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Validation of the Stratigraphic Method to Build Tithonian (Jurassic) Subsurface Structural Maps, Campeche Shelf, Southern Gulf of Mexico

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ABSTRACT

Stratigraphic interpretation of gamma-ray logs and identification of ammonites from the Kix 1A and Pich 1 wells confirm the existence of the Sinan-Mison syncline in the Campeche Shelf, southern Gulf of Mexico. The structural configuration of the syncline was determined once the contact between the Edzna-Akal formations was established at the Jurassic–Cretaceous boundary on the basis of depth data from wells in the region.

Subsurface data (1) yield new insights into the stratigraphic and structural position of the contact between the Edzna and Akal formations, which have great petroleum potential and (2) validate the certainty of the methodology applied.

The systematic study of specimens *Aspidostephanus* sp., *Cuyaniceras* sp., and cf. *Corongoceras* sp. from the Kix 1A and Pich 1 wells are characteristic of the Tithonian and the Berriasian. This is the first known occurrence of Berriasian ammonites in the subsurface of southern Mexico.

INTRODUCTION

Ammonites are the most important but scarce fossils used in dating Upper Jurassic strata from wells drilled in southeastern Mexico. The precise depth and age of the sequences from where the conventional cores containing the ammonites were collected are established through (1) the systematic study of those fossils, (2) their restricted stratigraphic distribution, and (3) gamma-ray logs.

Deformed and fragmented ammonites coming from deeper depths in the Kix 1A and Pich 1 wells are hard to identify. These specimens should not be thrown away because they yield ages of older beds that can be used in chronostratigraphic studies.

GEOLOGICAL BACKGROUND

This work represents a number of projects conducted by the author in several regions of southeastern Mexico over the years. These investigations began with the study of upper Tithonian ammonites from the Chac 1 and 2 and Tunich 1 wells (Cantú-Chapa, 1977, 1982).

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The genera *Salinites*, *Durangites*, *Parodontoceras*, and *Protancyloceras* are characteristic of the late Tithonian in Mexico, Cuba, and Louisiana, and they represent the same paleogeographic conditions at the top of the Jurassic (Cantú-Chapa, 1982, 1989; Imlay, 1980; Imlay and Hermann 1984; Myczynski, 1999).

The identification of these fossils permitted the dating of the formations and contacts in the southeastern region of Mexico. In the same way, the combination of gamma-ray logs and ammonites from oil wells has been used in stratigraphic and structural studies in several regions of Mexico (Cantú-Chapa, 1992).

In this study, the stratigraphic data were digitized to construct two structural maps at the top and base of the Tithonian in the Campeche Shelf. The objective was to prove the presence of the same structures in both maps (Cantú-Chapa and Ortuño-Maldonado, 2003).

In the southern Gulf of Mexico, the top of the Edzna Formation ranges from 1850 to 5500 m (6069 to 18,045 ft) below sea level. The Tithonian age of this formation was established with ammonites from several offshore oil wells. The structural maps of the Tithonian Edzna Formation were built using paleontologic and biostratigraphic data, as well as the gamma-ray log. The latter curve was used to determine the precise depth at which cores containing the specimens were collected.

Tithonian Stratigraphy of Campeche

Strata of this age were penetrated by all wells in the southern Gulf of Mexico. The Tithonian Edzna Formation generally consists of mudstone and calcareous, bentonitic shale, which is underlain and overlain by dolomitized limestone units. This formation had previously been divided in three members (Angeles-Aguino and Cantú-Chapa, 2001).

The transitional contact between the Akal (Lower Cretaceous) and Edzna (Tithonian) formations is characterized by a displacement to the right of the gamma-ray curve caused by the calcareous and bentonitic content of the shale.

The contact between the Edzna and Akimpech (Kimmeridgian) formations records a displacement to the right by left of the gamma-ray curve caused by a change in lithology of the Akimpech, which consists of microcrystalline dolomites (Angeles-Aguino and Cantú-Chapa, 2001; Cantú-Chapa and Ortuño-Maldonado, 2003). Commonly, this contact reflects abrupt changes of lithologies.

Structural Maps of the Tithonian Edzna Formation in the Campeche Shelf

Two structural maps depict the most well known regional structures affecting this formation: (1) the Ceeh-Cantarell anticlinorium in the northeast, (2) the Sinan-Mison syncline in the center, and (3) the May-Okan anticline in the south (Figure 1a).

The Sinan-Mison syncline is 70 km (43 mi) long and strikes west–east. In this structure, the top of the Edzna ranges from 3283 to 5594 m (10,771 to 18,353 ft) (Cantú-Chapa and Ortuño-Maldonado, 2003).

Studied ammonites come from conventional cores collected from the Pich 1 and Kix 1A wells, which are located along the flanks of the syncline (Figure 1b). These specimens define the Jurassic–Cretaceous boundary (Edzna and Akal contact). The specimens are identified as *Aspidostephanus* sp., *Cuyaniceras* sp., and *Corongoceras* sp. The first two genera correspond to the late Berriasian, and the last one is of late Tithonian age.

The stratigraphic data yielded by the ammonites are comparable to those previously used to construct two Tithonian maps in the same region of Mexico (Cantú-Chapa and Ortuño-Maldonado, 2003).

Comparison of Berriasian and Tithonian Subsurface Stratigraphic and Structural Data

The Pich 1 and Kix 1A wells were drilled in the Sinan-Mison syncline. Both wells penetrated the transitional contact between the Akal and Edzna formations at different depths. The contact in both wells is characterized by a displacement of the gamma-ray curve toward the left (Figure 1b).

Aspidostephanus sp. and *Cuyaniceras* sp. were obtained from core 1 at the interval 5415–5424 m (17,766–17,795 ft) in the Kix 1A well. Both genera of the upper Berriasian had only been recognized in Argentina (Steuer, 1897; Leanza, 1945; Wright et al., 1996). The presence of these specimens in Mexico will yield new insights into the biostratigraphic and paleogeographic relationships between the two regions.

One specimen assigned as cf. *Corongoceras* sp. was obtained from core 3 at the interval 4520–4529 m (14,829–14,859 ft) in the Pich 1 well. This genus has been reported from the upper Tithonian of Argentina, Austria, Cuba, Spain, Madagascar, Mexico, and Rumania (Klein, 2005).

The specimens of *Aspidostephanus* sp. and *Cuyaniceras* sp. are 175 m (574 ft) above the contact between the Edzna and Akal formations in the Kix 1A well (core 1), whereas the specimen of *Corongoceras* was obtained at the contact between the same formations in the Pich-1 well (Figure 1b).

Structural Observations

The new stratigraphic data, along with the structural data, were used to build the top of the Tithonian map in the Campeche Shelf (Cantú-Chapa and Ortuño-Maldonado,

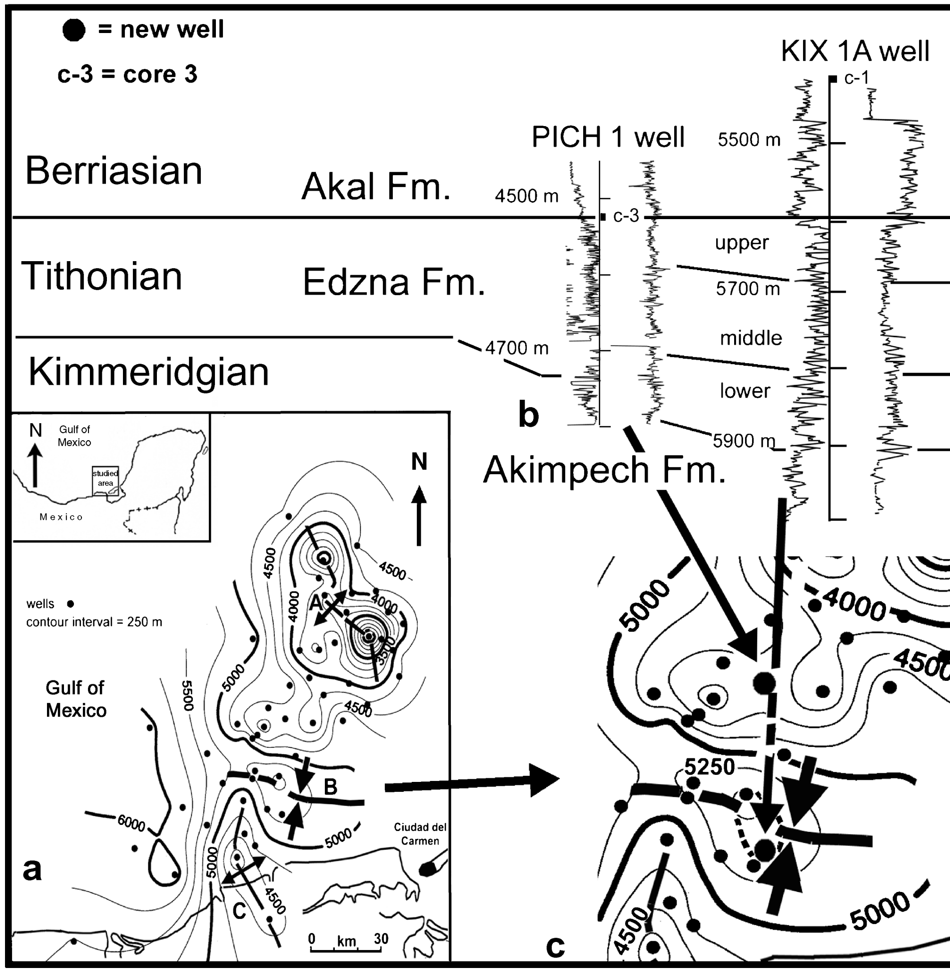

FIGURE 1. (a) Upper Tithonian structural map in the Campeche Shelf. (b) Gamma-ray logs showing the Akal-Edzna contact and core depths. (c) Sinan-Mison syncline and location of the Pich 1 and Kix 1A wells. Dotted lines indicate the new structural value along the axis of the structure.

2003). In addition, biostratigraphic data and radioactive well logs (gamma ray) support the mapping elements.

The exact structural position of the new stratigraphic data in both wells is confirmed in the original map, confirming thus, the validity of the methodology applied to build the top Tithonian map (Cantú-Chapa and Ortuño-Maldonado, 2003). The new subsurface data from both wells are located in the flanks of the Sinan-Mison syncline.

The Pich 1 well was drilled in the north flank of the Sinan-Mison syncline in a local structure perpendicular to the syncline axis. The structural position of the ammonite obtained (4520–4529 m, 14,829–14,859 ft) from the Tithonian–Cretaceous contact (Akal-Edzna formations) corresponds to the north flank of the Sinan-Mison syncline. At the well site, the new structural value changes from 4500 to 4530 m (14,764 to 14,862 ft), which is meaningless at the regional scale at which the map was built.

However, the contact between the Akal-Edzna formations changes from 5250 to 5500 m (17,224 to 18,045 ft) in the Kix 1A well. Berriasian ammonites obtained from the interval 5415–5424 m (17,766–17,795 ft) show that these fossils are 170 m (558 ft) above the Tithonian–Cretaceous contact, and thus, their position does not alter the originally proposed structural configuration (Cantú-Chapa and Ortuño, 2003). The precision of the new structural data documented for both wells coincides or is very close to the data used to build the original map. Thus, the Berriasian ammonites from the Kix 1A well are the deepest occurrences of these specimens in Mexico.

CONCLUSIONS

The results of this investigation demonstrate that an appropriate use of paleontology, stratigraphy, and well-log data are adequate to build subsurface structural maps.

New stratigraphic and structural information from two wells in the Campeche Self validates the mapping results previously achieved for this region, confirming the correctness of the methodology applied in earlier studies (Cantú-Chapa, 1982; Cantú-Chapa and Ortuño, 2003).

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SYSTEMATIC PALEONTOLOGY

Family Aspidoceratidae Zittel (1895)

Subfamily Simoceratinae Spath (1924)

Genus *Aspidostephanus* Spath (1925)

Type species

Holcostephanus (*Astieria*) *depressus* Steuer (1897).

Discussion

Aspidostephanus is known from the Berriasian of Argentina after an old description and illustration (Steuer, 1897; see Wright et al., 1996). *Aspidostephanus* is assigned here to the family and subfamily mentioned above by its evolute shell, which is ornamented with simple, large, and widely spaced ribs, and by its suture line with S1 rectangular, large base, and superficial subdivisions.

The latter structure characterizes the Subfamily Simoceratinae instead of the Subfamily Spiticeratinae, which was previously assigned by Wright et al. (1996) and Klein (2005).

Aspidostephanus sp. (Figure 2a, b)

Description

Small, evolute, and planulate shell with plain flanks; shallow umbilicus with inclined and low wall; and a row of long, large, slightly lateral nodes, inclined forward born freely at the internal part of the flank and separated by space as large as them. The ventral region, whorl cross section, and suture line are unknown.

Discussion

The two small, evolute, and fragmented specimens have well-preserved lateral sides. The specimens resemble the Argentine *Aspidostephanus depressus* (Steuer, 1897) by their evolute shell, shallow umbilicus, and simple, large, and separated lateral and long nodes, but the Mexican specimens differ by the lateral nodes that occur in the middle part of the flank instead of the ribs that characterize the Argentinian form.

Material

Two small and fragmented specimens. Kix 1A well, core 1 (5415–5424 m, 17,766–17,795 ft). IPN-1113-1114, respectively.

Age

Upper Berriasian: lower part of the Akal Formation.

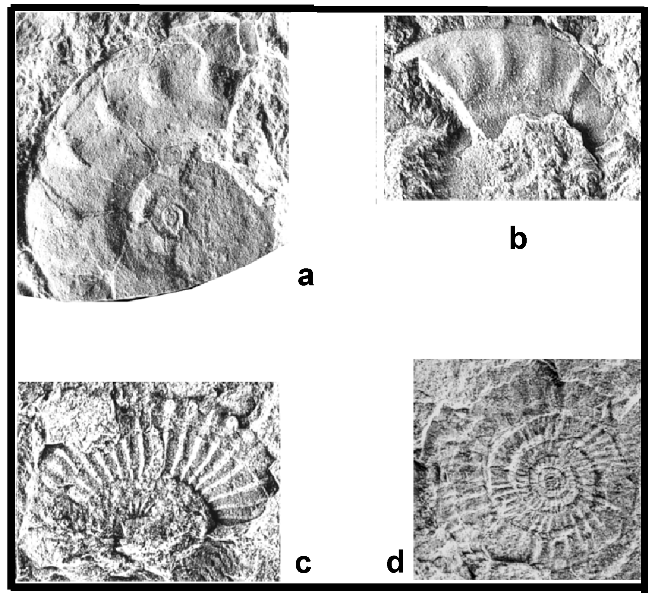

FIGURE 2. (a, b) *Aspidostephanus* sp.; (c) *Cuyaniceras* sp.; (d) cf. *Corongoceras* sp. All specimens with lateral view. (a–c) From the Kix 1A well (core); (d) from the Pich 1 well, Campeche Shelf, southern Gulf of Mexico. The scale for all specimens is ×2. Specimens are coated with ammonium chloride. (a, b) IPN-1113-1114; (c) IPN-1115; (d) IPN-1116.

Family Neocomitidae Salfeld (1921)

Genus *Cuyaniceras* A. F. Leanza (1945)

Type species

Odontoceras transgredians Steuer (1897); SD by Arkell (1952).

Cuyaniceras sp. (Figure 2c)

Description

Flat and evolute shell with fine, simple, and slighty flexuous ribs that are separated by larger interspaces, ending in small ventrolateral tubercles.

Discussion

This genus is from Argentina group species with evolute shell and fine and simple ribs, some of them branching from the umbilical margin. Our Mexican specimens resemble *Corongoceras raripartitum* (Steuer) *in* Leanza (1945, pl. 13, figure 3, p. 56) by its evolute shell and by its simple ribbing ending in ventrolateral tubercles. By the poor state of preservation, these specimens are assigned as genus level.

Material

Two fragmented specimens. Kix 1A well, core 1 (5415–5424 m, 17,766–17,795 ft). IPN-1115.

Age

Cuyaniceras characterizes the upper zone with *Spiticeras damesi* of the Berriasian from Argentina (Leanza, 1945).

Family Himalayitidae Spath (1925)

Genus *Corongoceras* Spath (1925)

Type species

Corongoceras lotenoense Spath (1925)

cf. *Corongoceras* sp. (Figure 2d)

Description

Very evolute and planulate shell, with a shallow umbilicus; it is ornamented with fine, simple, rectiradiate, evenly spaced primary ribs born freely at the umbilical edge. Ribs at unevenly spaced intervals and bifurcate alternate with simple ribs in the internal whorls. The ventral region is unknown.

Discussion

This crushed specimen with very evolute coiling and simple, radial ribs bears considerable resemblance to *Corongoceras cordobai* Verma and Westermann (1973, p. 248, pl. 52, figures 4, 5) from the upper Tithonian of Real de Catorce, central Mexico.

A piece of the preserved flank of this specimen is unidentifiable.

Material

One fragmented specimen. Pich 1 well, core 3 (4520–4529 m, 14,829–14,859 ft). IPN-1116.

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