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Paleokarst in the Marginal Cretaceous Rocks, Gulf of Mexico

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ABSTRACT

Some El Abra Formation carbonate reservoirs produce from fractured and brecciated rocks resulting from paleokarstic events.

The western margin of the Gulf of Mexico front of the Sierra Madre Oriental exposes Albian-Cenomanian rocks of the El Abra Formation. In the Actopan Platform, these outcrops allow the study of the paleokarst development in peritidal rocks. Included in the karst are dissolutional, depositional, fracturing, brecciation, and collapse features. *Toucasia* wackestone beds of restricted-marine lagoonal to intertidal environment overlay the paleokarst.

Similar events also occur in subsurface Albian-Cenomanian carbonate rocks around the Gulf of Mexico: Jordan Knoll (eastern Gulf of Mexico) and San Marcos and Cordoba Platforms (northwestern and western Gulf of Mexico).

Some of the paleokarsted rock intervals have been studied only by space-core samples or by geophysical methods (Jordan Knoll). The Actopan Platform rocks allow an Albian-Cenomanian model to be developed and to be compared to similar rocks around the Gulf of Mexico.

INTRODUCTION

Mexican Cretaceous carbonate rocks have been prolific hydrocarbons producers from different sedimentary facies since early in the 20th century. Oil production began in Mexico in 1904 after discovery of the Tampico-Misantla Geologic Province (Cruz and Meneses, 1998). Since then, oil fields have been discovered in the following Cretaceous carbonate provinces: Sabinas Basin, Tampico-Tuxpan Basin, Cordoba Platform, Tabasco-Chiapas, and the Campeche Provinces.

Production and oil shows have come from stratigraphic traps (Sabinas), basinal fractured carbonates (Panuco-Ebano), platform reefal rocks, and forereef debris and turbidites (Tampico-Tuxpan Basin, Golden Lane Platform, Cordoba Platform, Cactus-Sitio Grande Area, and the Campeche-Yucatan Platform) (Santiago et al., 1984, p. 1–36).

Paleokarst features in Mexican oil fields were first noted in exploration of the El Abra Limestone in 1916. The Pemex drilling report for the Cerro Azul well # 4, drilled in that unit, noted that the blowout in that well "threw pieces of stalactites into the air" (Viniegra et al., 1970, p. 316).

PURPOSE OF THE PRESENT STUDY

The present study has the following aims: (1) to document the presence of an important episode of karst formation in the Cretaceous El Abra Formation along the Actopan Platform, (2) to correlate or relate the subaerial exposure and development of the karst with other analogous and equivalent subsurface events around the Gulf of Mexico, and (3) to suggest the possibility of some other geologic areas

with suspected dissolution-collapsed system development that deserve future study.

KARST FEATURES

Terminology used by Mexican and American geologists to describe dissolution features in the El Abra Limestone has varied considerably. This nomenclature includes terms such as: ''limestone caverns'' (Viniegra et al., 1970), ''karstic erosion lithofacies'' (Carrasco, 1971), ''subaerial exposure (karst development)'' (Coogan et al., 1972), ''karstic collapse, cavern formation'' (Wilson, 1975), ''episodes of exposure, karst surface'' (Aguayo, 1978), ''karst topography, karst caverns'' (Enos et al., 1983), and ''karst formation, subaerial exposure surfaces, microkarst, karst event'' (Minero, 1988).

In the following discussion, the subsurface karst features in the Cretaceous rocks of Mexico are presented first. Coogan et al. (1972) studied 400 m of core from 14 wells: 10 in the Poza Rica trend and 4 on the Golden Lane Platform. They attributed the high and variable porosity and permeability to subaerial erosion (karst development) of the El Abra Limestone. They also presented evidence of surface exposure during the latest Cretaceous or earliest Tertiary, and they postulated that the Golden Lane Platform was tilted down toward the west during the Tertiary. However, they did not report any petrographic or macroscopic paleokarst features in samples of the four wells of the El Abra Limestone from the Golden Lane Platform.

A stratigraphic equivalent of the El Abra Limestone is present in the subsurface of the western margin of the Gulf of Mexico. One of the Mesozoic plays in the Cordoba Platform (Veracruz Basin) was described by Martínez et al. (2001) as karstic rock in the Orizaba Limestone (Albian-Cenomanian), but there is no description of the features in the subsurface samples.

On the border between the Chiapas-Tabasco area, in the southwestern margin of the Gulf of Mexico, Varela et al. (1997) studied the Middle Cretaceous (Albian-Cenomanian) rocks of Artesa–Mundo Nuevo Platform. They described an event in the tectonic evolution of the area in which there was a ''destruction of the platform during the pre-Late Eocene uplifting and erosion. This produced the unconformity at the Iris area, putting the Middle Cretaceous and Upper Eocene deposits in contact.'' In their Figure 1, an area of erosion is shown that is approximately 85 km long and 20 km wide.
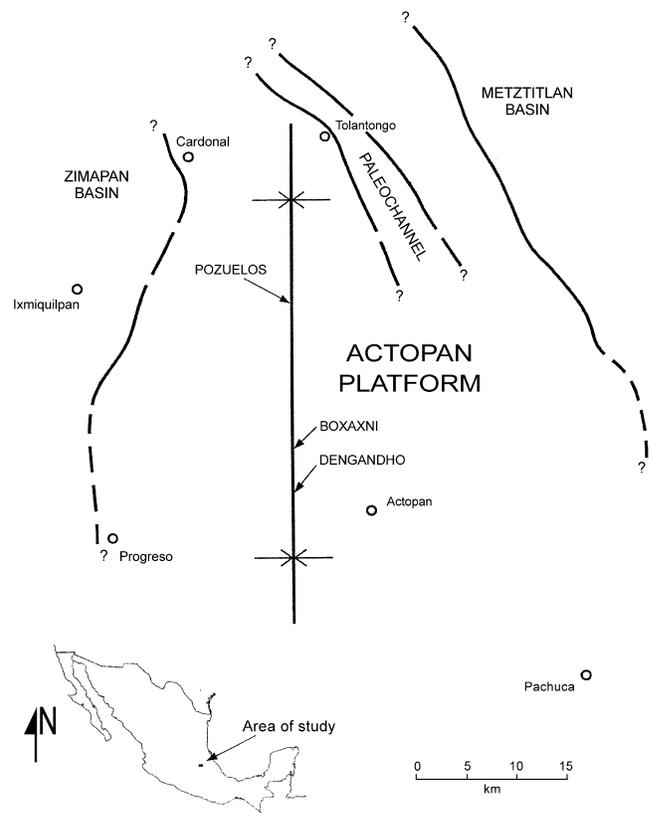

Figure 1. Albian-Cenomanian paleogeography of Actopan Platform with El Abra Formation and the basinal facies. There is a south-north syncline, and at the side of the structure are located the outcrops of Dengandho, Boxaxni, and Pozuelos sections.

However, they present no description of samples or other lithologic evidence.

At the surface, the El Abra Formation outcrops in the type locality had been studied by many geologists. Kellum (1930) described the ''miliolina phase'' and the ''Taninul phase.'' Muir (1936) followed Kellum's concepts and proposed another term, ''mixed facies,'' for the fore-reef deposits. Both facies are described on the basis of lithologic and paleontologic attributes of the two members of this formation (Taninul and miliolina). The first detailed and specific study was made by Aguayo (1978, p. 87, 96, 106, 110). The study included sedimentary environments, diagenetic characteristics, geochemistry, and detailed stratigraphy. He found that the reef complex was exposed and a karst surface formed during the Coniacian-Santonian and later was covered with Upper Cretaceous pelagic sediments. Aguayo also stated: ''in the final emergence of the platform during later periods of exposure, the limestones were extensively and non selectively dissolved, creating karst topography, and the remaining voids were partially filled

with vadose sediment, collapse breccias, and by drusy and blocky, sparry calcite cements.''

Enos et al. (1983, p. 13, 32, 73) in a fieldtrip guide book to the type locality of the El Abra Limestone in the Valles–San Luis Potosí Platform, indicated that the most spectacular oil fields in Mexico are those of the Golden Lane Trend, and the ''production in these wells was apparently from karst caverns at the summit of reef limestone bordering the Golden Lane atoll.'' They described some discontinuity surfaces as ''minor breaks in the sedimentary record, chiefly intraformational...'' including erosional and non-depositional hiatuses. Enos et al. (1983) make five observations that suggest that dissolution at the microkarst surfaces lowered the general surface only slightly: (1) surfaces form low-relief horizons, (2) correlation between quarries does not indicate convergence or divergence of surfaces, (3) microkarst is largely restricted to subaerial lithofacies, (4) karsted subaerial limestones are of similar thickness to non-karsted subaerial limestones, and (5) solution residues and paleosols are largely lacking. In addition, they note that average solution for microkarst formation in tropical and subtropical climates ranges from 5 to 100 mm/1000 years, varying largely in response to temperature and rainfall differences. The paleogeographic position of the type locality of the El Abra Formation in the Valles–San Luis Potosí Platform (15–25° N), the presence of rudist reefs, the abundance of solution porosity, and the microkarst horizons themselves are evidence of a warm, humid climate. Minero (1988) has the same description of the features as Enos et al. (''supratidal flats resulted in microkarst''). All the evidence given by Enos et al. (1983) and Minero (1988) certainly indicate the development of a ''microkarst'' but not of extensive paleokarst or paleocaves (in the sense of Wright, 1982; Esteban and Klappa, 1983; Esteban and Wilson, 1993; Choquette and James, 1988; Wilson et al., 1992; Kerans, 1989, 1993; Loucks and Hanford, 1992; and Loucks, 1999) developed in some Paleozoic or Mesozoic strata, or even in the Proterozoic (Kerans and Donaldson, 1988).

The subsurface Edwards Formation (Griffith et al., 1969, p. 121 and 123, Figures 3 and 6) of Texas, in the northwestern margin of the Gulf of Mexico, is a close stratigraphic and lithologic equivalent of the El Abra Formation. The rudist-reef facies, subtidal-platform facies, tidal-flat facies, and supratidal facies of the two formations are almost identical in sedimentary patterns and in fossil content. With respect to paleokarst, the Edwards Limestone is a prolific water resource (Edwards aquifer) in south-central Texas. Hovorka et al. (1996, p. 3, 15, 31, 33, 39, 43, 47, and 57) have shown that there was post-depositional alteration in the Edwards Group, which they attributed to prolonged subaerial exposure. They showed evidence from two cores of a karstic unconformity at the top of the Edwards Group beneath the Georgetown Formation. They stated that ''burrow-filling sediment may have been preferentially leached by meteoric water during exposure and then infilled with Georgetown sediment.'' In another paper, also related to the Edwards Group, Hovorka et al. (1998, p. 30) noted that the major episode of karstification occurred during development of a fresh-water aquifer in the post-Miocene to Holocene episode. Actually, there were two major periods of karstification in the Edwards Group, according to the concepts described by Hovorka et al. (1996, 1998), one in the upper Albian–lower Cenomanian and the other in the post-Miocene to Holocene.

REGIONAL GEOLOGIC SETTING

Part of Mexico during the Cretaceous was a major carbonate province with several shallow-water platforms. Wilson (1975, p. 325–328) presented a good review of all the regional facies around the Gulf of Mexico. He explained that this carbonate province is a result of the extensive Albian and Cenomanian marine transgression that prevented influx of terrigenous clastics from western North America. The distribution of known banks in Central Mexico include the Toliman, El Doctor, Actopan, Valles–San Luis Potosí Platforms, Faja de Oro (Golden Lane), and the Cordoba Platform.

The Actopan Platform is located at the southeastern end of the Valles–San Luis Potosí Platform (Carrillo, 1971). The basement is a paleogeographic unit formed of rocks of Precambrian, Paleozoic, and Triassic age built by the Permian-Triassic Orogeny. Marine transgression of the platform had begun by the Kimmeridgian and continued during the Cretaceous, culminating in the great carbonate banks of the Albian-Cenomanian.

In 1970–1972, Pemex geologists, along with the author, performed a detailed study (unpublished) of much of the stratigraphic section of the carbonate rocks of the Valles–San Luis Potosí Platform. They found that sedimentation in the Actopan area showed a specific sedimentary pattern distinct from that of other parts of the large platform; because of this, they

proposed that the region be designated the "Actopan Platform" (Figure 1). This platform is located between the mining district of Zimapan and the town of Actopan. The sedimentologic characteristics of this area have been discussed by some authors, including Wilson (1975, p. 324, 327, and 328). The platform was formally defined by Carrasco (1971, p. 5–6).

Carrasco (1971) described the Albian-Cenomanian carbonate strata on the carbonate platform. The lithofacies consist of breccias and turbidites, bioclastic grainstone, rudist boundstone, pellet packstone, miliolid wackestone, oolitic grainstone, and dolomitic supratidal mudstone; karstic erosional features also were described. Only the El Abra Limestone is exposed in the Actopan Platform; it has a measured thickness of 2098 m. (Carrillo, 1971, mentioned thicknesses of 1500 to 2000 m; in the Golden Lane platform, Guzmán, 1967, described a thickness of 2000 m; Wilson, 1975, described the total thickness of El Abra Formation as nearly 3000 m). In the Zimapan Basin and the El Doctor reef, the Upper Cretaceous Soyatal Formation appears. To the north and northwest of the present platform, calcareous-terrigenous basinal rocks of the Santuario and Trancas Formations of Neocomian and Upper Jurassic occur below the El Abra Formation.

The Cretaceous (Albian-Cenomanian) carbonate rocks of the El Abra Formation in Actopan (Figure 1) were deposited on a carbonate platform bounded to the northwest by the Zimapan Basin. In the north-central part of the basin is a small paleochannel, and to the northeast is located the Metztitlan Basin. The southern and northern limits of the Actopan Platform are covered by Tertiary volcanic rocks.

Outcrops of paleokarst horizons in the platform are located along a north-south syncline (Figure 1) and are exposed at three localities: Dengandho (south), Boxaxni (south-central), and Pozuelos (north). These localities are separated from one another (from south to north) by 5.5 km (Dengandho-Boxaxni) and 17.6 km (Boxaxni-Pozuelos). The stratigraphic thicknesses (Figure 2) of the karst intervals are: Dengandho 160 m, Boxaxni 143 m, and Pozuelos 142 m. The Dengandho section is the best of these localities in which to observe the paleokarst features.

STRATIGRAPHY OF THE KARST INTERVAL

In the worldwide stratigraphic column there are well-documented examples of paleokarst in the Proterozoic (Kerans and Donaldson, 1988), Cambro-Ordovician (Loucks and Hanford, 1992; Wilson et al., 1992, 1993), Silurian (Kahle, 1988), Mississippian (Sando, 1988), Lower Carboniferous (Wright, 1982), Permian (Craig, 1988), and Jurassic (Vera, et al., 1988). In the Lower Cretaceous rocks of Italy, Soudet et al. (1994) studied karstification of Oligocene to Miocene carbonate rocks. In contrast, examples of subsurface karst features in Cretaceous (Albian-Cenomanian) carbonate rocks around the world are rare.

Based on paleontologic studies done by Petróleos Mexicanos and the Instituto Mexicano del Petróleo, Carrillo-B. (1971, p. 40) assigned an Albian-Cenomanian age to the El Abra Limestone rocks of the western, central, and eastern areas of the Valles–San Luis Potosí Platform in the Sierra Madre Oriental Geographic Province. He assigned the same Albian-Cenomanian age to the platform carbonate rocks of the province of Altiplano Mexicano, where part of the Actopan Platform is located.

Carrasco (1970) also assigned an Albian-Cenomanian age to the El Abra rocks in his lithostratigraphic review of the characteristics of the El Abra Formation in the Valles–San Luis Potosí Platform, and he considered the El Doctor Formation, in the isolated El Doctor Platform, to be a time and lithologic equivalent of the El Abra Formation.

It is important to understand that the paleokarstic features of rocks of the El Abra Limestone of the Actopan Platform are the result of exposure of these carbonate platform rocks for a short time, possibly less than a million years. They were later covered by sediments of Albian-Cenomanian age, deposited under restricted-marine to lagoonal or intertidal conditions. The El Abra outcrops of the Actopan Platform resemble units described by Martínez et al. (2001) and Hovorka et al. (1996), and the event described by Schlager (1991, 1992). In other areas, Coogan et al. (1972), Aguayo (1978), and Varela et al. (1997) presented another interpretation of the timing of karst formation. They postulate that dissolution and karst formation occurred in the Upper Cretaceous and Tertiary, after deposition of the El Abra Limestone and equivalent platform rocks in Chiapas-Tabasco.

The Cretaceous period possibly embraced the warmest intervals in earth history (Frakes and Francis, 1990), as indicated by distribution of climate-dependent rock types and fossil flora and fauna and by oxygen-isotope paleotemperature measurements. A peak of warmth occurred in the Albian. The decline in evaporites and the distribution of coal deposits indicate that the Cretaceous period was considerably more humid than the arid late Jurassic period.
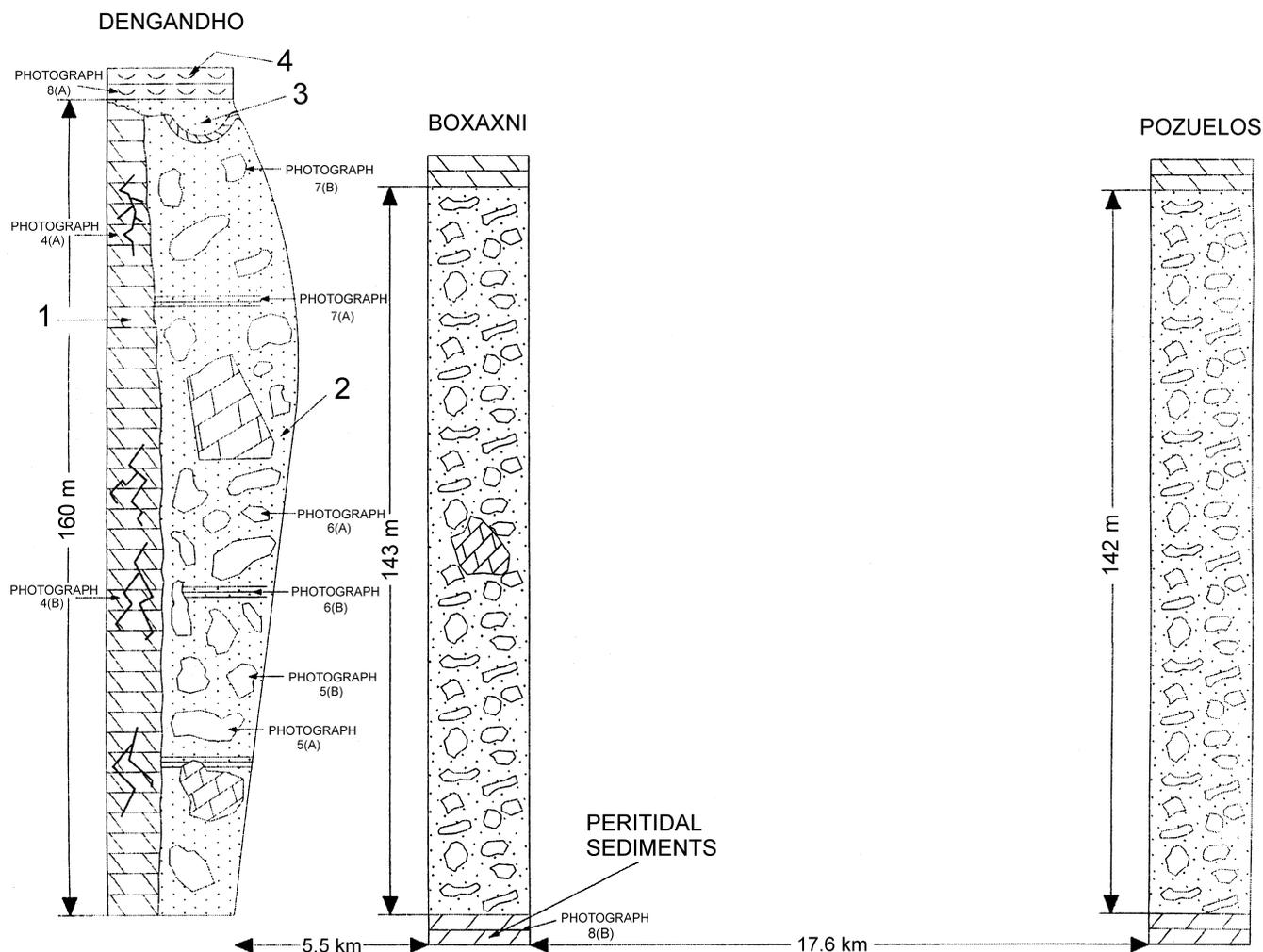
Figure 2. Stratigraphic section at the Dengandho, Boxaxni, and Pozuelos localities. See Figure 1 for geographic location and text for description of zones in the Dengandho section.

According to Schlager and Philip (1990), the "greenhouse Earth" of the Cretaceous differs drastically from the "icehouse Earth" in which we now live. Cretaceous platforms developed in a world with a much smaller ice volume and, therefore, underwent different patterns of sea-level fluctuation.

Relative fall of sea level in the Cretaceous produced exposure, karstification, and formation of calcrete (Schlager and Philip, 1990). According to Schlager (1992, Figures 6-4), in the Albian-Cenomanian, a platform subsiding at 50 m/Ma must have been exposed during fewer than a million years. Schlager (1991, Figure 10) showed geophysical evidence of the mid-Cretaceous unconformity in the southeastern Gulf of Mexico (northwestern Cuba, south Florida Platform, and eastern Campeche Platform). The Jordan Knoll is a Cretaceous feature represented by

the contours of the pre-unconformity and periplatform carbonates (Albian, early Cenomanian).

In the Actopan Platform, there is no the paleontologic evidence of the age of bank exposure and karstification. It is suspected that it happened between the upper Albian and the lower Cenomanian with span of exposure in geologic time of fewer than a million years, according to the Schlager criteria.

KARST FEATURES

Choquette and James (1988) have described karst as a dramatic feature of the earth's surface that is unique and complex. Paleocave features are only the most obvious in an array of surface and subsurface structures that range in size down to the

submicroscopic and comprise systems that just now are beginning to be well understood— systems that, quite uniquely, form almost entirely by dissolution.

In the geologic record, the general karst features and processes are identified mainly by speleothems (rarely preserved), cave sediments, and karst breccias.

According to Choquette and James (1988) and Wright (1982), for karst to be preserved, it must be buried by younger sediments, which commonly are marine carbonate sediments but may be terrestrial.

Features commonly associated with paleokarst are breccias that can be used at the surface or in the subsurface as criteria for recognition of paleokarstic events. The breccias themselves furnish information about their genesis (Wilson et al., 1992). Certain distinctive characteristics are significant in this regard. The breccia fabrics and petrology have been described by Kerans (1989, 1990, 1993), Loucks and Hanford (1992), Loucks and Mescher (1997), Loucks (1999), and Lucia et al. (1992), and Lucia (1996).

The classification proposed by Kerans, Loucks, and Lucia for the study of paleokarst is precise. I will follow the Loucks' concepts (Loucks, 1999) in describing the rocks in outcrops of the Actopan Platform, because this classification is clear, practical, and easy to apply. (Loucks, 1999 uses the term paleocaves in the same sense as paleokarst). Loucks (1999, p. 1807–1811) and Loucks and Mescher (2001) described in detail the classification of breccias and clastic deposits in paleokarst systems. They distinguish chaotic breccia, crackle breccia, and cave-sediment fill.

In the Actopan Platform (Figures 1 and 2) there are three stratigraphic sections: Dengandho, Boxaxni, and Pozuelos. Possibility for observation at both Boxaxni and Pozuelos is limited because exposures are poor and because the carbonate rocks are completely dolomitized. The Dengandho section has the best outcrop exposures (Figure 3), but the base of the karst material is partially covered. To complete the section, I will describe the base of the paleokarst at the Boxaxni section where it is well exposed, even though these rocks are dolomitized.

The Dengandho section (Figures 2 and 3) shows an exposure of paleokarst approximately 60-m wide, and 160-m thick. It is composed of four zones: (1) pillar, (2) breccias, (3) vertical shaft passage, and (4) paleokarst cover.

Zone 1: This zone is composed preferentially of crackle (Figure 4A) and mosaic breccia (Figure 4B). These rocks may correspond to a cave wall (pillar?), because the exposure strata are nearly continuous.

Zone 2: This is the major feature of the section; it is composed of nearly all eight types of breccia described by Loucks (1999), including chaotic breccia (Figure 5A); matrix-rich, clast supported, chaotic breccia (Figure 5B); matrix-supported chaotic breccia (Figure 6A); cave sediment with chips, slabs, and blocks (Figure 6B); cave-sediment fill (Figure 7A); and matrix-rich mosaic breccia (Figure 7B). A small percentage of crackle and mosaic breccia is also present.

Zone 3: The geometry and stratigraphic position of this zone suggest that it is part of a vertical shaft passage.

Zone 4: Capping all the zones is the well-bedded *Toucasia* wackestone (Figure 8A) deposited during the following transgression of the sea.

These relationships suggest that 160 m or more of caverns or systems of caverns existed in the El Abra Limestone before the deposition of upper *Toucasia* wackestone, and that perhaps the collapse of this cavern zone occurred before the deposition of these *Toucasia* beds. This is evident from the the lack of *Toucasia* carbonate sediments in any part of the breccias or clastic carbonate deposits in the paleokarst system.

The paleokarst lower-main features in the Boxaxni section (Figure 8B) are made of peritidal sediments. There is an upper and irregular, sharp contact with the breccias. The breccia zone shows only shadows of the original clastics and fabric replaced by dolomite.

Various paleokarstic features give evidence that surface exposure was fewer than one million years (upper Albian–lower-Cenomanian, according to Schlager and Philip, 1990). This evidence includes: (1) dolomitic breccia above the peritidal sediments in the Boxaxni Section (Figure 8B); (2) 160 m of fracture-dominated, clast-dominated,and sediment-dominated breccias of the Dengandho Section (Figures 2 and 3, zones 1 and 2); and (3) stratigraphic cover of the breccia bodies with restricted-marine lagoonal to intertidal *Toucasia* wackestone beds (Figure 8A, and Figures 2 and 3, zone 4).

The above evidence indicates that during the upper Albian–lower Cenomanian, there was exposure of the carbonate platform and subsequent dissolution that resulted in karsting. This was followed by collapse and extensive brecciation, and finally by burial beneath restricted lagoonal carbonate sediments.

The similar stratigraphic thickness of the karst features (Figure 2) in El Abra Limestone throughout the Actopan Platform— Dengandho Section 160 m,

Figure 3. View of the Dengandho section shows an exposure of paleokarst features almost 60-m wide, and 160-m thick. It is composed of four zones: pillar (1), breccias (2), vertical shaft passage? (3), and paleokarst cover (4).

Boxaxni Section 143 m, and Pozuelos Section 142 m— is evidence that the karst profile extended uniformly across the platform. Further study is needed to determine whether the karst phenomena covered the entire Cretaceous Valles–San Luis Potosí Platform.

The ancient Gulf of Mexico in the Albian-Cenomanian was surrounded almost completely by large carbonate platforms and banks with stratigraphic thicknesses ranging from hundreds to thousands of meters of carbonate rocks. Global evidence shows that the Cretaceous platforms developed during a period of sea-level fluctuation (Schlager and Philip, 1990). Schlager (1991, Figure 10) showed a mid-Cretaceous unconformity in the southeastern Gulf of Mexico on the Jordan Knoll. In the San Marcos and Cordoba Platforms there is evidence of prolonged subaerial exposure with a karsted unconformity at the top of the Edwards Group and the Orizaba Limestone (Albian-Cenomanian).

Other Cretaceous platform carbonate rocks of the region that may have undergone subaerial erosion and karstification include the Sierra Madre Limestone in Chiapas and equivalent rocks in northern Guatemala (Blount and Moore, 1969). According to Blount and Moore, there are good exposures of depositional and non-depositional breccias in northern Guatemala.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

Subaerial exposure of the El Abra Limestone peritidal carbonate platform led to the development of karst features in an Albian-Cenomanian stratigraphic
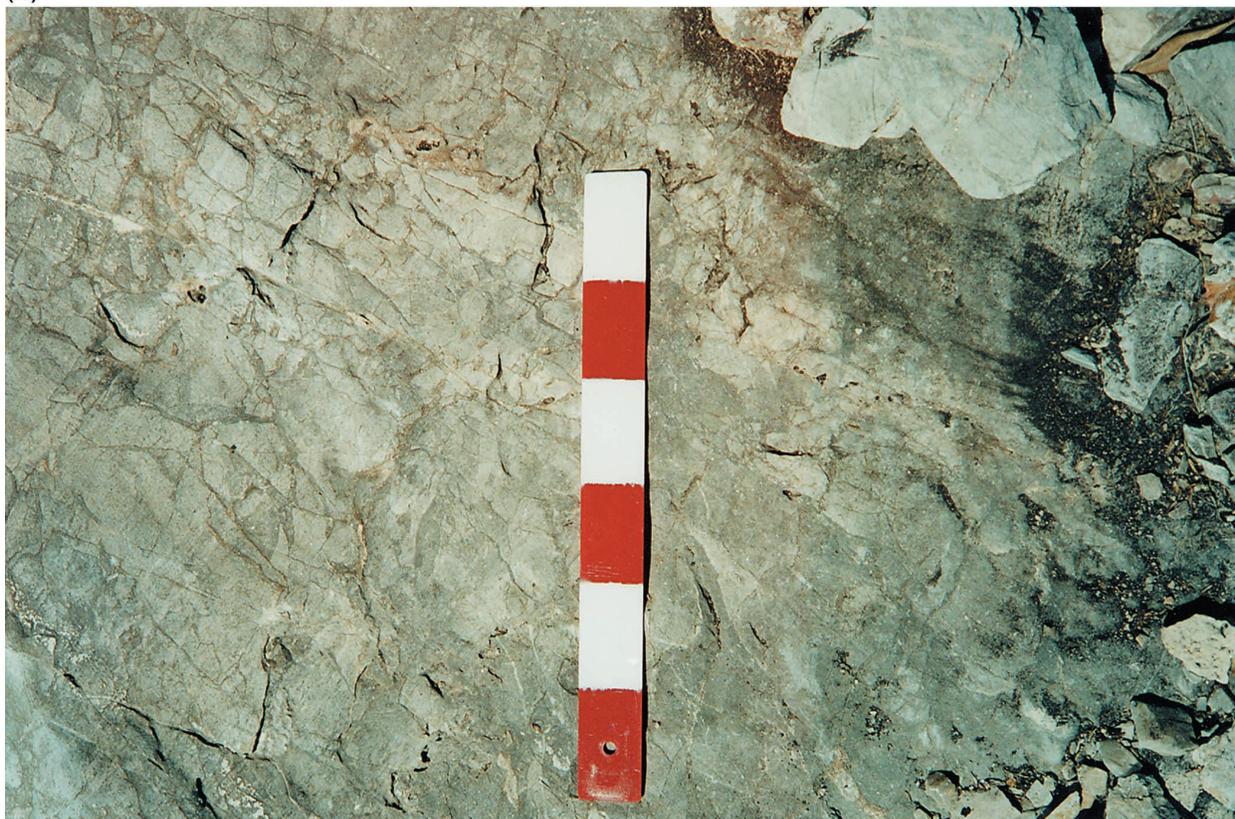
(A)

(B)

Figure 4. (A) Crackle breccia, part of a wall or a pillar. For scale, the pen is 12.5 cm long. (B) Mosaic breccia, part of a wall or a pillar. For scale, the rule is 30 cm long. Both outcrops are at the Dengandho section.

(A)

(B)

Figure 5. (A) Chaotic breccia. For scale, the rule is 30 cm long. (B) Matrix-rich, clast-supported chaotic breccia. For scale, the tape measure is 24 cm long. Both outcrops are at Dengandho section.

(A)

(B)

Figure 6. (A) Matrix-supported chaotic breccia. For scale, the rule is 30 cm long. (B) Cave sediment with chips, slabs, and blocks. For scale, the big hammer is 50 cm long. Both outcrops are at Dengandho section.

(A)

(B)

Figure 7. (A) Lower contact of a laminated cave-sediment fill. For scale, the pen is 12.5 cm long. (B) Matrix-rich mosaic breccia (left part of the photo) and mosaic breccia at the sides. For scale, the pocket knife is 8 cm long. Both outcrops are at Dengandho section.

(A)

(B)

Figure 8. (A) Bedded wackestone of *Toucasia* covering the upper part of the paleokarst in the Dengandho section; the camera case is shown for scale. (B) Base of the paleokarst in Dengandho Section. The peritidal (dolomitized) sediments have a massive aspect, with irregular, large, elongated (parallel with the stratigraphy) holes as long as 1.20 m and 30 cm high; above them are shadows of the dolomitized breccias. For scale, rule is 30 cm long.

profile in the Actopan Platform. Other stratigraphic-equivalent rocks in Texas, Cordoba, and Jordan Knoll also were exposed to karst or unconformity (non deposit) phenomena during the Albian-Cenomanian.

A complete spectrum of karst dissolutional and depositional features, including fracturing, brecciation, and collapse structures and textures, extend over the Actopan Platform in rocks of upper Albian–lower Cenomanian age. These karst features were covered later by restricted-marine lagoonal to intertidal *Toucasia* wackestone beds.

Some of the carbonate platform rocks of Albian-Cenomanian age were later exposed to another period of erosion and karst formation in the Upper Cretaceous–Tertiary. These multiply karsted rocks include the Edwards Group in Central Texas, the Golden Lane Platform, Sierra del Abra (type locality), and subsurface carbonate rocks of the Chiapas-Tabasco area.

The geologic evidence shows that a large part of the hydrocarbon production in Mexico comes from karstified rocks. There is much geologic work to be done in other related prospects.

The geologic province of the Actopan Platform is surrounded by many famous mine districts, such as Pachuca, Real del Monte, Cardonal, Santuario, and Zimapan. A relationship may exist between erosion and karst formation and base metal mineralization such as that found in the Lead-Zinc Province of the United States.

Severe water-supply problems exist in the central part of Mexico. It is possible that the porous paleokarstic rocks of the El Abra Formation would be as good an aquifer as the Edwards aquifer in Texas.

ACKNOWLEDGMENTS

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