv. sp.		? 2	-	-	-
		SUM	34	1008	**602**	–

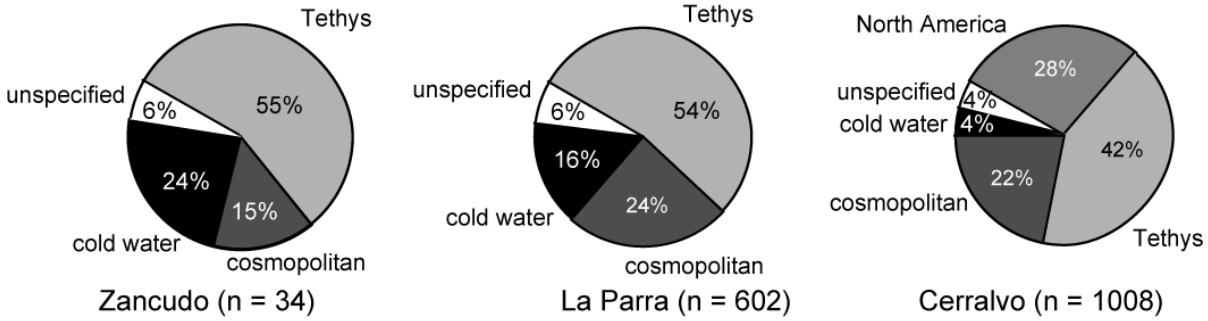

Figure 4. Paleobiogeographical distribution of the El Zancudo, La Parra and Cerralvo ammonoid assemblages. The category "unspecified" in the El Zancudo assemblage includes the specimens of *Discoscaphites*, which may also be classified as "North American". Data after Ifrim *et al*. (2004, 2010), and Table 1 herein. Note the similarities between the El Zancudo and La Parra assemblages despite the small data set at El Zancudo (n = 34), and their difference to the Cerralvo assemblage.

Results regarding the paleobiogeographical interpretation of the La Parra ammonoid assemblage are summarized in Table 1. According to these data, the assemblage is composed of 55 % Tethyan, 15 % cosmopolitan, 24 % cold water, and 6 % unclassified specimens (Figure 4).

The paleobiogeographical composition is thus strikingly similar to that of La Parra in Coahuila, *ca*. 200 km southwest of Nuevo Laredo. It differs from the Cerralvo fauna, which contains 28 per cent North American ammonoids, all related to *Nostoceras*, which was already extinct by the time the La Parra and El Zancudo assemblages were deposited. However, proportions of the categories "cosmopolitan", "Tethyan" and "cold water", relative to each other at Cerralvo, are also comparable to La Parra and El Zancudo.

5. Conclusions

The small collection of ammonoids from El Zancudo, a locality near Nuevo Laredo, Tamaulipas, contains eight taxa, seven of which were previously known from northeastern Mexico. The assemblage is similar to a fauna from La Parra, near Saltillo, Coahuila, > 200 km SSW of Nuevo Laredo, and indicates that taxa present in both localities inhabited a broad region on the western Gulf of Mexico shelf. The assemblage at El Zancudo differs from other ammonoid assemblages described before from Texas and Mexico due to formation at different ages or in facies. The El Zancudo assemblage provides an important biostratigraphic marker level for correlation of deeper facies to the shallow water sediments of northeastern Mexico.

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