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Subsurface Mapping and Structural Elements of the Top Jurassic in Eastern Mexico (Poza Rica and Tampico Districts)

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ABSTRACT

The configuration of the top Jurassic is based on structural maps derived from oil-well data on the subsurface from the Poza Rica and Tampico regions, eastern Mexico. The maps are based on depths to the contact of the Pimienta and Lower Tamaulipas Formations at the Jurassic-Cretaceous boundary. Lithostratigraphic and chronostratigraphic data are from gamma-ray logs and ammonites, respectively. In the Poza Rica district, the La Mesa syncline was surveyed in the northwest, and the Sultepec homocline in the southeast. The depth to the top Jurassic varies from 2000 to 3700 m in the east and southeast of this region. An elongated area remained emergent during deposition of the Tithonian Pimienta Formation, along the present Gulf of Mexico coast east of Poza Rica, continuing to the southeast of the Tampico area. The Pimienta Formation was eroded in the southeast of Poza Rica along the initial cut of the San Andrés paleocanyon. In the Tampico district, the top of the Pimienta Formation is found from 1000 to 3000 m in depth. Two structures, the Tranquitas anticlinorium and the Tanquian anticlinorium, are observed in the northwest and central part of the Tampico district, respectively. Various areas remained emergent during deposition of this formation to the east and southeast of Tampico. They were part of an ancient continent composed of metamorphic and intrusive rocks, and upper Paleozoic continental origin. In the Bejuco region east of the Tampico district, two structures, the Piedra de Cal anticline and the Jabonera syncline, are observed; depth to the top Jurassic varies from 1400 to 3000 m, respectively. In this same region, two areas, Llano de Bustos and La Aguada, remained emergent during the upper Tithonian.

INTRODUCTION

Various subsurface stratigraphic studies of upper Tithonian rocks have been made for northeastern, eastern, and southeastern Mexico, because these are important petroleum exploration areas (Figure 1). These studies are based on gamma-ray logs from wells, ammonites, and microfossils, which provide knowledge

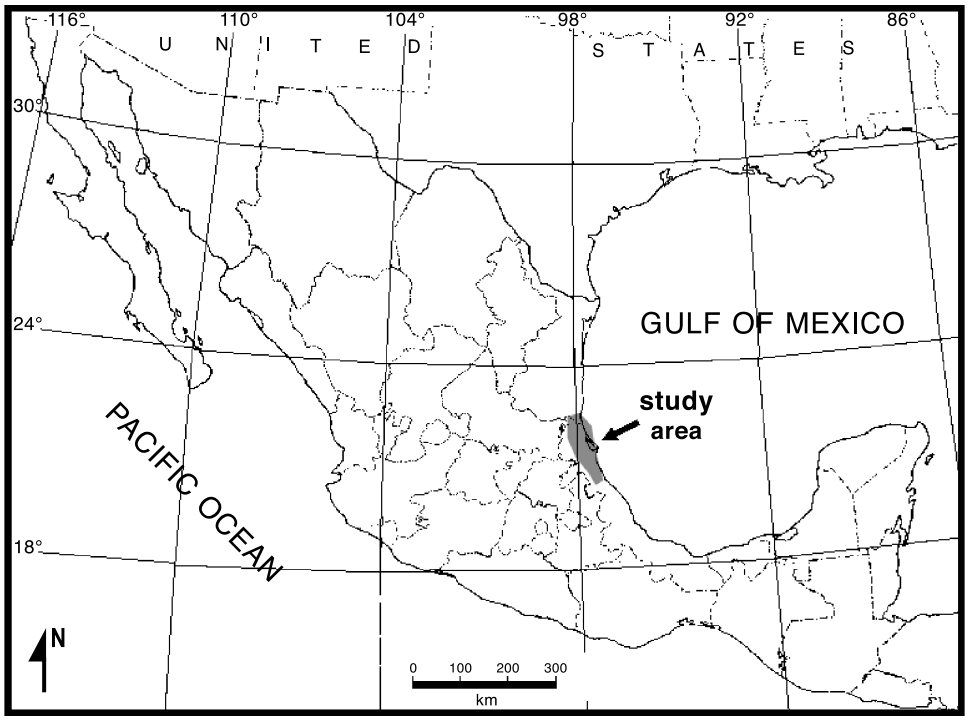

Figure 1. Location of the Tampico and Poza Rica districts of eastern Mexico.

of the regional distribution of rocks of this age and which characterize the Jurassic-Cretaceous boundary (Arkell, 1956; Burckhardt, 1930; Cantú-Chapa, 1982, 1987, 1989, 1992, 1999a, b, 2001a, b).

With these data, a stratigraphic correlation was established between gamma-ray logs and ammonites, providing a concordant contact between the Pimienta and Lower Tamaulipas Formations that corresponds precisely with the chronostratigraphic Jurassic-Cretaceous boundary. Ammonites are the only fossils capable of establishing precisely the age of the boundary, because of their limited biostratigraphic data (Cantú-Chapa, 1982, 1989, 1999b; Hillebrandt et al., 1992; Imlay, 1980; Imlay and Hermann, 1984; Judoley and Furrazola, 1968; Myczynski, 1999).

STRATIGRAPHIC PROBLEMS IN DETERMINING THE JURASSIC-CRETACEOUS BOUNDARY IN THE SUBSURFACE OF EASTERN MEXICO

The contact of the Pimienta and Lower Tamaulipas Formations is difficult to establish with certainty using only electric well logs. However, the contact between these formations has been identified correctly using gamma-ray curves. Likewise, the age of the contact of these two formations has been determined using ammonites more than with microfossils in wells in eastern Mexico (Cantú-Chapa, 1982, 1989, 1999b). This helps in drawing stratigraphic sections between various oil wells and in defining unconformities, hiatuses, and condensed sections in rocks of this age.

The following examples illustrate some cases of incorrect stratigraphy, which, on being resolved, permit the drawing of structural maps of the actual top Jurassic in two regions of eastern Mexico.

The Contact of the Pimienta and Lower Tamaulipas Formations (Jurassic-Cretaceous Boundary)

A recent comparison of electric logs (spontaneous potential, SP) and radioactivity logs (gamma ray) was performed on the Camaitlán-1 well, eastern Mexico, to determine the contact of the Pimienta and Lower Tamaulipas Formations at the Jurassic-Cretaceous contact (Cantú-Chapa, 1999b).

The two logs were expressed differently, which made it difficult to determine the depth of the contact between these formations. Whereas the SP curve is flat and does not define the contact, the gamma-ray curve shows clearly the abrupt change of lithology at the contact of these two formations. This type of problem has repercussions when the structural map of the top of a stratigraphic unit is drawn.

Stratigraphic problems similar to this occur when using only SP logs to characterize the Pimienta-Lower Tamaulipas formations contact in the Poza Rica and Tampico regions. Significant differences are observed in each type of log with regard to the depth assigned to the contact of these two formations.

Figure 2 shows a stratigraphic correlation of the contact of the Pimienta and Lower Tamaulipas Formations based on gamma-ray logs for wells from the central Poza Rica district. Gamma-ray logs characterize carbonate rocks and shaley limestones better than SP logs.

A dark, heavy, horizontal line at each well shows the proposed contact identified on SP logs from previous studies of wells northwest of Poza Rica. The SP log does not establish clearly the Pimienta–Lower Tamaulipas contact; furthermore, it proposes incorrect depths for this stratigraphic event. This problem affects the

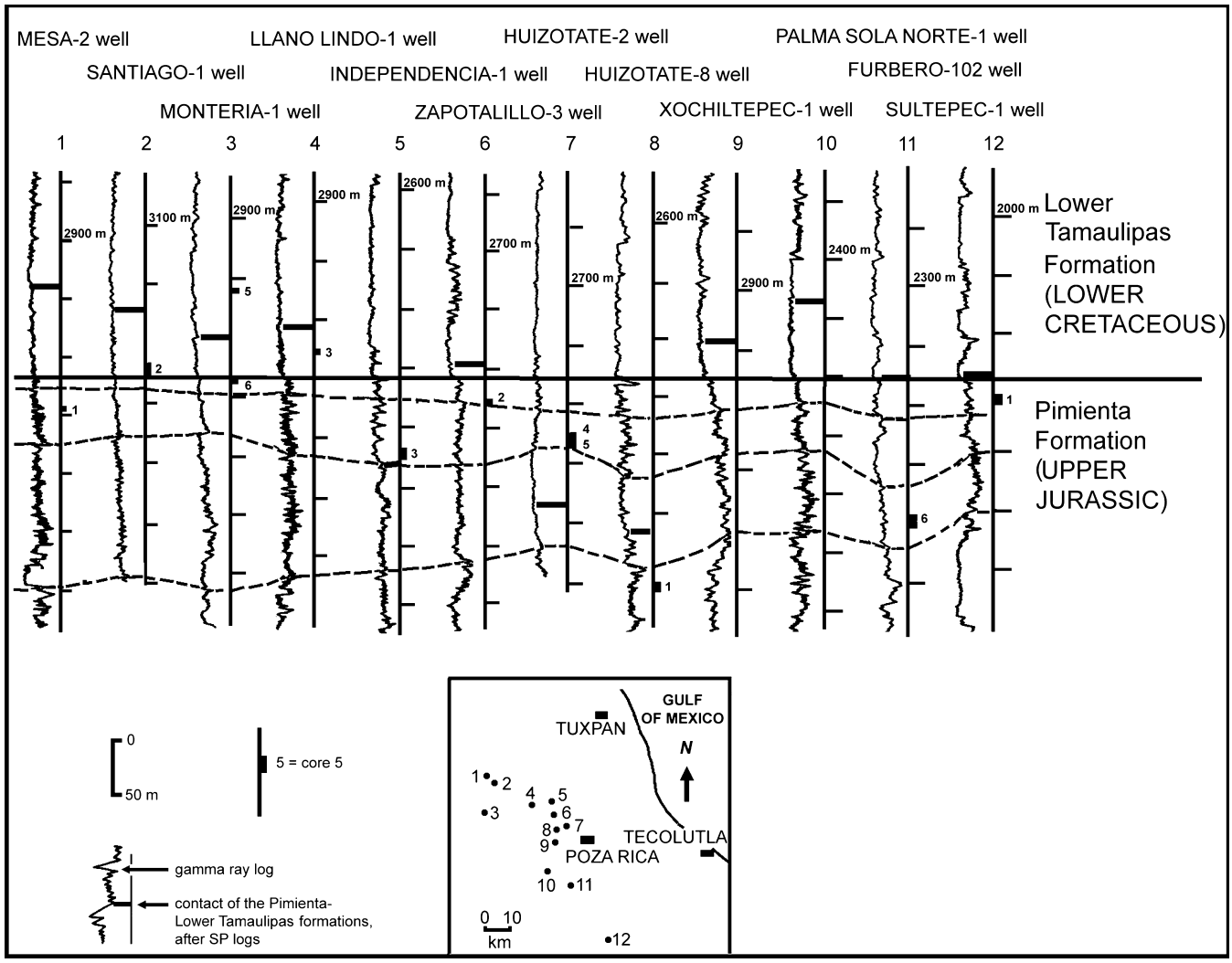

Figure 2. **Stratigraphic cross section of the contact between the Pimienta and Lower Tamaulipas Formations, based on gamma-ray curves from wells north of Poza Rica, eastern Mexico. Datum: Jurassic-Cretaceous boundary.**

accuracy of structure maps drawn on the top Jurassic (Figure 2).

Age of the Transgressive Sedimentary Sequence at the Jurassic-Cretaceous Boundary

The onlap of sedimentary sequences deposited close to or at the Jurassic-Cretaceous boundary is often overlooked in the subsurface stratigraphy of Mexico. The age of the onlap varies over short distances. Four neighboring areas show this variation where sediments were deposited over basement in the Tampico district, eastern Mexico. The marine sedimentary sequence initially onlapped metamorphic rocks in the Barcodon-102 well. Calcarenites of the San Andrés member of the Tamán Formation represent the base of a transgressive cycle; these rocks, in turn, were covered by a thin section of Pimienta Formation. Both units are Tithonian. In the Mantarraya-1 well, the onlap began with a thin section of the Tithonian Pimienta Formation deposited over red beds (Figure 3).

In the Topila-105 and Los Mangles-1 wells, onlap began at the base of the Cretaceous with micritic limestones of the Lower Tamaulipas Formation. This formation was deposited over metamorphic rocks and Cahuasas Formation red beds (Figure 3).

Other, similar cases were described recently in wells from eastern Mexico; there, the onlapping rocks were deposited over different types of nonsedimentary rocks over short distances (Cantú-Chapa, 2001a). In these cases, emergent areas are inferred at the Jurassic-Cretaceous boundary. Emergent areas are the remnants of an ancient continent.

Condensed Sections

In various cases, the thickness variation of a lithostratigraphic unit reveals condensed sections. Detailed

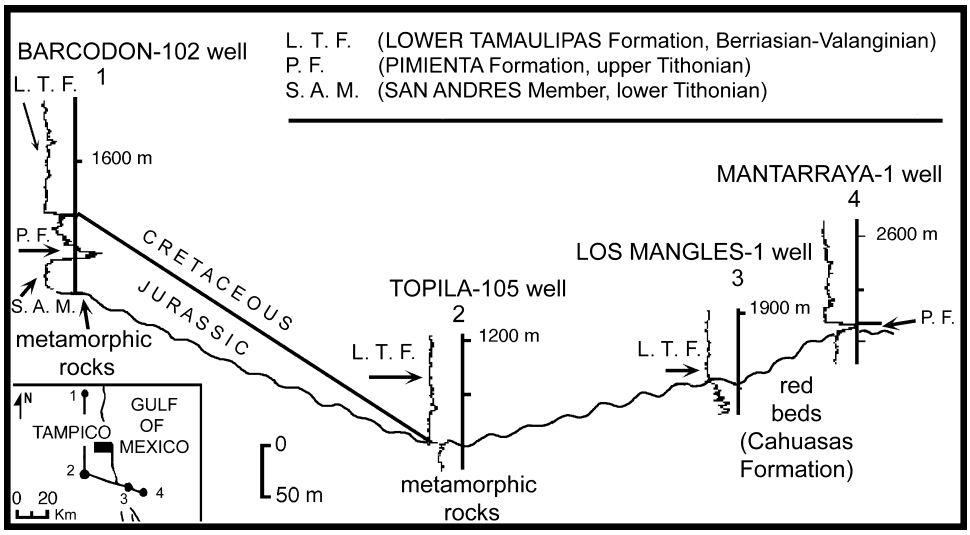

Figure 3. **Stratigraphic cross section of formations at the Jurassic-Cretaceous boundary in wells near Tampico, eastern Mexico, based on gamma-ray curves. Datum: Jurassic-Cretaceous boundary.**

biostratigraphy permits identification of a stratigraphically complete but thin lithostratigraphic unit and its respective depositional setting. Examples include the condensed Pimienta Formation in the Poza Rica district (Cantú-Chapa, 1992, 1999a, 2001a).

The stratigraphic section A-A′ in Figure 4 shows the Pimienta Formation and its contacts. The section is oriented southwest-northeast and is approximately 30-km long; it consists of gamma-ray logs of five wells located northwest of Poza Rica. The greatest thickness of the Pimienta Formation is approximately 150 m in the Castillo de Teayo-6 well. The Pimienta Formation is shown as a condensed section 40-m thick in the Pasarela-1 well east of the Poza Rica district (Figure 4).

The condensed deposition event of the Pimienta Formation is related to presence of the underlying calcarenite San Andrés Member of the Tamán Formation. This member is present in the northwestern, eastern, and southeastern Poza Rica district. In those areas, the Pimienta Formation is invariably characterized as a condensed section (Figures 4 and 5) and its contact with the San Andrés Member is abrupt, as is observed on the gamma-ray curves (Cantú-Chapa, 1992). Calcarenites of the San Andrés Member were deposited on a platform and could represent a depositional regulating element. Both units are of Tithonian age.

The contact of the shaley limestone of the Pimienta Formation with the micrites of the Lower Tamaulipas Formation (Lower Cretaceous) also is abrupt, as observed in gamma-ray curves of the condensed sections of that formation southeast of Poza Rica (Figure 5).

Identifying a Hiatus Caused by Submarine Erosion in the Subsurface of Poza Rica

The stratigraphic and regional identification of a hiatus related to submarine erosion of a sedimentary series explains the presence of the San Andrés paleocanyon in southeastern Poza Rica (Figure 6).

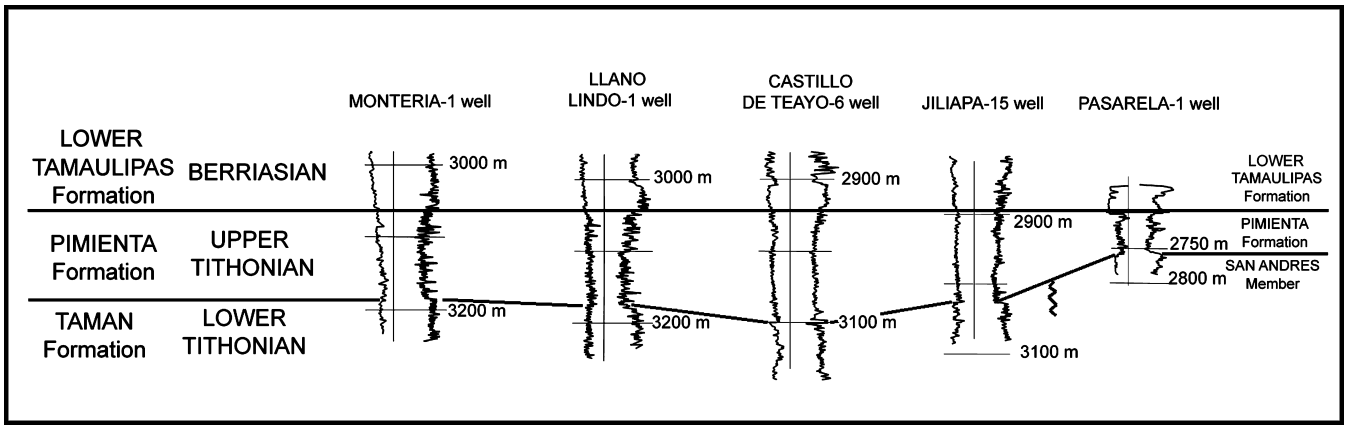

Figure 4. **Stratigraphic cross section of the Tithonian Pimienta Formation in wells northeast of Poza Rica based on radioactivity logs. Datum: contact between the Pimienta and Lower Tamaulipas Formations. The location of the section A-A′ is shown on Figure 6.**

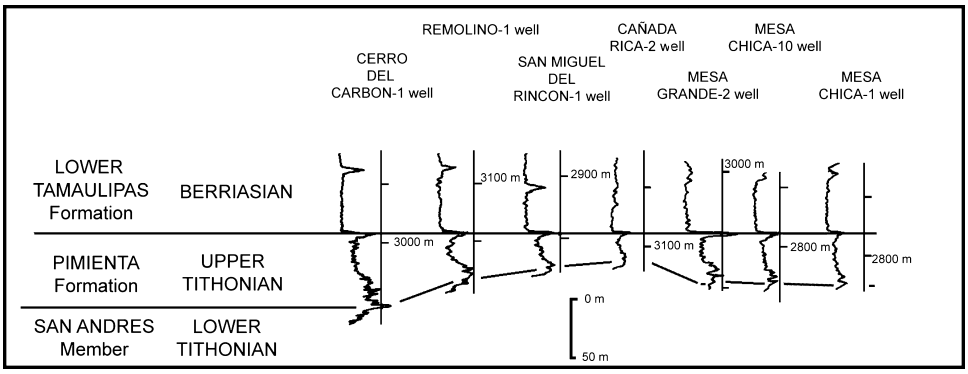

Figure 5. Stratigraphic cross section of the Tithonian Pimienta Formation in wells southeast of Poza Rica based on gamma-ray logs. Datum: contact between the Pimienta and Lower Tamaulipas Formations. The location of section B-B′ is shown on Figure 6.

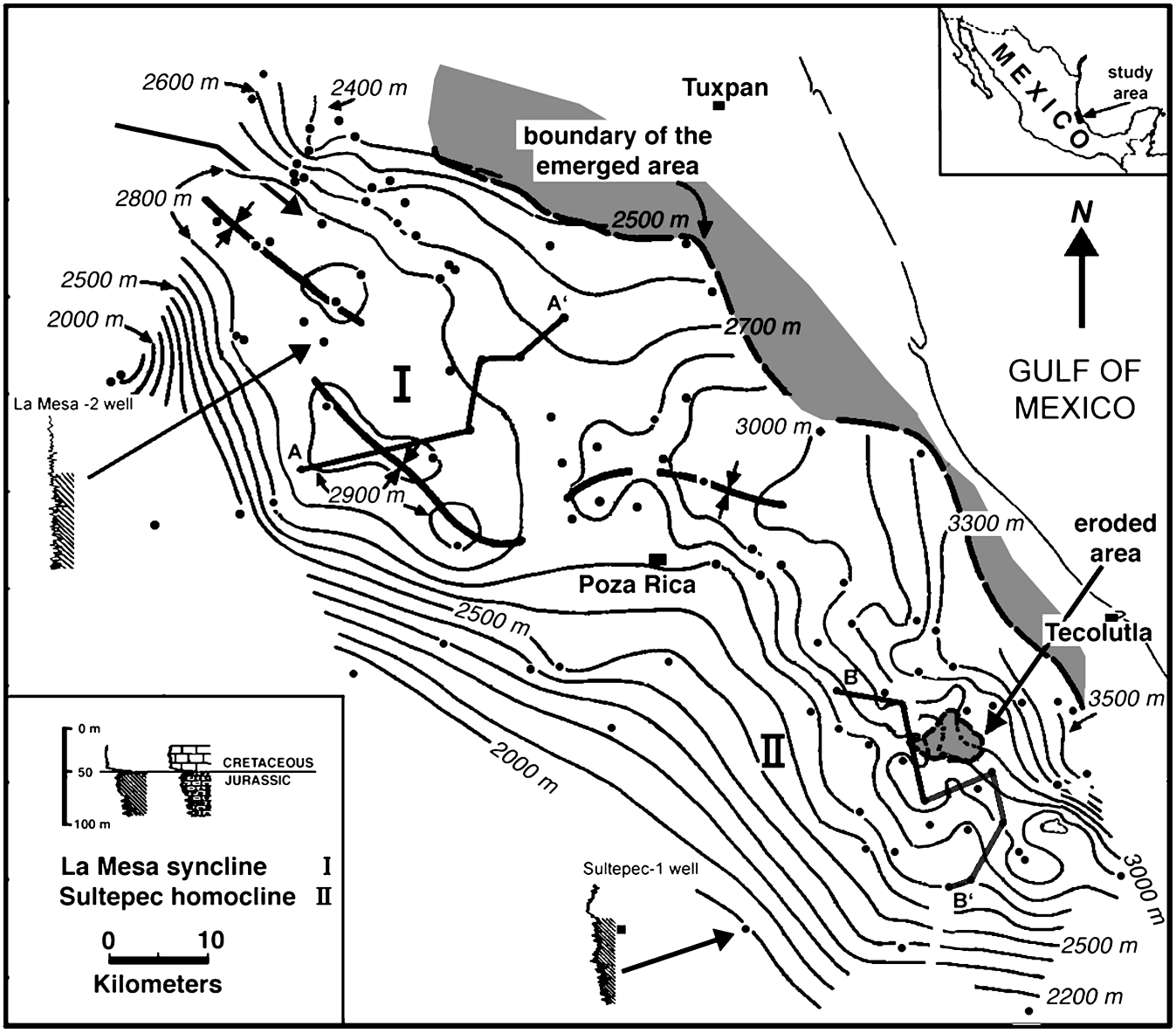

Figure 6. Structural map of the top Jurassic (Pimienta Formation) in the subsurface of the Poza Rica district, eastern Mexico. The map is based on well control, and shows the locations of the A-A′ and B-B′ cross sections.

The structural map of the Pimienta Formation in the Poza Rica district shows the location of the basal part of this paleocanyon of upper Tithonian age (Cantú-Chapa, 2001b) (Figure 6).

Delineating Areas Emergent During the Tithonian of Eastern Mexico

To create a structural map of a stratigraphic unit, one also must consider areas that remained emergent during deposition of the marine sediments being studied. In the three structural maps that will be described, areas emergent until the Tithonian are delineated; their configuration is based on oil wells in the Tampico and Poza Rica regions of eastern Mexico.

The data were digitized so that they might be plotted automatically as structural maps. These maps show the structural behavior of the top Jurassic and the absence of marine sediments of this age in limited areas. This last paleogeographic event occurred as a result of some areas remaining emergent; that is, deposition of marine sediments of this age was impeded.

In the region southeast of Poza Rica, one observes the absence of upper Tithonian sediments because of subaqueous erosion. This stratigraphic event represents the beginning of the development of the San Andrés paleocanyon. The area in which this paleogeographic structure is seen was increased with erosion of Cretaceous sediments until the aforementioned paleocanyon was formed (Cantú-Chapa, 1985, 2001b).

EROSION/NONDEPOSITION OF THE UPPER TITHONIAN PIMIENTA FORMATION

The Pimienta Formation: Lithology and Age

The Pimienta Formation consists of alternating clayey limestones and shales, with lenses of bentonite dominant at the top. Southeast of Poza Rica, this unit contains sandy biomicrite at the top (Mesa Grande-2 well, core 5). The formation is absent by erosion in a large part of the San Andrés and Hallazgo fields. The gamma-ray curves allow establishment of the contact between the Pimienta and overlying Tamaulipas Lower Formations (Figures 4 and 5).

Ammonites of the genus *Suarites*, *Durangites*, *Corongoceras*, *Dickersonia*, and *Salinites* dominate near the top of the Pimienta Formation. These characterize the upper Tithonian (Cantú-Chapa, 1971, 1976, 1989, 1992, 1999b). These genera also have been encountered in other regions of Mexico and in Cuba (Imlay, 1980; Myczynski, 1999).

POZA RICA

The Poza Rica district lies in the Veracruz petroleum province of eastern Mexico and covers a surface area of 8000 km^2. It is situated on the Gulf of Mexico coastal plain between the Sierra Madre Oriental and the Gulf of Mexico shoreline (Figures 1 and 6).

Various stratigraphic studies of the Jurassic-Cretaceous boundary and of the Huasteca series (Middle and Upper Jurassic) have been accomplished in the subsurface of the Poza Rica district, eastern Mexico, using radioactivity logs and fossils. The previous studies show, in stratigraphic sections, the distribution of ammonites across this boundary, the condensed sections of the Pimienta Formation, and erosion of this formation southeast of Poza Rica. Ammonites have a specific distribution across the Jurassic-Cretaceous boundary, whereas microfossils (calpionellids and nanoconnids) are inconsistent in their distribution across this geologic event (Cantú-Chapa, 1969, 1976, 1982, 1989, 1992, 1999b, 2001a).

A contribution to these stratigraphic studies is shown here on the structure map of the top upper Tithonian of the Poza Rica district (Figure 6). This map represents a compilation of biostratigraphic and lithostratigraphic data from 56 wells in this region of eastern Mexico. The figure shows the regional structure of rocks at the top of the Jurassic, the absence of sediments due to submarine erosion in a limited area southeast of Poza Rica, and a lack of deposition of sediments of this age in the eastern part of the region, which parallels the present coastline and corresponds to an ancient continent.

Erosion and Nondeposition

An important paleogeographic event characterizes the Pimienta Formation southeast of Poza Rica. The formation was eroded there by a submarine process; this represents the beginning of a great erosional episode that also affected Cretaceous sediments. The geographic outline during the upper Tithonian corresponds to an approximately triangular area with sides 30-km long. The area increased until formation of the San Andrés paleocanyon was formed, with erosion of Cretaceous sediments. This unconformity has implications for Upper Jurassic petroleum deposits in the region southeast of Poza Rica (Cantú-Chapa, 1992, 1999a, 2001b).

Another important paleogeographic characteristic of the Pimienta Formation during the upper Tithonian is observed in an elongate area parallel to the present coastline east of Poza Rica. This area was not

covered by marine sedimentation until the Early Cretaceous (Cantú-Chapa, 1992) (Figure 6).

Structural Elements

The structural map of the top Pimienta Formation shows two important structures: the La Mesa syncline in the northwest, and the Sultepec homocline southeast of Poza Rica (Figure 6).

The axis of the La Mesa syncline is oriented west-northwest–east-southeast; here, the top Pimienta surface is at a maximum depth of 2900 m below sea level. The average depth is 2400 m on the northeast flank and 2000 m on the southwest flank. The relief is between 500 and 900 m between the two flanks and the structural axis. The axis is divided into three parts along its 80-km length. The eastern section of the axis, north of the city of Poza Rica, is oriented west to east and is between 2800 and 3000 m deep.

The Sultepec homocline is a prominent structure located southeast of Poza Rica. Upper Tithonian–age sediments plunge east with an inclination averaging 50 m/km. Based on oil wells, the maximum known depth to top Tithonian is 3500 m in the southeast of Poza Rica. This contrasts with the maximum depth of 2000 m to top-Tithonian penetrated southwest of Poza Rica.

TAMPICO

In the Tampico district, various stratigraphic studies have been done on the Jurassic-Cretaceous boundary (Cantú-Chapa, 1976, 1982, 1989, 2001a, b). Also, the evolution of marine sediments has been analyzed from the Callovian to the top Tithonian. An uplift event that influences the stratigraphy of the region has been recognized in these studies; it reveals areas that remained emergent until the Early Cretaceous, and, therefore, were not covered by the late Tithonian sea. This uplift event might correspond to late indications of the breakup of the western margin of Pangea, from which developed the Gulf of Mexico (Cantú-Chapa, 2001a).

Some stratigraphic and structural sections were generated using well data that correlate the Upper Jurassic sedimentary series. They show the local absence of Tithonian sediments (Cantú-Chapa, 1987, 1999a, 2001b).

In the Tampico district, the Pimienta Formation has the same sedimentary characteristics as in the Poza Rica district. The presence of thin bentonite beds in shaley limestones causes the gamma-ray curve to deflect strongly to the right (Cantú-Chapa, 1976, 1989). This formation is also expressed locally as a condensed section. In some wells, it is barely 5-m thick (Mantarraya-1) (Figure 3); in others, it can be as much as about 200-m thick.

Emergent Areas

Construction of the map in Figure 7 required 120 wells covering 28,000 km^2 of eastern Mexico. Various areas remained emergent during deposition of the Tithonian Pimienta Formation; the geographic distribution of these areas is shown in Figure 7.

Four rock types comprise the subcrop to the Late Jurassic and they are distributed in belts south of Tampico, almost parallel to the coastline (Figure 7). A large area, about 100-km long by 30- to 50-km wide, just along the coastline, remained emergent until the earliest Cretaceous. This area consisted of exposed metamorphics, intrusives, and red beds; it represented an ancient continent that remained emergent during deposition of the Pimienta Formation. Only one well in the northwest of Tampico shows the presence of upper Paleozoic rocks at the subcrop. Another well in the southwest shows the presence of Lower Jurassic sediments at the subcrop of this region (Cantú-Chapa, 2001a).

Structural Elements

The top of the Jurassic, corresponding to the top of the Pimienta Formation, was encountered in wells to the northwest of Tampico at depths as shallow as 800 m, where the Tranquitas anticlinorium, oriented northeast-southwest and approximately 80-km long, is present. The name refers to the Tranquitas-1 well. A second structure, the Tanquian anticlinorium, located in the central part of the Tampico district, is oriented northwest-southeast, is approximately 90-km long, and has a crest at 1500 m. The name refers to the Tanquian-1 well. In the coastal plain area, the top Jurassic reaches its maximum depth of 2500 m (Figure 7).

Bejuco Area

A detailed study of the Bejuco area in the Tampico district provides a structural map of the top Jurassic (Figure 8). Three structures dominate this area. The Piedra de Cal anticline, located in the southwest of the Bejuco area, is oriented northeast-southwest, is approximately 40 km long, and has a crest at 1600 m.

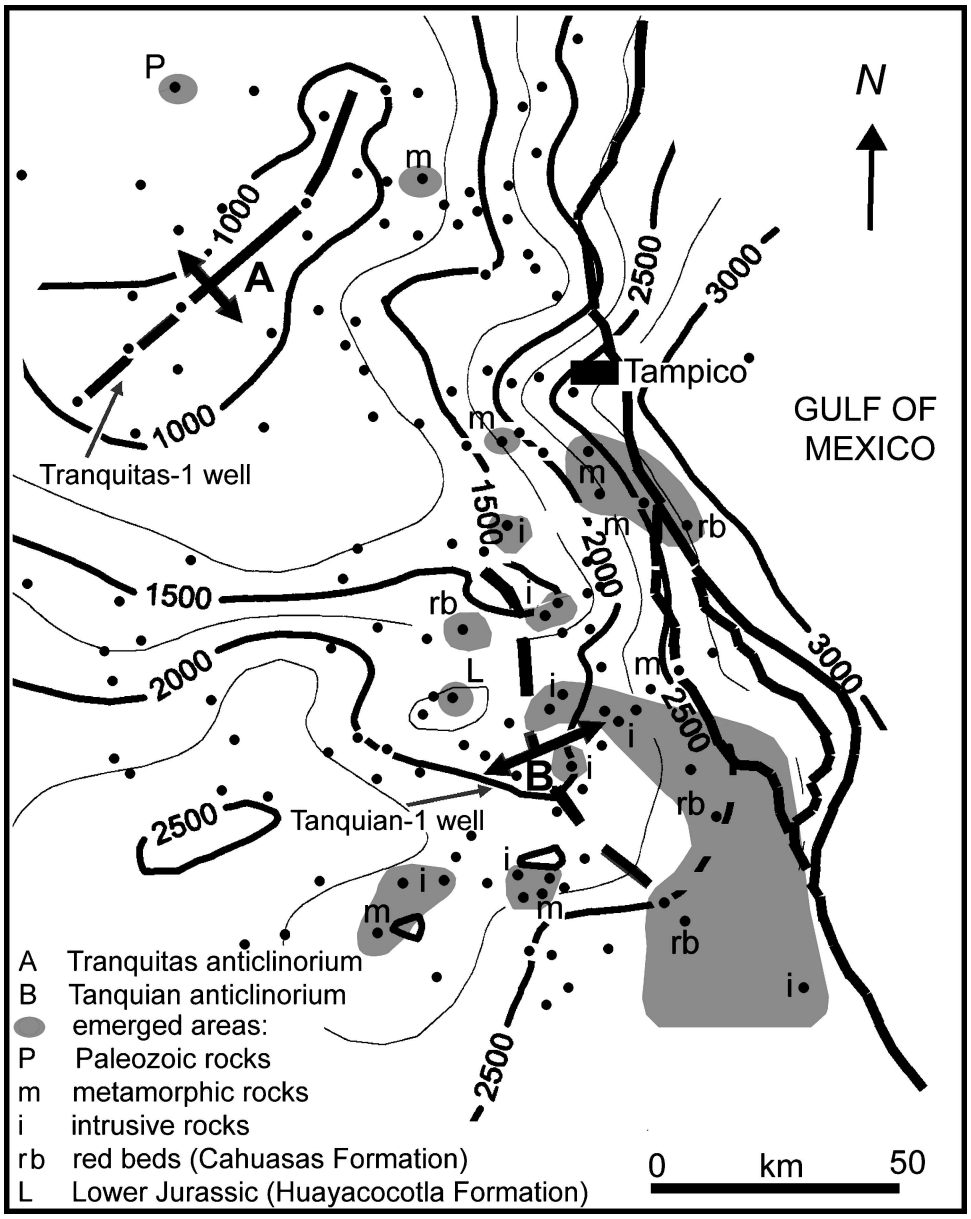

Figure 7. **Structural map of the top Jurassic (Pimienta Formation) in the subsurface of the Tampico district, eastern Mexico. The map is based on well control and shows the location of various emerged areas during the deposition of the Pimienta Formation.**

This structure continues to the north and is interrupted by the appearance of nonsedimentary rocks. The Jabonera syncline is located southeast of the Bejuco area. The axis of this syncline is oriented southwest-northeast, and is about 20 km long, with a maximum depth of 3000 m in the east and a minimum depth of about 2400 m in the west. A system of faults defines the Bejuco field in the center of the area. In this same region, two areas remained emergent during the upper Tithonian: (1) Llano de Bustos consists of continental rocks, metamorphics, and intrusives that cover an elongate area extending approximately 40 km southwest-northeast (2) the La Aguada area south of the Bejuco region is formed by intrusive rocks that were not covered by the upper Tithonian sea (Figure 8).

CONCLUSIONS

The structural configuration of the top Jurassic represents a contribution to the study of the regional geology of the subsurface of eastern Mexico. It shows structures not previously recognized that represent a regional stratigraphic uplift event. Representing the structures correctly requires consideration of well data, including gamma-ray logs and ammonite zonation. These maps take into account paleogeographic elements that remained emergent during deposition of the Tithonian Pimienta Formation such as metamorphics, intrusives, and rocks of continental origin. These Late Jurassic emergent and isolated areas represent remnants of the western margin of Pangea in eastern Mexico and were finally transgressed in the Early Cretaceous. One important stratigraphic element southeast of Poza Rica is an area of submarine erosion of the upper Tithonian. This represents the initial stage of a major erosional event, continuing in the Cretaceous, until the San Andrés paleocanyon was formed in this region of eastern Mexico (Cantú-Chapa, 2001b).

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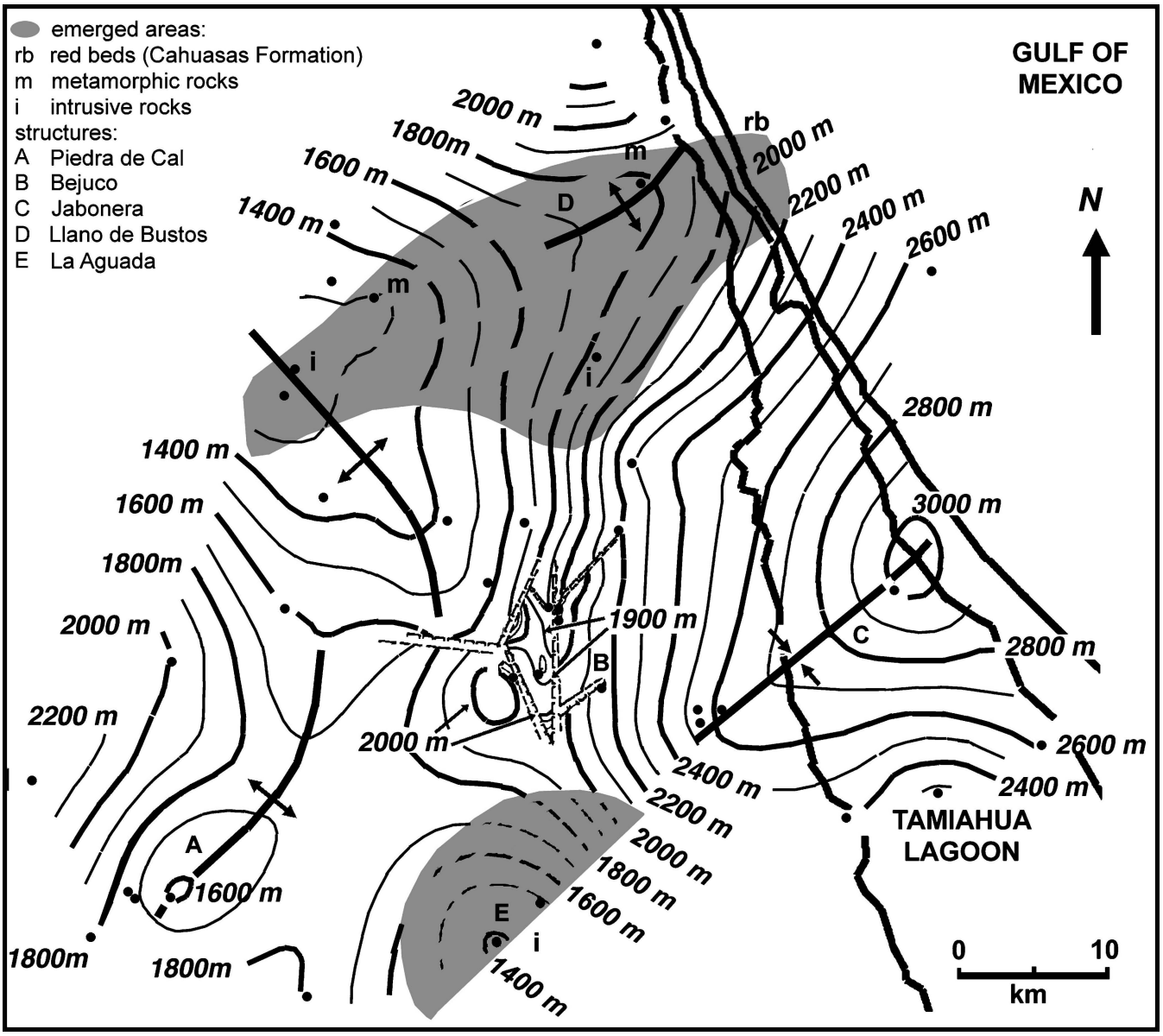

Figure 8. **Structural map of the top Jurassic (Pimienta Formation) in the subsurface of the Bejuco region, southern Tampico district, eastern Mexico. The map is based on well control and shows the location of various emerged areas during the deposition of the Pimienta Formation.**

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REFERENCES CITED

Arkell, W. J., 1956, Jurassic Geology of the World: Edinburgh-London, Oliver and Boyd Ltd., 806 p.

Burckhardt, C., 1930, Etude synthetique sur le Mesozoïque mexicain. Mémoire de la Societé Paleontologique Suisse, v. 49–50, 280 p.

Cantú-Chapa, A., 1969, Estratigrafía del Jurásico Medio-Superior del subsuelo de Poza Rica, Ver. (Area de Soledad-Miquetla): Revista del Instituto Mexicano del Petróleo, v. 1, no. 1, p. 3–9.

Cantú-Chapa, A., 1971, La Serie Huasteca (Jurásico Medio-Superior) del Centro Este de Mexico: Revista del Instituto Mexicano del Petróleo, v. 3, no. 2, p. 17– 40.

Cantú-Chapa, A., 1976, El contacto Jurásico-Cretácico, la Estratigrafía del Neocomiano, el Hiato Hauteriviano Superior-Eoceno Inferior y las amonitas del pozo Bejuco 6 (Centro-Este de México): Boletín de la Sociedad Geológica Mexicana, v. 37, p. 60–83.

Cantú-Chapa, A., 1982, The Jurassic-Cretaceous Boundary in the subsurface of Eastern Mexico: Journal of Petroleum Geology, v. 4, no. 3, p. 311–318.

Cantú-Chapa, A., 1985, Is there a Chicontepec Paleocanyon in the Paleogene of eastern Mexico?: Journal of Petroleum Geology, v. 8, no. 4, p. 423–434.

Cantú-Chapa, A., 1987, The Bejuco Paleocanyon (Cretaceous-Paleocene) in the Tampico District, Mexico: Journal of Petroleum Geology, v. 10, no. 2, p. 207–218.

Cantú-Chapa, A., 1989, Precisiones sobre el límite Jurásico-Cretácico en el subsuelo del Este de México: Revista de la Sociedad Mexicana de Paleontología, v. 2, no. 1, p. 26–69.

Cantú-Chapa, A., 1992, The Jurassic Huasteca Series in the subsurface of Poza Rica, Eastern Mexico: Journal of Petroleum Geology, v. 15, no. 3, p. 259–282.

Cantú-Chapa, A., 1999a, Two unconformable stratigraphic relationships between Upper Jurassic redbeds, and marine sequences in northeastern and eastern Mexico subsurface: Geological Society of America Special Paper 340, p. 1–5.

Cantú-Chapa, A., 1999b, Confrontation of stratigraphic methods to define the Jurassic-Cretaceous boundary in eastern Mexico subsurface: Geological Society of America Special Paper 340, p. 93–103.

Cantú-Chapa, A., 2001a, Mexico as the Western Margin of the Pangea Based on Biogeographic Evidence from the Permian to the Lower Jurassic, *in* C. Bartolini, R. T. Buffler, and A. Cantú-Chapa, eds., The western Gulf of Mexico Basin: Tectonics, sedimentary basins, and petroleum systems: AAPG Memoir 75, p. 1–27.

Cantú-Chapa, A., 2001b, Paleocanyons in the subsurface of eastern Mexico: Facts and uncertainties, *in* C. Bartolini, R. T. Buffler, and A. Cantú-Chapa, eds., The western Gulf of Mexico Basin: Tectonics, sedimentary basins, and petroleum systems: AAPG Memoir 75, p. 421–430.

Hillebrandt, A. von, P. Smith, G. E. G. Westermann, and J. H. Callomon, J. H., 1992, Ammonite zone of the Circum-Pacific region, *in* G. E. G. Westermann, ed., The Jurassic of the Circum-Pacific: Cambridge, Cambridge University Press, p. 247–272.

Imlay, R. W., 1980, Jurassic paleobiogeography of the conterminous United States in its continental setting: United States Government Printing Office, Washington, U. S. Geological Survey Professional Paper 1062, 134 p.

Imlay, R. W., and G. Hermann, 1984, Upper Jurassic ammonites from the subsurface of Texas, Louisiana and Mississippi. Gulf Coast Section Society for Sedimentary Geology (SEPM) Foundation, Third Annual Research Conference, Proceedings, p. 149–170.

Judoley, C. M., and B. G. Furrazola, 1968, Estratigrafía y fauna del Jurásico de Cuba: Instituto Cubano de Recursos Minerales, 126 p.

Myczynski, R., 1999, Some ammonite genera from the Tithonian of western Cuba and their paleobiogeografic importance: Krakow, Studia Geologica Polonica, v. 114, p. 93–112.