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Lower Cretaceous rocks of Sierra Los Chinos, east-central Sonora, Mexico

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RESUMEN

La gran mayoría de las rocas del Cretácico Inferior de Sonora son parte del Grupo Bisbee del sur de Arizona, depositadas a lo largo de la Cuenca Bisbee, una extensión del Golfo de México a Texas, Nuevo México, Arizona y Sonora. Sin embargo, las rocas del Cretácico Inferior de la Sierra Los Chinos están relacionadas con las rocas del área de Lampazos del este de Sonora, y consecuentemente con la estratigrafía de Chihuahua. En el área de Los Chinos, las unidades del Cretácico Inferior son las Formaciones Agua Salada, Lampazos y Los Picachos; unidades tomadas del área de Lampazos. El Cretácico Superior está constituido por rocas volcanosedimentarias, sobreyacidas por rocas terciarias intrusivas, volcánicas y sedimentarias. Las rocas del Cretácico Inferior en la Sierra Los Chinos están fuertemente plegadas y falladas, siendo las estructuras kilométricas (pliegues volcados y fallas de cabalgadura) las más visibles. Además el área fue afectada por al menos dos episodios de fallas normales. El Cretácico Inferior de la Sierra Los Chinos está paleogeográfica y tectónicamente relacionado con el Cinturón Tectónico de Chihuahua y no con el Grupo Bisbee de Sonora. Además el conglomerado marino en la base de la Formación Los Picachos representa un episodio tectónico activo al final del Albiano, y que aunque localmente importante, puede ser evidencia de reactivación de fallas de desplazamiento horizontal, relacionadas con transpresión tectónica. Las estructuras de compresión en Los Chinos es muy similar a la deformación de rocas de la misma edad en Chihuahua, Coahuila y Nuevo León.

PALABRAS CLAVE: Cretácico Inferior, Sonora, cuenca de Chihuahua.

ABSTRACT

Most Lower Cretaceous rocks in Sonora are part of the Bisbee Group of southern Arizona, deposited within a basin considered to be an extension of the Gulf of Mexico into Texas, New Mexico, Arizona and Sonora. However, the Lower Cretaceous rocks of the Sierra Los Chinos are more closely related to the Lampazos rocks of eastern Sonora, and consequently, to Chihuahua stratigraphy. In the Los Chinos area, the exposed Lower Cretaceous units include the Agua Salada, Lampazos and Los Picachos Formations. The Upper Cretaceous sequence is made up of volcanosedimentary rocks overlain by Tertiary intrusive, volcanic, and sedimentary rocks. Lower Cretaceous rocks of the Sierra Los Chinos area are strongly folded and faulted, with kilometer-scale overturned folds and thrusts. The area was affected by at least two episodes of normal faulting. The Sierra Los Chinos sequence is paleogeographically and tectonically related to the Chihuahua tectonic belt and is unrelated to the Bisbee Group of Sonora. The marine conglomerate at the base of the Los Picachos Formation represents a significant active tectonic episode at the end of the Albian, possibly related to re-activation of strike-slip faulting due to tectonic transpression. The compressional structures in the Los Chinos area are similar to structures of the same age in the states of Chihuahua, Coahuila, and Nuevo León.

KEY WORDS: Lower Cretaceous, Sonora, Chihuahua trough.

INTRODUCTION

Lower Cretaceous rocks exposed in Sonora are believed to have been deposited within the Bisbee basin, an extension of the Gulf of Mexico into Texas, New Mexico, Arizona, and Sonora (Hayes, 1970; González-León, 1994; Monreal, 1995). Most Lower Cretaceous rocks of Sonora have been assigned to the Bisbee Group of southern Arizona (Monreal, Valenzuela, and González, 1994b). However, the Sierra Los Chinos Lower Cretaceous stratigraphy is similar to the Chihuahua trough succession (Scott and González-León, 1991; Monreal, Longoria, and Valencia, 1994a, Monreal and Longoria, 1999).

Little work has been done in the Sierra Los Chinos area (Figure 1) (Grijalva, 1991; Grijalva, Fernández, and Cubillas, 1994, Pubellier, 1987). Its stratigraphy and geologic history is poorly known. The stratigraphic sequence exposed in this area may have been incorrectly assigned to the Bisbee Group (Grijalva, 1991; Grijalva, Fernández, and Cubillas, 1994). The Los Chinos stratigraphy is closely related to the Lampazos sequence and, therefore, to the stratigraphic

Fig. 1. Location of Sierra Los Chinos and Lampazos areas. Sections A-A' and B-B' are the same as on Figure 4.

sequence of the Chihuahua trough. Thus, the Cretaceous rocks exposed in the Sierra Los Chinos and Lampazos areas represent deeper basin facies counterparts of the platform facies (Mural Limestone) of the Bisbee Group, exposed in north and central Sonora. We propose that they are connected with platform and basin open-marine facies of the Mexican sea to the southeast, extending from Chihuahua to Tamaulipas (Monreal and Longoria, 1999). The style of deformation of the stratigraphic succession exposed in the Sierra Los Chinos area closely resembles that of the Lampazos sequence and is similar to that of the Chihuahua tectonic belt (Monreal and Longoria, 1999).

Based on lithology and stratigraphy, the nomenclature used herein for the Sierra Los Chinos sequence is the same as for the Lampazos area.

The purpose of this study is to contribute to undestanding of the Cretaceous sequence in the Los Chinos area and its paleogeographic relationship with the Lampazos area in east-central Sonora, and with the Chihuahua trough.

GEOLOGICAL SETTING

Lower Cretaceous rocks in Sonora are exposed mostly in the northern half of the State (Figure 2). Most of these outcrops are similar to the Bisbee Group exposed in southeastern Arizona (Monreal, Valenzuela, and González; 1994). This sequence was deposited within an irregular basin. The lower areas where filled by alluvial sediments of the Glance Conglomerate, followed by fluvial and deltaic sediments of the Morita Formation, which grades upward into the shallow-marine facies of the Mural Limestone, and finally, the fluvial facies of the Cintura Formation (Monreal, 1995). In contrast to the stratigraphic sequence of the Bisbee Group, a different stratigraphy is exposed in the Lampazos and Sierra Los Chinos areas, which is related to the Chihuahua trough located to the east in eastern Chihuahua (Monreal, 1995; Monreal and Longoria, 1999).

The Chihuahua tectonic belt is the structural equivalent of the Chihuahua trough . The belt is characterized by a series of mountain ranges oriented north-northwest, consisting of antiformal folds and faults that display an “en échelon” pattern. Most of the mountain ranges are anticlines; the structures are often upright whereas others display overturning and twisting (Monreal, 1993, 1996; Monreal and Longoria, 1995). A characteristic feature of the Chihuahua tectonic belt is the opposite vergences of folds and thrust faults, a feature that indicates a transpressional regime

Fig. 2. State of Sonora and adjacent areas during Aptian-Albian interval, showing Bisbee Group (BG) and related rock outcrops (dashed line) and the Chihuahua trough-related rock outcrops (dotted line). CH: Sierra Los Chinos area; LA: Lampazos area.

(Longoria, 1985, 1988, 1994; Monreal, 1993, 1996; Monreal and Longoria, 1995).

STRATIGRAPHY

The Lower Cretaceous sequence exposed in the Lampazos area includes El Aliso, Agua Salada, Lampazos, Espinazo del Diablo and Los Picachos Formations. The Lower Cretaceous units in the Los Chinos area are the Agua Salada (KAS), Lampazos (KLA) and Los Picachos (KLP) Formations (Figures 3 and 4).

The Upper Cretaceous includes a volcanosedimentary unit (KVS). Overlying the Cretaceous units are three Tertiary units that include an intrusive (TI), volcanic rocks (TV) and the Baucarit Formation (MBl and MBu). These units are overlain by Tertiary-Quaternary sediments (Q-T) and alluvial deposits (Qal).

Agua Salada Formation (KAS). The Agua Salada Formation was originally named by Herrera and Bartolini (1983) for a stratigraphic sequence exposed in the Lampazos area of Sonora. It was later redefined by González-León (1988) and Monreal and Longoria (1999).

In the Sierra Los Chinos, the Agua Salada Formation consists of alternating thin- to medium-bedded fine-grained black sandstone, thin- to thick-bedded calcareous black shale, and thin-bedded nodular sandy dark-gray limestone (Figure 5). Interval of olistostromes composed of thick-bedded oyster-bearing limestone occur near the top of the unit (Figure 6). The Agua Salada Formation is found south of Cerro Caloso in the Arroyo Chipajora (Figure 4). The formation is 330 m thick (base is not exposed) and is transitionally overlain by the Lampazos Formation.

The microfauna (radiolaria and planktonic foraminifera) in the Agua Salada Formation indicates marine deposition in pelagic to slope-basin environments, with gravity-flow conditions, evidenced by the olistostrome beds near the top. In the Lampazos area, this unit was assigned to the upper Aptian by Scott and González-León (1991); however Monreal and Longoria (1999) assigned it to the lower Aptian, because of the presence of *Caucasella hauterivica* in its middle part.

Lampazos Formation (KLA). The term was first used by Solano Rico (1970) and Herrera and Bartolini (1983) in the Lampazos area. It was later redefined by González-León (1988) and Monreal and Longoria (1999).

In the Sierra Los Chinos, the Lampazos Formation consists of alternating thin- to medium-bedded nodular dark-gray limestone, dark-gray shale, and some layers of thin-bedded dark-gray shale and sandstone (Figures 7 and 8). The entire unit weathers light gray and light brown. The Lampazos

Fig. 3. Stratigraphic column of the Sierra Los Chinos area.

Fig. 4. Generalized geologic map of the Sierra Los Chinos area. Sections A-A' and B-B' are the same as in Figures 14 and 15 respectively. KAS: Lower Cretaceous Agua Salada Formation; KLA: Lower Cretaceous Lampazos Formation; KLP: Lower Cretaceous Los Picachos Formation; KVS: Upper Cretaceous volcanosedimentary unit; TI: Tertiary intrusive; TV: Tertiary volcanic rocks; MBl: lower Baucarit Formation; Mbu: upper Baucarit Formation; Q-T: Tertiary-Quaternary sediments; Qal: Alluvial deposits.

Fig. 5. Sandstone and shale interval at the base of the Agua Salada Formation (KAS) as exposed in the Arroyo Chipajora south of Cerro Caloso.

Fig. 6. Medium-bedded oyster-bearing limestone near top of the Agua Salada Formation exposed in the Arroyo Chipajora south of Cerro Caloso. Cactus tree in center of photograph is about 3 meters high.

Fig. 7. Thin- to medium-bedded limestone and shale of the Lampazos Formation exposed in the Arroyo Chipajora south of Cerro Caloso. Small bush on limestone beds is about 1.5 meters high.

Formation is exposed from Arroyo Chipajora south of Cerro Caloso to Cerro Agua Caliente. It constitutes the main body of the Sierra Los Chinos (Figure 4). In Arroyo Chipajora, this unit is 520 m thick and is unconformably overlain by the Los Picachos Formation (Figure 9).

The microfauna (planktonic foraminifera, calpionellids, benthic foraminifera, ostracodes, and calcified radiolaria) is characteristic of outer-neritic to pelagic environments of deposition. González-León and Buitrón (1984), based on the presence of *Orbitolina texana* (Roemer), assigned the Lampazos Formation to the lower-middle Albian. Based on planktonic foraminifera and calpionellid assemblages, Monreal and Longoria (1999) assigned it to the upper Aptian to middle Albian.

Los Picachos Formation (KLP). The term was originally introduced in the Lampazos area by Herrera and Bartolini (1983). It was later redefined by González-León (1988) and Monreal and Longoria (1999). In the Sierra Los Chinos area, the Los Picachos is divided into three parts (Figure 10). (a) The lower part is an interval of medium- to thick-bedded calcareous conglomerate with limestone clasts up to boulder size (>25 cm in diameter), intercalated with sandstone and shale beds (Figures 11 and 12). Clasts are made up mainly of limestone with rudists, gastropods and other mollusks (Figure 13), but some clasts of sandstone and chert also occur. (b) The middle part is an alternating sequence of medium-bedded, occasionally fossiliferous (rudists and orbitolinids) limestone, shale, conglomerate, and sandstone. (c) The upper part is thin-bedded nodular limestone and shale, and medium-bedded to massive fossiliferous (rudists, gastropods and other mollusks) limestone. The Los Picachos Formation is exposed in the Cerro Caloso and in Cerro Alamo (Figure 4), and it is approximately 300 m thick.

The textural characteristics (grainstone, packstone, floatstone and wackestone) and fauna (rudists, miliolids, gastropods, echinoderms, green algae and orbitolinids) of the limestone in this unit indicate a shallow-water neritic environment of deposition, with local development of ooidal high-energy banks. The intraformational limestone conglomerate at its base is evidence of the reworking of a carbonate substratum in a shallow-marine shelf. The limestone clasts are similar to the limestone beds in the Espinazo del Diablo Formation exposed in the Lampazos area about 10 km northwest of Sierra Los Chinos.

In the Lampazos area, Scott and González-León (1991) assigned the Los Picachos Formation to the upper Albian; however, because of the occurrence of *Colomiella* sp. and *Favusella* sp. at the base of the unit, Monreal and Longoria (1999) considered the formation to range from middle to upper Albian.

Upper Cretaceous Volcanosedimentary (KVS). In the Sierra Los Chinos area, this unit is characterized by thin-bedded gray, light-tan to reddish-tan siltstone and clayey sandstone with intercalations of purplish-gray and greenish-gray tuff and agglomerate and light-tan andesite.

Fig. 8. Outcrop of the Lampazos Formation in the southwestern flank of Sierra Los Chinos.

Fig. 9. Los Picachos Formation unconformably resting (Black line) on the Lampazos Formation at Arroyo Chipajora south of Cerro Caloso.

Fig. 10. Stratigraphic section (LP) of Los Picachos Formation at the southern flank of Cerro Alamo. LPL: lower part of Los Picachos Formation; LPM: middle part; LPU: upper part.

Fig. 11. Limestone conglomerate, shale and sandstone in Los Picachos Formation in Cerro Alamo.

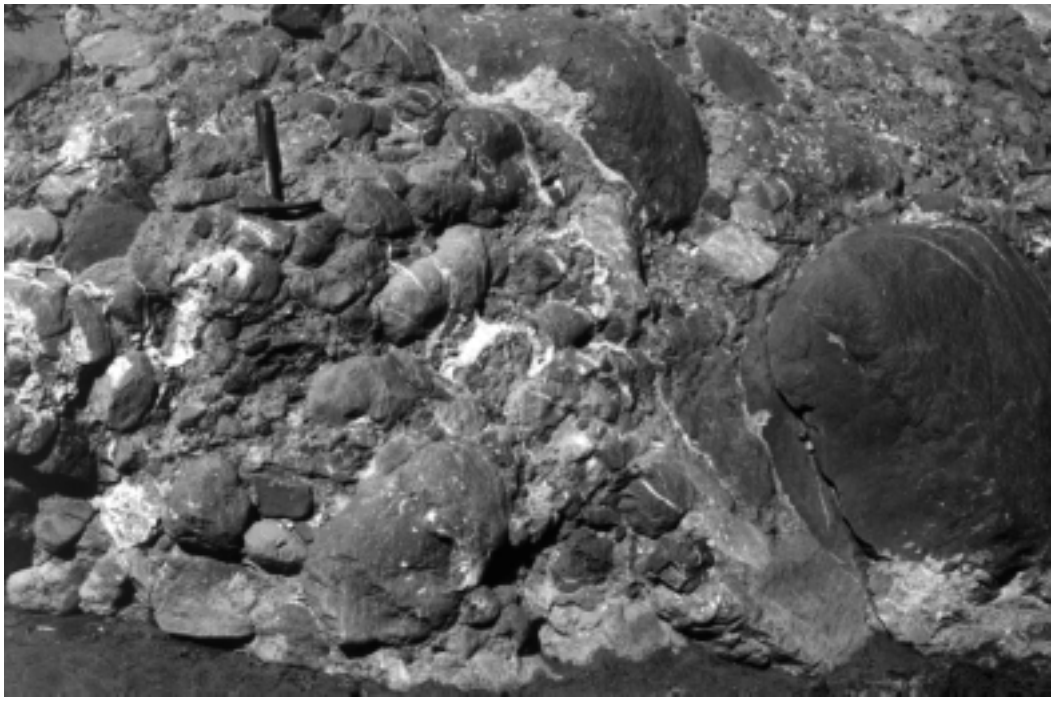

Fig. 12. Limestone conglomerate cobbles and boulders of the Los Picachos Formation on top of the Lampazos Formation in the Arroyo Chipajora south of Cerro Caloso.

Conglomerate lenses occur at the top. The lower part is characterized by siltstone and tuffaceous sandstone. The siltstone beds are reddish brown, thin-bedded and locally contain sandy nodules. The middle part consists of alternating beds of clayey sandstone, marly limestone, siltstone, sandy tuff, and some intervals of andesite and agglomerate. The upper part is a sequence of siltstone intercalated with marly limestone, sandstone, and conglomerate lenses. Grijalva and

Fig. 13. Limestone boulders with rudists (*Coalcomana ramosa*) in Los Picachos Formation at Cerro Alamo.

Cubillas (1990) reported *Caprinuloidea* sp and *Orbitolina* sp in the limestone clasts of the conglomerate lenses. This volcanosedimentary sequence is at least 500 meters thick (Grijalva, Fernández, and Cubillas, 1994).

On the basis of stratigraphic, structural relationship and resemblance to the Tarahumara Formation, this unit is provisionally assigned to the Upper Cretaceous.

STRUCTURE

The Lower Cretaceous rocks exposed in the Los Chinos area are strongly folded and faulted. The main structures are isoclinal and asymmetric both upright and overturned, decametrical and kilometrical folds and thrust faults, mostly oriented NW-SE with vergences both to the northeast and southwest. Although the rocks are folded at meter scale as in the Lampazos Formation (Figure 7), the kilometer-scale megastructures are the most conspicuous (Figure 16), for example in Cerro Caloso, Agua Caliente, and Sierra Los Chinos (Figure 4). Many folds are twisted, that is, the vergences of the folds change directions from upright to overturned, from one part of the fold to the other, as seen in the anticline in Sierra Los Chinos, south of Cerro Agua Caliente, and in Cerro Caloso (Figure 4).

One conspicuous feature is the thrusting of the Los Picachos Formation (KLP) over the Upper Cretaceous volcanosedimentary unit (KVS), southeast of Cerro Alamo (Figures 4 and 15). This thrusting must have occurred at the end of the Cretaceous and may represent a true Laramide event, before the emplacement of the Tertiary intrusive (TI) which may be Eocene in age.

In addition, the area was affected by at least two episodes of normal faulting (Figure 4).

PALEOGEOGRAPHIC AND TECTONIC IMPLICATIONS

The Lampazos succession is similar to the Aptian-Albian succession of the Chihuahua trough, and represents an intermediate paleogeographic element between the Bisbee basin and the deep-water facies of the Mexican seaway (Monreal and Longoria, 1999). In addition, the Lower Cretaceous sequence exposed in the Sierra Los Chinos area constitutes a connection with the stratigraphy of the Lampazos area and, therefore, is also related to the Chihuahua trough. Thus, the Sierra Los Chinos succession and the Lampazos sequence (Scott and González-León, 1991; Monreal and Longoria, 1999) are paleogeographically related to the Chihuahua trough and not directly to the Bisbee Group of Sonora. Their structural style is similar to the Chihuahua tectonic belt.

The Agua Salada and the Lampazos Formations of the Los Chinos area are lithologically similar and represent similar facies; however, the Espinazo del Diablo Formation of the Lampazos area is not present in the Los Chinos area,

Fig. 14. Generalized structural section A-A' across Sierra Los Chinos. KAS: Lower Cretaceous Agua Salada Formation; KLA: Lower Cretaceous Lampazos Formation; KVS: Upper Cretaceous volcanosedimentary unit; TV: Tertiary volcanic rocks.

Fig. 15. Generalized structural section B-B' across Cerro Caloso, Cerro Agua Caliente, and Cordón El Varal. KAS: Lower Cretaceous Agua Salada Formation; KLA: Lower Cretaceous Lampazos Formation; KLP: Lower Cretaceous Los Picachos Formation; KVS: Upper Cretaceous volcanosedimentary unit; TV: Tertiary volcanic rocks; Mbu: upper Baucarit Formation.

where the marine conglomerate of the Los Picachos Formation rests unconformably on the Lampazos Formation. Te clasts in this conglomerate were derived from the Espinazo del Diablo Formation. It represents a significant tectonic episode near the end of the Albian, suggesting that the area of Lampazos was an elevated block from which the Espinazo del Diablo rocks were eroded and transported a short distance into a shallow marine environment of the Los Chinos area. Toward the end of this tectonic episode carbonate marine conditions returned to the area as shown by rudist bioherms in the upper part of the Los Picachos Formation.

The compressional structures of the Los Chinos area are similar in deformational style to coeval rocks in Chihuahua, Coahuila and Nuevo León States, especially in the Chihuahua tectonic belt (Monreal, 1993; Monreal and Longoria, 1995). The Los Chinos area differs from the Chihuahua area in the presence of extensional structures formed during Basin and Range deformation.

CONCLUSIONS

The Aptian-Albian sequence in the Lampazos area is

Fig. 16. Panoramic view of Cerro Caloso looking east showing a recumbent syncline.

the result of a regional transgression from the proto-Gulf of Mexico into the Mexican seaway west-northwest into east-central Sonora. The Sierra Los Chinos sequence, related to the Lampazos succession, is a critical area for the paleogeographic reconstruction of the Lower Cretaceous Chihuahua trough, and the facies transition from the Chihuahua trough and the Mexican sea into the Bisbee basin.

The El Aliso, Agua Salada, Lampazos, Espinazo del Diablo, and Los Picachos Formations of east-central Sonora represent the western migration of a marine incursion from the proto-Gulf of Mexico. The Los Chinos area records a tectonic episode at the end of the Albian that may represent re-activation of strike-slip faulting related to tectonic transpression. Northern Mexico underwent tectonic transpression during and after Mesozoic time (Longoria, 1985, 1987, 1988, 1993, 1994; Monreal, 1989, 1990, 1993, 1996, Monreal and Longoria, 1995), this transpressional tectonism may have been active during Albian time and may be responsible for the development of elevated terrains along a strike-slip fault, that resulted in erosion and deposition of the limestone conglomerate at the base of the Los Picachos Formation.

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BIBLIOGRAPHY

GONZALEZ-LEON, C. M., 1988. Estratigrafía y geología estructural de las rocas sedimentarias cretácicas del área de Lampazos, Sonora: Univ. Nacional. Autónoma de México, Instituto de Geología, *Revista, 7, 2*, 148-162.

GONZALEZ-LEON, C. M., 1994. Early Cretaceous tectono-sedimentary evolution of the southwestern margin of the Bisbee Basin: *Revista Mexicana de Ciencias Geológicas, 11, 2*, 139-146.

GONZALEZ-LEON, C. M. and B. E. BUITRON, 1984. Bioestratigrafía del Cretácico Inferior del área de Lampazos, Sonora, México: Memoria III Congreso Latinoamericano de Paleontología, Universidad Nacional Autónoma de México, Instituto de Geología, 371-377.

GRIJALVA, A. S., 1991. Cartografía y estratigrafía de la región de Badesi, Municipio de Sahuaripa, Sonora: Gobierno de Estado de Sonora, Dirección General de Fomento Minero (unpublished report), 40 p.

GRIJALVA, A. S. and R. CUBILLAS, 1990. Geología del área de Sahuaripa: Gobierno de Estado de Sonora, Dirección General de Fomento Minero, unpublished report, 60 p.

GRIJALVA, A. S., M. A. FERNANDEZ and R. CUBILLAS, 1994. Estratigrafía y yacimientos minerales de la región de Badesi, Municipio de Sahuaripa, Sonora. Escala 1:50,000: Gobierno de Estado de Sonora, Dirección General de Fomento Minero and Centro de Estudios Superiores del Estado de Sonora, Publication No. 14 (unpublished report), 16 p.

HAYES, P. T, 1970. Cretaceous paleogeography of southeastern Arizona and adjacent areas: U.S. Geol. Survey Prof. Paper 658-B, 42 p.

HERRERA, S. and C. BARTOLINI, 1983. Geología del área de Lampazos, Sonora: Hermosillo, Universidad de Sonora, tesis profesional, 120 p.

LONGORIA, J. F., 1985. Tectonic transpression in the Sierra Madre Oriental, northeastern Mexico: an alternative model. *Geology, 13,* 453-456.

LONGORIA, J. F., 1987. Paleogeographic development of Mexico during the Cretaceous: *In:* J. M. Barbarín C., H. J. Gursky, and P. Meiburg (eds.), Simposio Internacional: El Cretácico de México y América Central, Resúmenes, Actas Fac. Ciencias Tierra, U.A.N.L., Linares, Nuevo León, 2, 177-190.

LONGORIA, J. F., 1988. Tectonic evolution of the western margin of Mexico: Geodynamics Research Institute Texas A & M Univ., Geodynamics Symposium, April 28-29, 1988, 34-37.

LONGORIA, J. F., 1993. La terrenoestratigrafía: un ensayo de metodología para el análisis de terrenos con un ejemplo en México: Boletín de la Asociación Mexicana de Geólogos Petroleros, XLIII, 2, 30-48.

LONGORIA, J. F., 1994. Recognition and characteristics of a strike-slip fault system in Mexico and its Mesozoic transpressional regime: implications in plate tectonics and paleogeographic reconstruction: Boletín del Departamento de Geología, Universidad de Sonora, 11, 1, 77-104.

LONGORIA, J. F., 1998. The Mesozoic of the Mexican Cordillera in Nuevo Leon, NE Mexico. *In*: Longoria, J.F., Krutak, P.R., and Gamper, M.A., eds., Geologic Studies in Nuevo Leon, Mexico: Sociedad Mexicana de Paleontología, A.C., Special Publication, July 5, 1998, p. 1-44.

MONREAL, R., 1989. Regional stratigraphic studies of the Lower Cretaceous in northern Mexico and the southern United States: Richardson, Texas, University of Texas at Dallas, Dissertation, 371 p.

MONREAL, R., 1990. Paleogeografía y tectónica del Cretácico Inferior del centro-norte de México: Centro de Estudios Superiores del Estado de Sonora, *Revista Vinculación, 2,* 15, 13-29.

MONREAL, R., 1993. Paleogeografía y tectónica de la cuenca de Chihuahua durante el Cretácico Inferior: Boletín del Departamento de Geología, Universidad de Sonora, 10, 1, 1-20.

MONREAL, R., 1995. Las facies marinas (Aptiano-Albiano) del Grupo Bisbee y cronocorrelabvas en Sonora: Boletín del Departamento de Geología, Universidad de Sonora, 12, 1, 65-78.

MONREAL, R., 1996. Cretaceous stratigraphy and structure of Sierra Grande, northeastern Chihuahua. *In:* Roldán, J., Jacques, C. and González C. (eds.), Studies of the Mesozoic of Sonora and Adjacent Areas: Geological Society of America, Special Paper 301, 167-178.

MONREAL, R. and J. F. LONGORIA, 1995. Transpressional deformational pattern related to basement faults in the mesozoic of northeastern Chihuahua: Boletín del Departamento de Geología, Universidad de Sonora, 12, 2, 17-34.

MONREAL, R., J. F. LONGORIA and V. A. VALENCIA, 1994a. Stratigraphic, structural and paleogeographic significance of the Aptian-Albian sequence in east-central Sonora, Mexico: Geological Society of America Abstracts with Programs, Vol. 26 No. 7, Annual Meeting, Seattle Washington, October 24-28, p. 501.

MONREAL, R., M. VALENZUELA and C.M. GONZALEZ-LEON, 1994b. A revision of the stratigraphic nomenclature for the Cretaceous of northern Sonora, and some paleogeographic implications: Boletín del Departamento de Geología, Universidad de Sonora, 11, 1, 171-190.

MONREAL, R. and J. F. LONGORIA, 1999. A revision of the Upper Jurassic and Lower Cretaceous stratigraphic

nomenclature for the Chihuahua trough, north-central Mexico: implications for lithocorrelations. *In:* Bartolini, C., Wilson, J., and Lawton T. (eds.), Mesozoic Sedimentary and Tectonic History of North-Central Mexico: Boulder, Colorado, Geological Society of America Special Paper 340, 69-92.

SOLANO-RICO, B., 1970. Geología y yacimientos minerales del distrito de Lampazos, Sonora: México D.F., Universidad Nacional. Autónoma de México, Facultad de Ingeniería, tesis profesional, 103p.

SCOTT, R. W. and C. M. GONZALEZ-LEON, 1991. Paleontology and biostratigraphy of Cretaceous rocks, Lampazos area, Sonora. *In:* Pérez-Segura, E. and Jacques-Ayala, C., eds., Studies of Sonoran Geology: Geological Society of America Special Paper 254, 51-67.

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