Lower Aptian (Lower Cretaceous) ammonites from the basal strata of the La Peña Formation of Nuevo León State, northeast Mexico: biochronostratigraphic implications

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ABSTRACT

Detailed paleontological studies of the basal strata of the La Peña Formation from a stratigraphic section of the State of Nuevo León, northeastern Mexico, reveal a rich ammonite assemblage representative of the local biozone indicative of the uppermost level of the early Aptian corresponding to the Dufrenoyia justinae Taxon Range Zone. The Lower Aptian assignment of this Mexican biozone is corroborated by its distinctive ammonite assemblage characteristic of both uppermost early Aptian standard ammonite zones of the stage; namely the Dufrenoyia furcata Zone, of the tripartite Mediterranean standard scheme, and its equivalent Tropaeum bowerbankii Zone of the northeastern Europe bipartite scheme. Thus, in Mexico, the shift of deposition from a shallow carbonate platform locally represented by facies of the Cupido Formation, to the deeper facies of the La Peña Formation took place sometime during the late early Aptian and not in the late Aptian as previously assigned. To avoid diachronic interpretations of the Cupido-La Peña formational contact, the ammonites analyzed in this study for biochronostratigraphic purposes, were compared to other coeval assemblages reported from the basal strata of the La Peña Formation on a regional scale.

Keywords: Ammonites, Lower Cretaceous, early Aptian, La Peña Formation, Mexico.

RESUMEN

Estudios paleontológicos detallados de los estratos basales de la Formación La Peña de una sección estratigráfica del Estado de Nuevo León, en el Noreste de México, revelaron una asociación de ammonites representativa de la biozona local indicativa del nivel más superior del Aptiano temprano correspondiente a la Zona de Rango del Taxón Dufrenoyia justinae. La asignación al Aptiano temprano de esta biozona mexicana es corroborada por su asociación distintiva de ammonites característica de las dos biozonas estándar de ammonites de la parte más superior del subpiso; la Zona Dufrenoyia furcata, del esquema tripartita para la Provincia Mediterránea, y su equivalente, la Zona Tropaeum bowerbankii del estándar para el noreste de Europa en el esquema bipartita del piso. Así, en México, el cambio de régimen de depósitos de plataforma carbonatada somera representada localmente por facies de la Formación Cupido, a facies pelágicas más profundas de la Formación La Peña ocurrió en algún momento durante el

término del Aptiano temprano y no en el Aptiano tardío como ha sido previamente asignado. Para evitar interpretaciones diacrónicas del contacto formacional Cupido-La Peña, los ammonites analizados en este estudio para propósitos biocronoestratigráficos, fueron comparados con otras asociaciones similares reportadas de los estratos basales de la Formación La Peña a escala regional.

Palabras clave: Ammonites, Cretácico Inferior, Aptiano temprano, Formación La Peña, México.

INTRODUCTION

The sedimentary cover of northeastern Mexico consists mainly of Upper Jurassic to Lower Cretaceous marine facies that crop out along the Sierra Madre Oriental fold belts. Excellent outcrops of Barremian-Aptian sequences are particularly well-exposed within the Sierra Madre Oriental Transverse near Monterrey, Nuevo León State (Figure 1). This area includes well established lithostratigraphic units formally described as the Cupido Formation (Imlay, 1937; Humphrey, 1949) of Barremian-Aptian age, and the La Peña Formation (Imlay, 1936; Humphrey, 1949) of late Aptian age. In Nuevo León State, the Barremian-Aptian rocks of the Cupido Formation are thick-bedded (decimeter to meter scale), shallow-water deposits known as the Cupido platform carbonates. These facies are consistently overlain by the La Peña Formation, characterized by thinly bedded (centimeter to decimeter scale) limestones, marly limestones, marls, and calcareous shales with abundant ammonites. The La Peña Formation facies represent a transgressive unit that crops out over an extensive area of northeastern Mexico, and was assigned a late Aptian age on the basis of ammonite occurrences (Cantú-Chapa, 1963, 1976; Young, 1969; Contreras-Montero, 1977). This original assignment of age was based on the bipartite subdivision of the stage into lower and upper Aptian in accordance with the biochronostratigraphic standard scheme established for northeastern Europe (Casey, 1961). However, the exact age of this Mexican Aptian stratigraphic unit remained uncertain, because most of the published fauna lacked precise stratigraphic control impeding the recognition of standard biozones and consequently broad regional correlations (Barragán, 2000).

Further stratigraphic works by Wilson and Pialli (1977), Smith (1981), Goldhammer *et al*. (1991) and Wilson and Ward (1993) argued that the carbonate deposition of the Cupido platform was abruptly terminated by terrigenous input that changed previous conditions into those that led to facies of the La Peña Formation. This event can be correlated with a global transgressive episode that began in the late early Aptian, which eventually drowned the Mexican carbonate platforms that had been flourished since the Barremian, as is recorded in other parts of the world (Barragán, 2001).

Recent bed-by-bed sampling of a stratigraphic section of the Cupido-La Peña formational contact has been carried out at La Huasteca canyon in northeastern Mexico, situated in the western part of the state of Nuevo León, southwest of Monterrey City (25º 37.109' N – 100º 28.869' W) (Figure 1). The studied section is located along the north-exposed limb of an open anticline at the eastern end of Sierra de Los Muertos. It is part of the tightly folded and thrusted tectono-sedimentary terranes that include the structures of the Sierra Madre Oriental, related to the Laramide orogeny in northeastern Mexico.

High-resolution sampling and careful recovery of the ammonites at the basal strata of the La Peña Formation in the studied section yielded a distinctive assemblage of index ammonite species within the first levels immediately in contact with the infrajacent Cupido Formation.

The aims of this work are to present the studied ammonite faunal assemblage of these strata, and its age interpretation in regards to the local biostratigraphic scheme

Figure 1. Map of northeastern Mexico displaying the location of the Aptian stratigraphic section of this study. Abbreviations of State names: COA: Coahuila, NL: Nuevo León, SLP: San Luis Potosí, and TAM: Tamaulipas (Modified from Barragán and Szives, 2007).

(Barragán-Manzo and Méndez-Franco, 2005). Our study also establishes the biochronologic correlation of this ammonite assemblage with the newly revised standard biostratigraphic framework for the Tethyan Realm [Reboulet and Hoedemaeker (reporters), 2006]. Our results further provide more precision on the timing of the event characterized by a shift in conditions of deposition from the Cupido carbonate platform to the La Peña transgressive facies in northeastern Mexico.

MATERIAL AND METHODS

The present research focused on detailed lithological and paleontological characteristics of the different facies recorded in the formational contact between the Cupido and the La Peña Formations in the stratigraphic section at La Huasteca canyon in Nuevo León State, northeastern Mexico. The study included four dedicated field seasons in order to complete detail observation of variations of individual strata, as displayed in the column shown in Figure 2. The section was measured on a bed-by-bed scale, up to a total thickness of 28 m, from which the lower 22 m represent facies of the Cupido Formation, while the upper 6 m correspond to facies of the La Peña Formation. Rock samples from each individual stratum were recently prepared in thin sections for the characterization of the microfacies, inorganic, and organic carbon variations throughout the stratigraphic sequence (Barragán, 1999; Méndez-Franco, 2003; Maurrasse *et al*., 2006; Ponton-Guerrero, 2006). In the present work, three hundred and thirty seven specimens were collected all throughout the facies of the La Peña Formation, and the total collection represents a well-diversified assemblage, which in general consists of partly deformed but well-preserved casts. However, special emphasis was given to the ammonite assemblages of the basal strata of this lithostratigraphic unit,

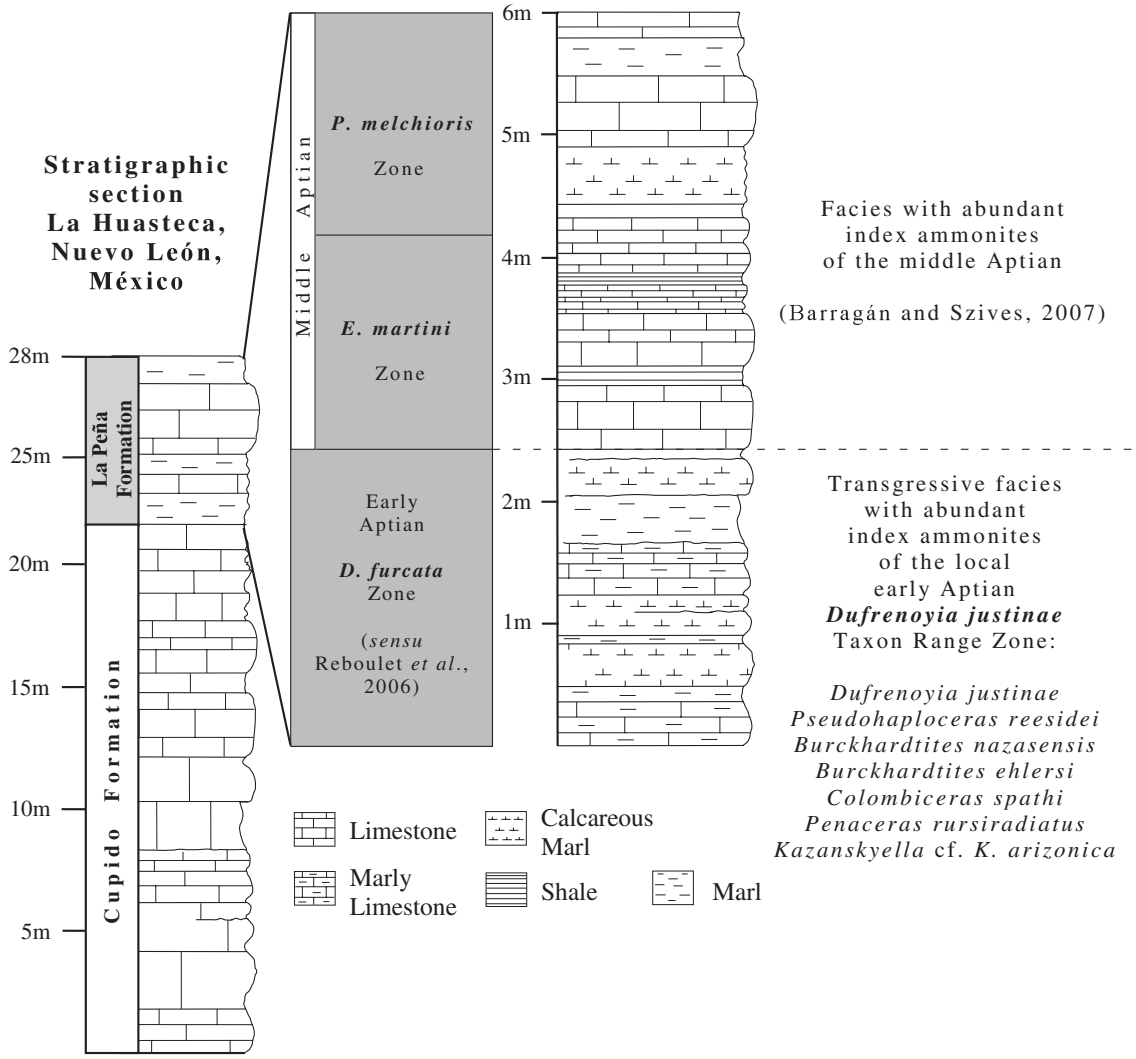

Figure 2. Stratigraphic column showing lithology and the basal strata of the La Peña Formation yielding ammonites representative of the local uppermost early Aptian *Dufrenoyia justinae* Taxon Range Zone.

which make a total of eighty six specimens. Ammonites were prepared, studied, and those illustrated in this work were deposited in the invertebrate collection of the Museum of Paleontology at the Institute of Geology, UNAM under catalogue numbers IGM 8838 through IGM 8845. On account of a well-documented taxonomic provinciality that was already established for this time interval (Barragán, 2000), the systematic study of the ammonites focused on index species that served to recognize recently proposed local biostratigraphic units on the basis of these macrofossils (Barragán-Manzo and Méndez-Franco, 2005). Timing of the shift in environment of deposition, from the shallow-water Cupido carbonate platform to the more terrigenous and deeper waters sediments of the La Peña Formation, was interpreted through biostratigraphic correlation of the local ammonite biozone recorded at the base of the La Peña with the standard zonal scheme for the Tethyan Realm [Reboulet and Hoedemaeker (reporters), 2006]. Since chronostratigraphic units may not be isochronous, in order to avoid diachronic interpretations of the Cupido-La Peña formational contact at the studied section, the ammonites analyzed in this study for biochronostratigraphic purposes were compared to other coeval assemblages reported from the basal strata of the La Peña Formation on a regional scale (Cantú-Chapa, 1963; Cantú-Chapa, 1976; Contreras-Montero, 1977; Barragán, 2000; Méndez-Franco, 2003).

LITHOLOGY AND PALEONTOLOGICAL CONTENT

The Barremian-Aptian section exposed at La Huasteca canyon and subject of this study is essentially composed of marine carbonates (Figure 2). At the field scale these rocks show a sharp contrast between facies of the Cupido limestones that are competent beds rich in rudists, and those of the La Peña Formation composed of thinner beds characteristically more ductile, extremely compressed, often sheared, and rich in ammonites. As stated above, these sedimentary facies and their total inorganic carbon (TIC) and total organic carbon (TOC) variations throughout the section were previously investigated (Barragán, 1999; Méndez-Franco, 2003; Maurrasse *et al*., 2006; Ponton-Guerrero, 2006). The lowermost 22 m of the section are dominated by an alternation of extensively bioturbated pale grey biocalcirudites with rudists, and biocalcarenites with ooids, abundant benthonic foraminiferal assemblages mainly miliolids, orbitolinids, and textularids. These limestones also include common pellets, pelecypods, gastropods, algal fragments and scarce ostracods. Their calcium carbonate content ($CaCO_3$ = TIC equivalent calculated from the total carbon) varies between 78 and 99 %, while total organic carbon (TOC) values remain constantly below 1 %. These facies are typical of the shallow-water carbonates of the Cupido platform, an important paleogeographic element of the Barremian-early Aptian times of northeastern Mexico (Böse, 1923; Imlay, 1936, 1937, 1938, 1944; Kellum, 1944). The uppermost 6 m of the measured section assigned to the La Peña Formation consist of a rhythmic alternation of grey to black biocalcilutites, which, by contrast with the underlying Cupido limestones, show extreme variations in TIC (from a low of 17% to a high of 92.18 %) as well as in TOC (between 0.34 and 3.2 %). Thus, their sharp contrasting physical appearances reflect their composition, as the Cupido limestones are consistently higher in TIC, whereas the La Peña rocks always have higher organic carbon and terrigenous components (Barragán, 2000; Maurrasse *et al*., 2006; Ponton-Guerrero, 2006). Also, one of the most important hallmarks the La Peña beds is the faunal change associated with these facies. They include common planktonic foraminifera, while benthic taxa are very rare or absent, although there are other epibenthic fauna such as mollusk pelecypods and echinoid fragments. These facies represent the transgressive unit referred to as the La Peña Formation. All stratigraphic levels of this unit at La Huasteca canyon are dominated by ammonites, which represent 96 % of the macrofauna, and the rest of the accompanying macrofossils comprises mostly echinoids and pelecypods. The great abundance of partly deformed, but well-preserved ammonites that constitute the assemblage include index Aptian species within six genera: *Pseudohaploceras*, *Burckhardtites*, *Dufrenoyia*, *Colombiceras*, *Kazanskyella*, and *Penaceras*.

SYSTEMATIC PALEONTOLOGY

In the present work, the ammonite taxonomy used to identify taxa to the genus level is after Wright *et al*. (1996), whereas subsequent identification of species within genera used mostly the works of d'Orbigny (1840-1842), Kilian (1889), Hill (1893), Anthula (1900), Burckhardt (1925), Riedel (1938), Scott (1940a), Humphrey (1949), Stoyanow (1949), Cantú-Chapa (1963, 1976), and Contreras-Montero (1977). The scientific nomenclature rules used follow the conventional Linnean hierarchy as prescribed by the 4th edition of the International Code of Zoological Nomenclature (ICZN, 1999), which took effect on January 1, 2000.

This study gives basic information about the genus or species characteristics. The most significant specimens are illustrated in Figure 3a-3h.

Order Ammonoidea Zittel, 1884
Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea Zittel, 1895
Family Desmoceratidae Zittel, 1895
Subfamily Puzosiinae Spath, 1922
Genus *Pseudohaploceras* Hyatt, 1900

Type Species. *Ammonites liptoviensis* Zeuschner, 1856, p. 181: by original designation.

Diagnosis. Moderately involute ammonites with slightly compressed shells and convex sides. Regular straight or sinuous constrictions, sometimes collared. Fairly fine, sharp or rounded, branching ribs between constrictions, originating on umbilical edge, extending across the flanks and crossing the venter.

***Pseudohaploceras reesidei* (Humphrey, 1949)**
Figure 3a

Uhligella reesidei Humphrey, 1949, p. 152-153, pl. 18, figs. 3-4.
Caseyella reesidei (Humphrey), Cantú-Chapa, 1976, p. 15, pl. 1, figs. 9-9 a; 14-14 a.
Pseudohaploceras reesidei (Humphrey), Wright et al., 1996, p. 73; Barragán, 2000, p. 75-78, pl. 50, figs. 1-16; Méndez-Franco, 2003, p. 39-41, pl. 2, figs. 3-11.

Material. Seventeen specimens. The specimen illustrated is identified as IGM-8838.

Description. Shell discoidal, moderately involute. Last whorl embracing about two thirds of preceding whorls. Whorl section subellipsoidal. Flanks flattened. Umbilicus broad. Venter narrowly rounded in inner whorls, squarish and much wider on last part of outer whorl. Ornamentation consists of flexuous well-marked flanges, constrictions, and finer intercalated ribs.

Remarks. *Pseudohaploceras reesidei* was originally described by Humphrey (1949, p. 152) as *Uhligella reesidei* from one specimen collected in the La Peña Formation of Coahuila, Mexico. Subsequently Cantú-Chapa (1976) found similar forms in a stratigraphic study of the La Peña Formation in the area of Nuevo León, Mexico, and proposed the new genus *Caseyella* to include his specimens and those classified as *Uhligella aguilerae* and *Uhligella jacobi* by Burckhardt (1925). Cantú-Chapa (1976) emphasized the differences in the ornamentation pattern between the Mexican specimens and the genus *Uhligella*, particularly because the Mexican specimens displayed strong and flexuous flanges on their shells, a morphological feature that is not observed on specimens of the genus *Uhligella* from Europe. Although his observations were correct, the characteristics of the ornamentation pattern displayed by the Mexican specimens are rather typical of the genus *Pseudohaploceras* defined by Hyatt (1900). In view of this fact, Wright *et al*. (1996) grouped specimens of this species under the name of *Pseudohaploceras reesidei* (Humphrey), and they reassigned the rest of the Mexican species previously labeled as *Uhligella* to this genus. Present authors concur with Wright *et al*. (1996) opinion.

Suborder Ancyloceratina Wiedmann, 1966
Superfamily Deshayesitoidea Stoyanow, 1949
Family Deshayesitidae Stoyanow, 1949
Subfamily Deshayesitinae Stoyanow, 1949
Genus *Dufrenoyia* Kilian and Reboul, 1915

Type Species. *Ammonites furcatus* J. de C. Sowerby, in Fitton, 1836, p. 339: by original designation.

Diagnosis. Moderately evolute ammonites with compressed shells and flat sides and venter. Ribs sinuous, fine or coarse, commonly broad and flat, branching or long and short, interrupted on venter in inner whorls, later continuous, and raised into ventrolateral clavi.

***Dufrenoyia justinae* (Hill, 1893)**
Figure 3b-3c

Acanthoceras? *justinae* Hill, 1893, p. 38, pl. 7, figs. 1-3.
Hoplites roemeri Cragin, 1893, p. 234, pl. 44, fig. 4-5.
Ammonites justinae (Hill), Hill, 1901, pl. 21, fig. 6.
Dufrenoyia justinae (Hill), Burckhardt, 1925, p. 17, pl. 10, fig. 14-15; Riedel, 1938, p. 48-49, pl. 8, fig. 15-19; Scott, 1940a, p. 1022-1025, pl. 60, fig. 7-8; pl. 62, fig. 9; Humphrey, 1949, p. 122, pl. 6, fig. 1-7; pl. 7, fig. 1-9; Cantú-Chapa, 1963, p. 57-58, pl. 4, fig. 6; Cantú-Chapa, 1976, p. 9, pl. 1, fig. 3, 5, 11-11a; Renz, 1982, p. 18-19, pl. 1, fig. 8 a-b; Barragán, 2000, p. 102-107, pl. 53, fig. 5-10; pl. 54, fig. 1-12; pl. 55, fig. 1-6; Barragán, 2001, p. 193, fig. 3 (1-6); Méndez-Franco, 2003, p. 59-62, pl. 5, fig. 7-13; Bogdanova and Hoedemaeker, 2004, p. 205-207, pl. 16, fig. 6; pl. 17, fig. 1-4; pl. 18; pl. 19, fig. 1.

Material. Thirty one specimens. The specimens illustrated are identified as IGM-8839 and IGM-8840.

Description. Shell discoidal, compressed, with whorls increasing rapidly in height, slowly in width; semi-evolute with last whorl embracing about one-third of preceding whorls. Whorl section ellipsoidal, widest in third portion closest to umbilicus; flanks slightly convex toward dorsum, flattened and inclined toward venter. Umbilicus shallow and moderately narrow. Venter truncated, flattened, and squarish, with pronounced ventro-lateral angles. Ornamentation consists of falciform, regularly alternating, primary and secondary ribs. Primaries begin on umbilical wall, curve convexly toward aperture on inner third portion of flank, and are convex toward the opposite direction in the middle of the flank, bending toward the aperture again in the outer third portion of the flanks, to form clavate tubercles on ventro-lateral angles. Secondary ribs originate in the middle region of the flanks and are equal in strength to primaries on the outer third region of flanks. In inner whorls, all ribs are interrupted in the ventro-lateral margins without crossing the venter. All ribs in outer whorl are of equal prominence and evenly spaced on venter, which they cross transversely. Density of ribbing usually greater on young whorls, with ribs

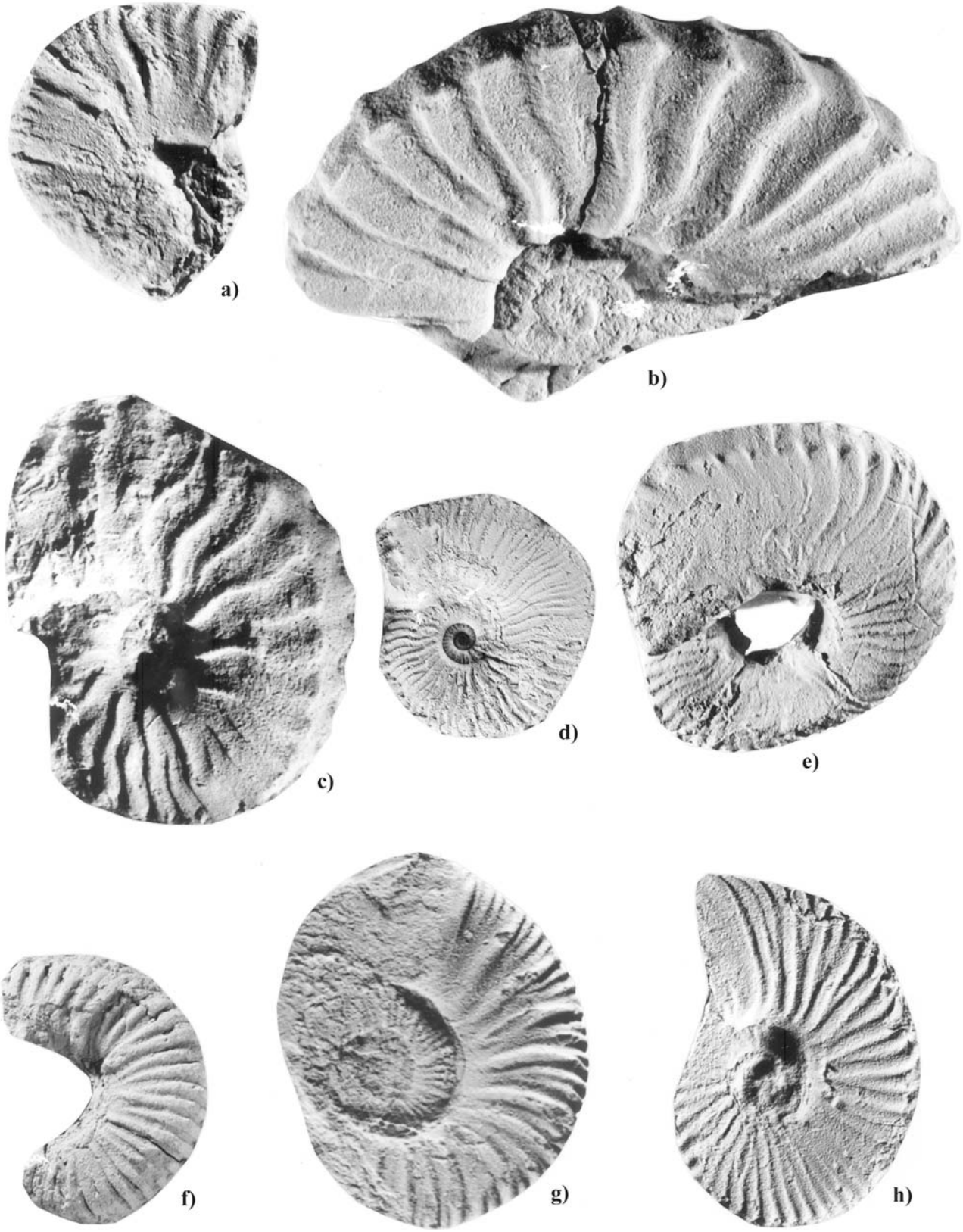

Figure 3. Index species of the uppermost early Aptian *Dufrenoyia furcata* Zone [Biozonation *sensu* Reboulet and Hoedemaeker (reporters), 2006] sampled from the basal strata of the La Peña Formation from the studied section at La Huasteca canyon. a: *Pseudohaploceras reesidei* (Humphrey), X2, IGM-8838; b: *Dufrenoyia justinae* (Hill), X3, view of the last whorl, IGM-8839; c: *Dufrenoyia justinae* (Hill), X2, view of the inner whorls, IGM-8840; d: *Burckhardtites nazasensis* (Burckhardt), X1, IGM-8841; e: *Burckhardtites ehlersi* Humphrey, X2, IGM-8842; f: *Colombiceras spathi* Humphrey, X1, IGM-8843; g: *Penaceras rursiradiatus* (Humphrey), X1, IGM-8844; h: *Kazanskyella* aff. *arizonica* Humphrey, X2, IGM-8845.

becoming coarser and more separated with age, although rather evenly spaced.

Remarks. *Dufrenoyia justinae* (Hill) is easily recognized by the characteristics of its ventral region, particularly by the squared venter and the prominence of the ribs when they cross it transversely. Based on differences in the ventral region of the shells of specimens from Mexico, as well as on comparison of specimens from Texas, and Colombia, Bürgl (1956) proposed several varieties of *Dufrenoyia justinae* that were identified as *Dufrenoyia texana* by Burckhardt (1925). Specimens studied in the present work have been compared to those reported by Burckhardt (1925) and Humphrey (1949) from northeastern Mexico, as well as those studied by Stoyanow (1949) and Scott (1940a) from Arizona and Texas, respectively, and those illustrated by Riedel (1938) and Bogdanova and Hoedemaeker (2004) from Colombia, and Renz (1982) from Venezuela. All the forms from these different areas are here considered conspecific with *Dufrenoyia justinae*, and the differences observed on the ventral region on all of them can be easily considered within the range of variation of a single species.

Genus *Burckhardtites* Humphrey, 1949

Type Species. *Neocomites nazasensis* Burckhardt, 1925, p. 14: by original designation.

Diagnosis. Very similar to *Dufrenoyia* from which it differs by its more rapidly increasing whorl height and a finer, irregular, biconcave ribbing that never crosses the venter.

***Burckhardtites nazasensis* (Burckhardt, 1925)**
Figure 3d

Neocomites nazasensis Burckhardt, 1925, p. 4, pl. 3, fig. 4-7.

Burckhardtites nazasensis (Burckhardt), Humphrey, 1949, p. 130-131, pl. 10, fig. 1-5; Cantú-Chapa, 1976, p. 9, pl. 1, fig. 1; Renz, 1982, p. 24, pl. 1, fig. 17 a-b, 18; Barragán, 2000, p. 89-92, pl. 51, fig. 4-7; Barragán, 2001, p. 194, fig. 4 (1-2); Méndez-Franco, 2003, p. 54-56, pl. 5, fig. 1-3.

Material. Seventeen specimens. The specimen illustrated is identified as IGM-8841.

Description. Shell flattened and semi-evolute. Flanks convex passing into a very high, but abrupt, umbilical wall. Venter truncated, flattened, and narrow. Whorl section much higher than wide, oblong, with its greatest thickness somewhat within the middle of the flanks. Ornamentation on flanks consists of narrow, fine, and flexuous ribs. They consist of principal ribs which rise on the umbilical wall, and one or two intercalated ribs, which appear in the interspaces near the umbilical region, or toward the middle of the flank. The ribs are projected towards the aperture before reaching the middle of the flanks and towards the opposite direction on the outer half of the flank, becoming falciform on the part of the flank closest to venter. The majority of the ribs are of equal strength. Only a few of the principal ribs, generally alternatively, thicken slightly on the inner third portion of the flanks, where they are somewhat prominent and stand out on the umbilical border as tuberculiform prominences. All ribs thicken toward the ventral margin where they end, forming slight marginal tubercles. The venter is almost entirely smooth, with only weak transverse striae present.

Remarks. The genus *Burckhardtites* was introduced by Humphrey (1949, p. 130) to include all forms described by Burckhardt (1925, p. 14, plate III, figs. 4-7) as *Neocomites nazasensis* from the Aptian of Río Nazas, Durango, Mexico. As argued by Humphrey, "the genus *Neocomites* disappeared in the Hauterivian and is characterized by very involute, much compressed forms with ribs inclined towards the apertural zone, equally spaced, and which bifurcate from tubercles located at mid flanks". *Burckhardtites nazasensis* (Burckhardt) is an Aptian species more related to *Dufrenoyia*, than it is to *Neocomites* (Wright *et al*., 1996). Nonetheless, *Burckhardtites* can be easily separated from *Dufrenoyia* by its whorl height that increases more rapidly, and its fine, irregular, biconcave ribs.

***Burckhardtites ehlersi* Humphrey, 1949**
Figure 3e

Burckhardtites ehlersi Humphrey, 1949, p. 136, pl. 12, fig. 4-6.

Material. Six specimens. The specimen illustrated is identified as IGM-8842.

Description. Shell discoidal, moderately evolute, embracing about one-half of preceding whorls. Whorl section of subequal height and width, thickest in lower third; greatly expanding anteriorly. Flanks convex , flattened, and inclined toward a broadly truncated venter. Umbilicus moderately wide and deep; umbilical wall almost straight; umbilical shoulder strongly rounded. Posterior portion of last whorl bears regularly alternating, coarse, widely spaced primary and secondary ribs in a crowded manner. Primaries begin on umbilical wall and are radial across umbilical shoulder. They curve forward on inner half of flanks, bend backward, and are flattened and falciform on outer half of flanks, curving forward again to terminate in prominent clavate tubercles on ventro-lateral angles. Secondaries originate well down on inner half of flanks, and are equal in strength to primaries across the rest of the flank. At this stage, venter smooth or marked slightly by faint swellings between opposed clavi. Ornamentation on the anterior portion of last whorl changes in a marked manner. Ribs are less crowded and attenuated,

and cross the venter transversely. Ventro-lateral tubercles become less clavate and tend to disappear anteriorly.

Remarks. Humphrey (1949) erected this species from his observations on one specimen from the La Peña Formation at Cañón de San Antonio, Sierra de Los Muertos, Coahuila, Mexico. Even though its inner whorls are not preserved, the single specimen of this study assigned to *Burckhardtites ehlersi* shows morphological similarities to the specimen described by Humphrey.

Family Parahoplitidae Spath, 1922
Subfamily Acanthohoplitinae Stoyanow, 1949
Genus *Colombiceras* Spath, 1923.

Type Species. *Ammonites crassicostatus* Orbigny, 1840, p. 64: by original designation.

Diagnosis. Rather evolute ammonites with slightly compressed shells. Inner whorls with convex sides and flat-topped ribs branching at umbilical shoulder or mid-flank, where one tubercle may be present. Outer whorls compressed, with flat sides and flat to subrounded venter and less flat-topped ribs.

***Colombiceras spathi* Humphrey, 1949**
Figure 3f

Colombiceras spathi Humphrey, 1949, p. 151-152, pl. 18, fig. 7-8; Barragán, 2000, p. 117-119, pl. 57, fig. 3-10; Barragán, 2001, p. 194, fig. 4 (5); Méndez-Franco, 2003, p. 69-72, pl. 7, fig. 1-3.
Colombiceras sp. Cantú-Chapa, 1976, pl. 1, fig. 8-8a.

Material. Eight specimens. The specimen illustrated is identified as IGM-8843.

Description. Shell discoidal, compressed, and moderately evolute; with last whorl embracing about one-fourth of preceding whorls. Flanks convex. Venter narrow and flattened. Whorl section subquadrate higher than wide. Umbilicus wide. Ornamentation consists of irregularly alternating primary and secondary ribs. Primaries rise on umbilical wall, quickly gain prominence on umbilical shoulder and pass radially or very slightly flexuous across flanks, widening rapidly toward venter. On last whorl, several primaries bifurcate on the inner third portion of flanks or from tubercle-like swellings on umbilical shoulder. Two or more primaries may follow each other or alternate with single secondaries. Secondary ribs originate over the inner third portion of flanks, and may simulate bifurcation by rising very close to an adjoining primary rib near umbilical area. On the outer third portion of flanks, all ribs present typical flat-topped, steep-sided appearance characteristic of the genus. Ribs are widest and have most relief on venter, where they are evenly spaced, equal in size, and transverse.

Remarks. Humphrey (1949, p. 151) described *Colombiceras spathi* based on observations made on a single tectonically-distorted specimen from Coahuila State, northeastern Mexico. As discussed by Humphrey, this species is morphologically similar to *Colombiceras subtobleri* (Kasansky) from Daghestan, northern Caucasus of the western Caspian Sea Region. The main difference is that *C. subtobleri* is more involute and the bifurcation of its primary ribs takes place on the third portion of the flanks closer to the venter, whereas in *C. spathi* the bifurcation occurs on the third portion of the flanks closer to the dorsum. The eight specimens studied herein are morphologically similar to that one illustrated by Humphrey (1949, p. 151-152, plate 8, figs. 7-8).

Genus *Penaceras* Cantú-Chapa, 1963

Type Species. *Hypacanthoplites*? *rursiradiatus* Humphrey, 1949, p. 142: by original designation.

Diagnosis. Like *Colombiceras*, but primary ribs recti- or rursiradiate on inner half of side, then branching and rursiradiate, flattening toward venter; periodic ribs enlarged on early whorls. Perhaps synonymous with *Colombiceras*.

***Penaceras rursiradiatus* (Humphrey, 1949)**
Figure 3g

Hypacanthoplites? *rursiradiatus* Humphrey, 1949, p. 142, pl. 14, fig. 11-12.
Peñaceras rursiradiatus (Humphrey); Cantú-Chapa, 1963, p. 54-55.
Pegnaceras rursiradiatus (Humphrey); Etayo Serna, 1979, p. 53.
Penaceras rursiradiatus (Humphrey); Wright et al., 1996, p. 275; Barragán, 2000, p. 122-125, pl. 58, fig. 1-3.

Material. Three specimens. The specimen illustrated is identified as IGM-8844.

Description. Shell discoidal, semi-evolute, with last whorl embracing about a quarter of preceding whorls. Flanks flattened. Whorl section subovoidal, slightly higher than wide. Venter flattened. Umbilicus occupies about one-third of total diameter; umbilical wall steep; umbilical shoulder rounded. Ornamentation consists of equally spaced, regularly alternating primary and secondary ribs. Sometimes, two primaries or two secondaries may follow. A marked curving of the ribs toward the protoconch on the outer half portion of flanks, and across ventral area is characteristic. Primary ribs originate on umbilical shoulder, thicken rapidly and maintain their strength across the flanks, forming transverse swellings on the ventro-lateral margins. Secondary

ribs originate from interspaces at mid-flanks, or occasionally at outer third portion of flanks, and are equal to primaries on ventro-lateral border where all ribs thicken and may bifurcate. Across mid line of venter, ribs are straight and equally spaced.

Remarks. *Penaceras rursiradiatus* was originally described by Humphrey (1949) as *Hypacanthoplites*? *rursiradiatus* based on observations made on one specimen from the La Peña Formation in Coahuila State, northeastern Mexico. Humphrey (1949, p. 142), assigned the specimen to *Hypacanthoplites* with some degree of doubt because of the flattened venter and transverse swellings of the ribs on the ventro-lateral margins, characters that are not diagnostic of the genus. The issue of morphological differences with *Hypacanthoplites* was raised by Cantú-Chapa (1963) who pointed out the marked curving of the ribs toward the protoconch on the outer half of flanks, and across ventral area, characteristic that also gives the name of the type species. Hence, Cantú-Chapa (1963) proposed the new genus *Peñaceras*. Further emendations of the genus name as *Pegnaceras* and *Penaceras*, were introduced by Etayo-Serna (1979), and Wright *et al*. (1996), respectively.

The specimens assigned in this work to *Penaceras rursiradiatus* are morphologically similar with the one identified as *Hypacanthoplites*? *rursiradiatus* by Humphrey (1949).

Subfamily Parahoplitinae Spath, 1922
Genus *Kazanskyella* Stoyanow, 1949

Type Species. *Kazanskyella arizonica* Stoyanow, 1949, p. 100-101: by original designation.

Diagnosis. Rather involute ammonites with whorl section oval or rectangular. Ribs normally rigid and rectiradiate throughout.

***Kazanskyella* aff. *arizonica* Stoyanow, 1949**
Figure 3h

Material. Four specimens. The specimen illustrated is identified as IGM-8845.

Description. Shell moderately involute; with last whorl embracing about two-thirds of preceding whorls. Whorl section compressed. Flanks flattened. Umbilicus occupying about one-third of total diameter. Umbilical wall inclined and umbilical shoulder rounded. Venter flattened and slightly arched on half portion of outer whorl close to the apertural zone. Ornamentation on the posterior half portion of last whorl, consists of fine, irregularly alternating simple primary and secondary ribs. Primaries originate on the umbilical wall and are flexuous and inclined toward the apertural zone across the flanks. Two or three primaries may follow. Secondary ribs originate on the umbilical shoulder and are equal to primaries on the outer third portion of flanks and on venter, which all ribs cross unaltered. Ornamentation on the anterior half portion of last whorl is characterized by coarser and more widely spaced ribs. The alternation of ribs is more regular, consisting of one secondary intercalating between primaries and originating at the middle portion of the flank. Primary ribs may form small and elongate swellings on the umbilical margin.

Remarks. Assignment of the specimens collected at La Huasteca canyon section to *Kazanskyella arizonica* is based on comparison with Stoyanow's work (1949) from Arizona. We decided to leave the nomenclature open due to the fact that the four specimens assigned to this species display ribs bent forward on venter through the outer third of last whorl, an index characteristic of the genus *Parahoplites*.

DISCUSSION ON THE AMMONITE ASSEMBLAGE AND ITS AGE

Taxonomy and biostratigraphy of Aptian ammonite assemblages of the La Peña Formation in northeastern Mexico have been useful conventional media used in stratigraphic correlation in the region as advocated in the works by Burckhardt (1925), Humphrey (1949), Cantú-Chapa (1963), Young (1969), Cantú-Chapa (1976), Contreras-Montero (1977), and Barragán (2000). However, very little attention has been given to the detailed sedimentological aspects to address the issue of prevailing existing conditions associated with deposition of the ammonite-rich rock units of this age. The lack of integration of biostratigraphic and sedimentological data makes the delimitation of biostratigraphic units a difficult task, and as a consequence, diminished the biochronological value of the Aptian ammonite biozones of northeastern Mexico. This problem was equally heightened by the absence of broad regional correlation between the Mexican ammonite biozones, and their relationship to taxonomic provinciality at that time. Such factors must have certainly played a key role in the specific character of the northeastern Mexican Aptian ammonite assemblages, as progressive westward opening of the Tethys sea resulted in the development of open marine connections over a broad area, allowing the dispersal of the Tethyan ammonite biota into the proto-Gulf of Mexico by Early Cretaceous time (Frakes, 1979). In fact, Johnson (1974) argued that the migrant fauna was influenced by the newly developed environments because of their specific ecological constraints, as previous studies based on ammonite distribution versus facies relationships (Scott 1940b; Wiedmann, 1973) established a bathymetric distribution of the ammonite populations of that time. Their studies concluded that Lower Cretaceous ammonites lived only in the environments represented by the outer and inner shelves, and were excluded from the deeper basinal environments.

This is supported by recent findings of Tethyan Valanginian ammonites in northeastern Mexico (González-Arreola and Barragán, 2007), which are conform to other coeval assemblages of western Europe. The influence of bathymetry on ammonite distribution thus explained why their larvae were unable to travel long distances (Scott, 1940b), and the deep oceans formed actual natural barriers that prevented further migration as they were unable to cross a widening Tethys. The ammonite fauna does show, indeed, that main centers of endemism within the Tethyan province appear to have developed from the Hauterivian onward, when the Lower Cretaceous seas became widely separated (Pozaryska and Brochwicz-Lewinski, 1975; Smith *et al*., 1981) and vast sedimentary basins developed in northeastern Mexico.

Thus, one of the main problems of broad regional correlations of pioneering Aptian biozonations of northern Mexico stemmed from apparent taxonomic provinciality during this age. This endemism apparently prevented the presence in Mexico of the index ammonites species that conform to the standard schemes for the Mediterranean or eastern Tethyan Realm (Barragán, 2000). To alleviate this limitation, Barragán-Manzo and Méndez-Franco (2005) proposed a new ammonite biozonation for the Aptian of northern Mexico, intended for regional use and constructed on the basis of the stratigraphic ranges of local index taxa. This Mexican scheme can be further correlated to the biozonal scheme of northeastern Europe (Casey, 1961), as well as to the former ammonite zonal standard of the Mediterranean area [Hoedemaeker and Reboulet (reporters), 2003] (Barragán-Manzo and Méndez-Franco, 2005, p. 45).

The present high-resolution analysis of the La Huasteca canyon strata provides further precision in local Aptian ammonite biostratigraphy that can be correlated with the latest comprehensive Tethyan standard ammonite zonal scheme now in use [Reboulet and Hoedemaeker (reporters), 2006].

On the basis of its record of occurrences (Wright *et al*., 1996), *Dufrenoyia* is considered as essentially a Tethyan genus that stratigraphically spans throughout the Aptian. However, the absence of ammonite taxa in the infrajacent biocalcirudite layers of the Cupido Formation limits our true assessment of its chronostratigraphic range in northeastern Mexico. The presence of other faunal elements associated with the Mexican specimens of the species *Dufrenoyia justinae,* such as *Pseudohaploceras resideei*, *Burckhardtites nazasensis*, *B. ehlersi*, *Colombiceras spathi*, *Kazanskyella* aff. *arizonica*, and *Penaceras rursiradiatus*, indicate that the interval represented by the basal strata of the La Peña Formation at the La Huasteca canyon section of this study clearly belongs to the upper part of the local early Aptian *Dufrenoyia justinae* Taxon Range Zone (Barragán-Manzo and Méndez-Franco, 2005). On account of its distinctive ammonite assemblage, the Mexican *Dufrenoyia justinae* Zone can be further correlated to both: the uppermost early Aptian *Dufrenoyia furcata* Zone of the Mediterranean standard zonation [biozonation *sense* Reboulet and Hoedemaeker (reporters), 2006] concurrent with the tripartite scheme of the stage; and to the uppermost early Aptian *Tropaeum bowerbankii* Zone of the northeastern European standard zonation (biozonation *sensu* Casey, 1961) associated with the classic bipartite scheme of the stage (Figure 4). Thus, the basal strata of the La Peña Formation are of late early Aptian age regardless of the scheme of subdivision of the stage used.

As pointed out earlier, it is important to emphasize the lack of the lowermost ammonite biozones for the Bedoulian (lower Aptian) in northern Mexico. The absence of a record for the *Deshayesites oglanlensis* through the *Deshayesites deshayesi* zones in northern Mexico is best explained by the dominance of extensive shallow carbonate platforms in the area through most of the Bedoulian, as in other parts of the world. A transgressive event, which drowned most of these carbonate platforms at the end of this substage, is characterized locally by the interruption of deposition of facies of the Cupido platform and the onset of deposition of the La Peña Formation. Nonetheless, the uppermost beds of the underlying Cupido Formation include brief intermittent marly levels impoverished in benthic foraminifera, and with few ammonite shell fragments heralding the development of conditions that favored the incursion of the ammonoid faunas into these areas of Mexico (Barragán, 2001). Thus, the first stratigraphic record of identifiable Aptian ammonites in this part of Mexico is represented by a rich assemblage of species belonging mainly to the genus *Dufrenoyia* deposited in the basal strata of the La Peña Formation.

The placement of the basal units of the studied section in the uppermost part of the early Aptian is further corroborated by superjacent ammonite assemblages. Indeed, recent work by Barragán and Szives (2007) reported from the same stratigraphic section subject of this study the presence of *Mathoceras* spp. This taxon is part of a rich ammonite assemblage representative of the middle Aptian *Epicheloniceras subnodosocostatum* Zone [*E. martini sensu* Reboulet and Hoedemaeker (reporters), 2006]. The specimens of *Mathoceras* were collected from strata deposited immediately above those comprising *Dufrenoyia* studied herein. This succession further supports the validity of the biochronostratigraphic assignment of the shift of deposition from the shallow carbonate Cupido platform to the deeper facies of the La Peña Formation. Thus, full development of the conditions related to deposition of the La Peña Formation took place sometime during the late early Aptian in the interval represented by the *Dufrenoyia furcata* Zone (=*Dufrenoyia justinae* Zone in Mexico), and not in the late Aptian as previously assigned.

CONCLUSIONS

The results of the present study provide evidence that the basal strata of the La Peña Formation of northern Mexico

FORMATION	STAGE	MEDITERRANEAN AND SUBMEDITERRANEAN (Reboulet *et al*., 2006)		NORTHEAST MEXICO (Barragán-Manzo and Méndez-Franco, 2005)	NORTHEAST EUROPE (Casey, 1961)	
CUPIDO — LA PEÑA	APTIAN	UPPER	*Hypacanthoplites jacobii*	*Hypacanthoplites* cf. *leanzae* Taxon Range Zone	UPPER	*Hypacanthoplites jacobii*
			Acanthohoplites nolani	*Acanthohoplites aschiltaensis* Taxon Range Zone		
		MIDDLE	*Parahoplites melchioris*	*Epicheloniceras* cf. *subnodosocostatum*/ *Acanthohoplites acutecosta* Interval Zone		*Parahoplites nutfieldiensis*
			Epicheloniceras martini			*Epicheloniceras martinoides*
		LOWER	*Dufrenoyia furcata*	*Dufrenoyia justinae* Taxon Range Zone	LOWER	*Tropaeum bowerbanki*
			Deshayesites deshayesi			*Deshayesites deshayesi*
			Deshayesites weissi			*Deshayesites forbesi*
			Deshayesites oglanlensis			*Prodeshayesites fissicostatus*

Figure 4. Standard ammonite zonation of the Aptian Stage for the Mediterranean and Submediterranean Faunal Provinces [after Reboulet and Hoedemaeker (reporters), 2006] and its correlations to the standards of northeastern Mexico and northeastern Europe. The ammonite assemblage from the basal strata of the La Peña Formation discussed in this paper is considered to be part of the uppermost early Aptian *Dufrenoyia justinae* Zone (shaded area).

include index ammonites representative of the uppermost early Aptian *Dufrenoyia justinae* Taxon Range Zone. The chronostratigraphic position of this Mexican Biozone can be correlated elsewhere with well established lower Aptian ammonite zonations (Figure 4) for both the Mediterranean region [*Dufrenoyia furcata* Zone, *sensu* Reboulet and Hoedemaeker (reporters), 2006], and northeastern Europe (*Tropaeum bowerbankii* Zone *sensu* Casey, 1961). Thus, in Mexico, the shift of deposition from the predominately biocalcarenites and biocalcirudites with rudists, distinctive of the shallow carbonate Cupido platform, to the marly C-organic rich beds of the deeper facies, La Peña Formation, took place sometime earlier – *i.e*. late early Aptian – instead of the late Aptian as previously assigned.

ACKNOWLEDGEMENTS

This work was financially supported by the Project DGAPA PAPIIT IN-107106 and private funds. The authors express their gratitude to Antonio Altamira for the excellent photographs of the ammonites. Heartfelt thanks to Gilberto Nieto, Rüdiger Marten, Fabian Duque-Botero and Marco Antonio Argáez for their assistance in the field. The authors also express their gratitude to Dr. Jaap Klein and Dr. Alexander Lukeneder who suggested many useful improvements to the manuscipt.

REFERENCES

Anthula, D.J., 1900, Über die Kreidefossilien des Kaukasus mit einem allegemeinen Ueberblick über die Entwicklung der Sedimentärbildungen des Kaukasus: Beitraege zur Palaeontologie und Geologie Oesterreich-Ungarns und des Orients, 12 (1899), 54-159, pl. 1-14.

Barragán, R., 1999, Sedimentary facies and organic carbon variations in Barremian-Aptian sequences of northeastern Mexico: Revista Española de Micropaleontología, 31(3), 305-314.

Barragán, R., 2000, Ammonite biostratigraphy, lithofacies variations, and paleoceanographic implications for Barremian-Aptian sequences of northeastern Mexico: Miami, Florida, U. S. A., Florida International University, Department of Geology, Ph. D. Thesis, 296 p. Unpublished.

Barragán, R., 2001, Sedimentological and paleoecological aspects of the Aptian transgressive event of Sierra del Rosario, Durango, northeast Mexico: Journal of South American Earth Sciences, 14, 189-202.

Barragán, R., Szives, O., 2007, New records of *Mathoceras Casey* (Deshayesitidae, Ammonoidea) from the Aptian (Lower Cretaceous) of Mexico and Hungary: Biostratigraphic and paleobiogeographic implications: Geobios, 40, 21-30.

Barragán-Manzo, R., Méndez-Franco, A.L., 2005, Towards a standard ammonite zonation for the Aptian (Lower Cretaceous) of northern Mexico: Revista Mexicana de Ciencias Geológicas 22(1), 39-47.

Bogdanova, T.N., Hoedemaeker, Ph. J., 2004, Barremian-Early Albian Deshayesitidae, Oppelidae, Desmoceratidae and Silesitidae of Colombia: Scripta Geológica 128, 183-312, 49 pls., 2 figs.

Böse, E., 1923, Vestiges of an ancient continent in northeast Mexico: American Journal of Science, 206, 127-136.

Burckhardt, C., 1925, Faunas del Aptiano de Nazas (Durango): Boletín del

Instituto de Geología de México, 45, 71 p., 10 lám.

Bürgl, H., 1956, La variabilidad de la Amonita *Dufrenoya texana* Burckhardt: Boletín Geológico de Bogotá, 4(2-3), 1-22, 3 pl.

Cantú-Chapa, A., 1963, Étude Biostratigraphique des Ammonites du Centre et de l'est du Mexique (Jurassique supérieur et Crétacé): Société Géologique de France, Mémoire no. 99, nouvelle série, 42(4), 102 p.

Cantú-Chapa, M., 1976, Estratigrafía de la Formación La Peña (Aptiano Superior) en el área de Monterrey, N. L.: Revista del Instituto Mexicano del Petróleo, 8(4), 7-16.

Casey, R., 1961, The Stratigraphical Paleontology of the Lower Greensand: Palaeontology, 3, 487-621.

Contreras-Montero, B., 1977, Bioestratigrafía de las Formaciones Taraises y La Peña (Cretácico Inferior) de La Goleta, Coahuila y Minillas, Nuevo León: Revista del Instituto Mexicano del Petróleo, 9(1), 8-17.

Cragin, F.W., 1893, A contribution to the Invertebrate Palaeontology of the Texas Cretaceous: Geological Survey of Texas, Annual Report, 4(2), 141-295, pl. 24-46.

Etayo-Serna, F., 1979, Zonation of the Cretaceous of central Colombia by Ammonites: Bogotá, Colombia, Ingeominas, Publicaciones Geológicas Especiales, 2, 186 p., 15 pl.

Fitton, W.H., 1836, Observations on some of the strata between the Chalk and the Oxford Oolite in the south-east of England. Including Appendix A: Descriptive notes respecting the shells figured in pl. xi-xxiii, by J. de C. Sowerby: Transactions of the Geological Society of London (series 2), 4, 103-390, pl. 11-23.

Frakes, L.A., 1979, Climates throughout geologic time: Elsevier Scientific Publishing Company, Amsterdam, 310 p.

Goldhammer, R.K., Lehmann, P.J., Todd, R.G., Wilson, J.L., Ward, W.C., Johnson, C.R., 1991, Sequence stratigraphy and Cyclostratigraphy of the Mesozoic of the Sierra Madre Oriental, Northeast Mexico: A Field Guidebook: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section, 84 p.

González-Arreola, C., Barragán, R., 2007, *Oosterella* (Ammonoidea) from the Taraises Formation (upper Valanginian), Durango, northeast Mexico: Cretaceous Research, 28(3), 419-427.

Hill, R. T., 1893, Paleontology of the Cretaceous formations of Texas: The invertebrate paleontology of the Trinity Division: Proceedings of the Biological Society of Washington, 8, 9-40, 8 pl.

Hill, R. T., 1901, Geography and geology of the Black and Grand prairies, Texas: United States Geological Survey, Annual Report, 21(7), 666 p.

Hoedemaeker, Ph.J., Reboulet, S. (reporters); Aguirre-Urreta, M.B., Alsen, P., Aoutem, M., Atrops, F., Barragán, R., Company, M., González-Arreola, C., Klein, J., Lukeneder, A., Ploch, I., Raisossadat, N., Rawson, P.F., Ropolo, P., Vašíček, Z., Vermeulen, J., Wippich, M., 2003, Report on the 1st International Workshop of the IUGS Lower Cretaceous Ammonite Working Group, the 'Kilian Group' (Lyon, 11 July 2002): Cretaceous Research, 24, 89-94.

Humphrey, W.E., 1949, Geology of Sierra de Los Muertos area, Mexico (with descriptions of Aptian cephalopods from the La Peña Formation): Geological Society of America Bulletin, 60, 89-176.

Hyatt, A., 1889, Genesis of the Arietitidae: Washington, D. C., Smithsonian Contributions to Knowledge, 673, xi + 238 p., 14 pl.

Hyatt, A., 1900, Cephalopoda, *in* Zittel, K.A. (ed.), Textbook of Palaeontology, 1st English Edition, translated by C. R. Eastman: London and New York, Macmillan, 502-592.

Imlay, R.W., 1936, Evolution of the Coahuila Peninsula, Mexico, Part IV. Geology of the western part of the Sierra de Parras: Geological Society of America Bulletin, 47, 1091-1152.

Imlay, R.W., 1937, Geology of the middle part of the Sierra de Parras, Coahuila, Mexico: Geological Society of America Bulletin, 48, 587-630.

Imlay, R.W., 1938, Studies of the Mexican geosyncline: Geological Society of America Bulletin, 49, 1651-1694.

Imlay, R.W., 1944, Cretaceous formations of Central America and Mexico: Bulletin ofthe American Association of Petroleum Geologists, 28, 1077-1195.

International Commission on Zoological Nomenclature, 1999, International Code of Zoological Nomenclature, 4th Edition: The International Trust for Zoological Nomenclature, Publisher, 306 p.

Johnson, J.G., 1974, Extinction of perched faunas: Geology, 2(10), 479-482.

Kilian, W., 1889, Sur quelques fossiles du Crétacé inférieur de la Provence: Bulletin de la Société Géologique de France, 3(16) (1888), 663-691, pl. 17-21.

Kilian, W., Reboul, P., 1915, Contribution à l'étude des faunes paléocrétacées du Sud-Est de La France. I La faune de l'Aptien inférieur des environs de Montelimar (Drôme): Mémoires pour Servir a l'Explication de la Carte Géologique Détaillée de La France, 1-221, 9 pl., 10 fig.

Kellum, L. B., 1944, Geologic history of northern Mexico and its bearing on petroleum exploration: American Association of Petroleum Geologists Bulletin, 28, 301-325.

Maurrasse,0 F.J-M.R., Barragan-Manzo, R., Ponton, C., 2006, Cupido-La Peña Formations: High-productvity to super-productivity during Cretaceous enhanced greenhouse conditions: Geological Society of America <http://gsa.confex.com/gsa/2006AM/finalprogram/abstract_116414.htm>, Abstracts with Programs, 38(7), p. 491.

Méndez-Franco, A.L., 2003, Bioestratigrafía de ammonites y variaciones de litofacies en una secuencia estratigráfica del Barremiano-Aptiano (Cretácico Inferior) del área del Cañón de La Huasteca, Estado de Nuevo León: México, D. F., Universidad Nacional Autónoma de México, Facultad de Ciencias, Tesis de Licenciatura, 179 p.

Orbigny, A. d', 1840-1842, Paléontologie Française. Terrains Crétacés. I: Cephalopodes: Paris, Masson, 662 p., 148 pl.

Ponton-Guerrero, C., 2006, Aptian deposits from the Mexican versus the Provencal (France) Platforms: Paleoenvironmental implications: Miami, Florida, USA, Florida International University, M.Sc. Thesis, 115 p.

Pozaryska K., Brochwicz-Lewinski, W., 1975, The nature and origin of Mesozoic and early Cenozoic marine faunal provinces. Some reflections: Mitteilungen aus dem Geologisch-Palaeontologischen Institut der Universitaet Hamburg, 44, 207-216.

Reboulet, S., Hoedemaeker, Ph. J. (reporters); Aguirre-Urreta, M.B., Alsen, P., Atrops, F., Baraboshkin, E.Y., Company, M., Delanoy, G., Dutour, Y., Klein, J., Latil, J.-L., Lukeneder, A., Mitta, V., Mourgues, F.A., Ploch, I., Raisossadat, N., Ropolo, P., Sandoval, J., Tavera, J.M., Vašíček, Z., Vermeulen, J., with the participation of Arnaud, H., Granier, B., Premoli-Silva I. (chairwoman of the Subcommission on Cretaceous Stratigraphy), 2006, Report on the 2nd International meeting of the IUGS lower Cretaceous ammonite working group, the "Kilian Group", Neuchatel, Switzerland, 8 September 2005: Cretaceous Research 27, 712-715.

Renz, O., 1982, The Cretaceous ammonites of Venezuela: Maraven, Caracas, 132 p., 40 pl.

Riedel, L., 1938, Amonitas del cretácico inferior de la Cordillera Oriental: Bogotá, Colombia, Ministerio de Industria y Trabajo, Departamento de Minas y Petrología, Estudios Geológicos y Paleontológicos sobre la Cordillera Oriental de Colombia, Parte 2, 7-80, lám. 3-14.

Scott, G., 1940a, Cephalopods from the Cretaceous Trinity Group of the south-central United States: University of Texas, Publication 3945, 969-1106, pl. 56-70.

Scott, G., 1940b, Paleoecological factors controlling the distribution and mode of life of Cretaceous ammonoids in the Texas area: Journal of Paleontology, 14 (4), 299-323.

Smith, C.I., 1981, Review of the geologic setting, stratigraphy, and facies distribution of the lower Cretaceous in northern Mexico, *in* Katz, S.M., Smith, C.I. (eds.), Lower Cretaceous Stratigraphy and Structure, Northern Mexico: Fieldtrip Guidebook, 11-16 November 1981: West Texas Geological Society, Publication 81-74, 1-27.

Smith, A.G., Hurley, A.M., Briden, J.C., 1981, Phanerozoic paleocontinental world maps: Cambridge University Press, Cambridge Earth Sciences Series, 102 p.

Spath, L.F., 1922, On the Senonian ammonite fauna of Pondoland: Transactions of the Royal Society of South Africa, 10, 113-148,

pl. 5-9.

Spath, L.F., 1923-1943, Ammonoidea of the Gault: Paleontographical Society Monographs, 2 vols., 16 pts., 787 p, 72 pl.

Stoyanow, A., 1949, Lower Cretaceous Stratigraphy in Southeastern Arizona: Geological Society of America Memoir, 38, 169 p., 27 pl., 2 fig.

Wiedmann, J., 1966, Stammesgeschichte und System der posttriadischen Ammonoideen, ein Ueberblick (2. Teil): Neues Jahrbuch für Geologie und Palaeontologie, 127, 13-81, fig. 14-47, pl. 3-6.

Wiedmann, J., 1973, Evolution or revolution of ammonoids at Mesozoic system boundaries: Biological Reviews, 48, 159-194.

Wilson, J.L., Pialli, G., 1977, A lower Cretaceous shelf margin in northern Mexico, *in* Bebout, D.C., Loucks, G. (eds.), Cretaceous carbonates of Texas and Mexico - Applications to subsurface exploration: University of Texas at Austin, Bureau of Economic Geology, Report of Investigation, 89, 286-294.

Wilson, J. L., Ward, W. C., 1993, Early Cretaceous carbonate platforms of northeastern and east-central Mexico, *in* Simo, J.A., Scott, R.W., Masse, J.-P. (eds.), Cretaceous Carbonate Platforms: American Association of Petroleum Geologists, Memoir 56, 35-49.

Wright, C.W., Calloman, J.H., Howarth, M.K., 1996, Treatise on Invertebrate Paleontology, Part L revised, Mollusca 4, Cretaceous Ammonoidea: Boulder, Colorado, and Lawrence, Kansas, The Geological Society of America Inc. and The University of Kansas Press, 362 p.

Young, K., 1969, Ammonite zones of northern Chihuahua, *in* Guidebook of the border region, Chihuahua and the United States: Sante Fe, Northern Mexico Geological Society, 97-101.

Zeuschner, L., 1856, Geognostische Beschreibung des Liaskalkes in der Tatra und in den angrenzenden Gebirgen: Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien, 19, 135-182, 2 pl.

Zittel, K.A., von, 1884, Cephalopoda, *in* K.A. Zittel (ed.), Handbuch der Palaeontologie: Muenchen und Leipzig, R. Oldenburg, Band 1, Abt. 2, Lief. 3, 329-522.

Zittel, K.A., von, 1895, Grundzüge der Paläeontologie: Muenchen und Leipzig, R. Oldenburg, viii + 971 p., 2,048 fig.

Manuscript received: June 7, 2007
Corrected manuscript received: November 7, 2007
Manuscript accepted: November 10, 2007