Evaporite Diapirs In The La Popa Basin, Nuevo Leon, Mexico.

Robert C. Laudon
Missouri University of Science and Technology, rlaudon@mst.edu

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ROBERT C. LAUDON *Department of Geology and Geophysics, University of Missouri-Rolla, Rolla, Missouri 65401*

ABSTRACT

Reconnaissance mapping and stratigraphic work in the La Popa basin of Nuevo León, northern Mexico, has revealed two large structural features with cores of gypsum and anhydrite at the surface. These features are interpreted to be the surface expression of evaporite diapirs. They are exposed in folded sedimentary rocks belonging to the Potrerillos Formation of the Difunta Group of Maastrichtian age (Late Cretaceous). Sandstone units within the Potrerillos Formation pinch out toward the piercement features. Carbonate lentils composed of rudistid reefs and associated carbonate clastics flank the features and pinch out away from the features into marine shale members of the Potrerillos Formation. Most carbonate lentils occur in the immediate vicinity of the evaporite features and are interpreted to be genetically related to the diapirs. Syndiapiric sedimentary-facies patterns can be documented over 4,000 vertical feet (1,200 m) of section within the Potrerillos Formation. The large vertical extent of facies peculiarities near the piercement features indicates that the features were active for an extended period corresponding to at least two regressive-transgressive cycles during Maastrichtian time. A radial drainage pattern away from the northern feature indicates that the features are probably active today.

A limestone inclusion from within one of the features has been dated as Kimmeridgian in age (Zuloaga or Smackover equivalent) and suggests that the evaporites are probably derived from the Jurassic Minas Viejas Formation. It is not known at present whether salt underlies the surface crust of gypsum and anhydrite.

At the time that the first syndiapiric sediments of the Potrerillos Formation were deposited, the Minas Viejas Formation was buried at an estimated depth of 17,000 ft (5,200 m). The thick pre-Laramide cover, the pre-Laramide age of at least some of the syndiapiric sedimentary features, and the location of stocks away from major anticlines indicate that the emplacement of the diapirs is not related to Laramide compression. Geostatic loading is considered to be the most important mechanism for emplacement of the domes.

INTRODUCTION

The La Popa basin is located to the northeast of the Parras basin and to the south of the Sabinas basin (Fig. 1) within what Murray (1959) referred to as the Coahuila Marginal Folded Province of Coahuila and Nuevo León, Mexico. The Coahuila Marginal Folded Province is characterized by widely separated, breached, anticlinal mountains and intervening basins. The cores of many of the breached anticlines contain masses of gypsum and anhydrite that Wall and others (1961) and Humphrey (1956) concluded were intrusive and derived from the underlying Minas Viejas Formation (Fig. 2) of Jurassic or perhaps pre-Jurassic age. The backbones of the mountain ranges are composed of steeply dipping to overturned sections of the Upper Jurassic and Lower to middle Cretaceous beds of the formations shown in Figure 2. The gypsum-cored, breached anticlines form the spectacular "potreros," or box canyons, that characterize the Coahuila Marginal Folded Belt.

The geologic history of northern Mexico is fairly complicated. The pre-Mesozoic history is obscure because of scarcity of older rock out-

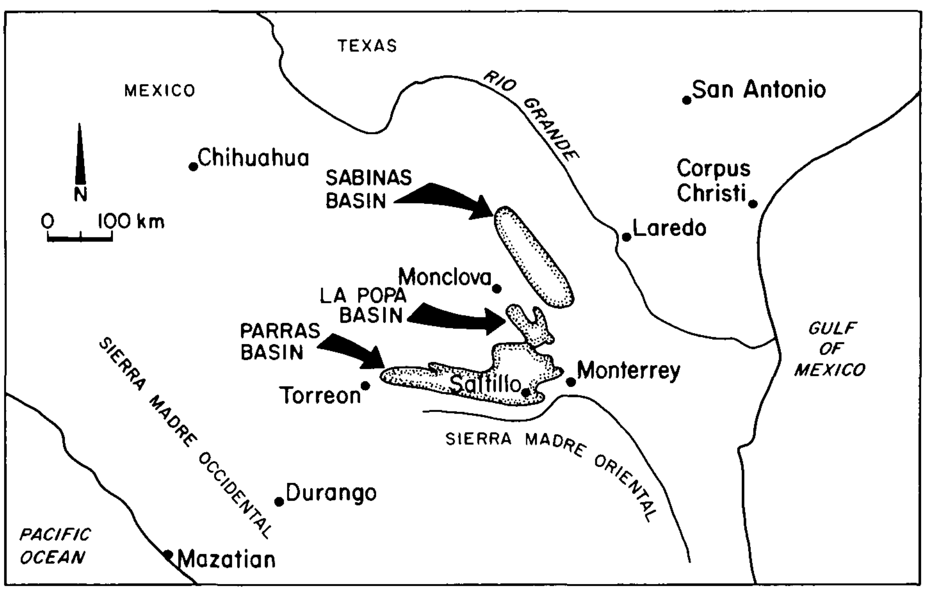

Figure 1. Reference map showing the location of the La Popa basin.

Geological Society of America Bulletin, v. 95, p. 1219–1225, 9 figs., October 1984.

	EPOCH	LA POPA BASIN	EAST OF LA POPA BASIN
TERTIARY			
CRETACEOUS	GULFIAN	Difunta Group	Mendez Shale
		Parras Shale	San Felipe Fm.
		Indidura Fm.	Agua Nueva Fm.
	COMANCHEAN	Cuesta Del Cura Fm.	
		Aurora Limestone (Tamaulipas Superior)	
		La Peña Formation	
	COAHUILAN	Cupido Formation	
		Taraises Formation	
LATE JURASSIC	SABINASIAN	La Casita Group	
		Zuloaga Fm.	Olvido Fm.
		Huizachal Group: La Jova Fm.	Minas Viejas Fm.
TRIASSIC		Huizachal Group: La Boca Formation	

Figure 2. Stratigraphic units in the La Popa basin area (modified from Weidie and Murray, 1967).

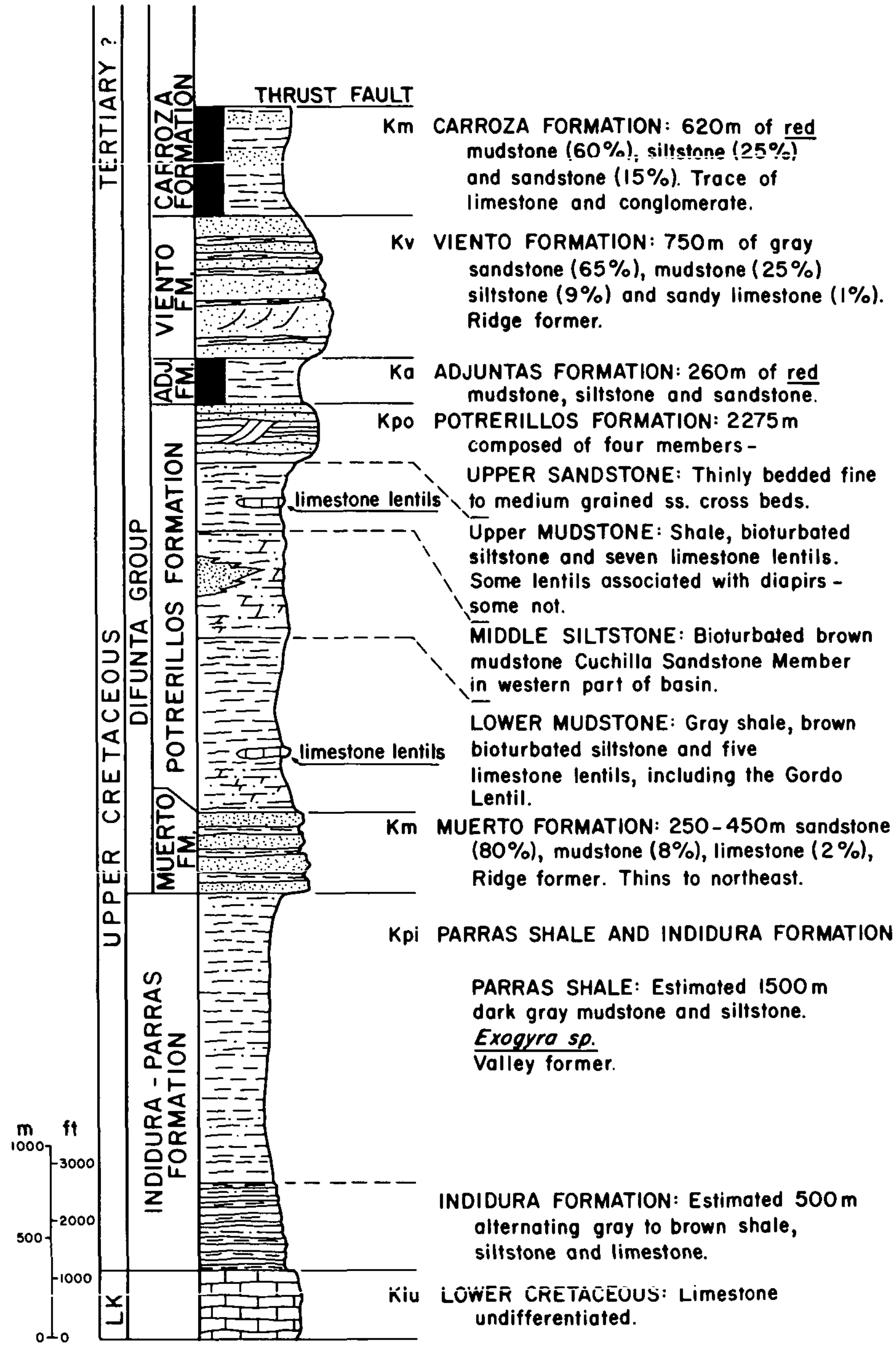

Figure 3. Stratigraphic column for the La Popa basin (from Laudon, 1975).

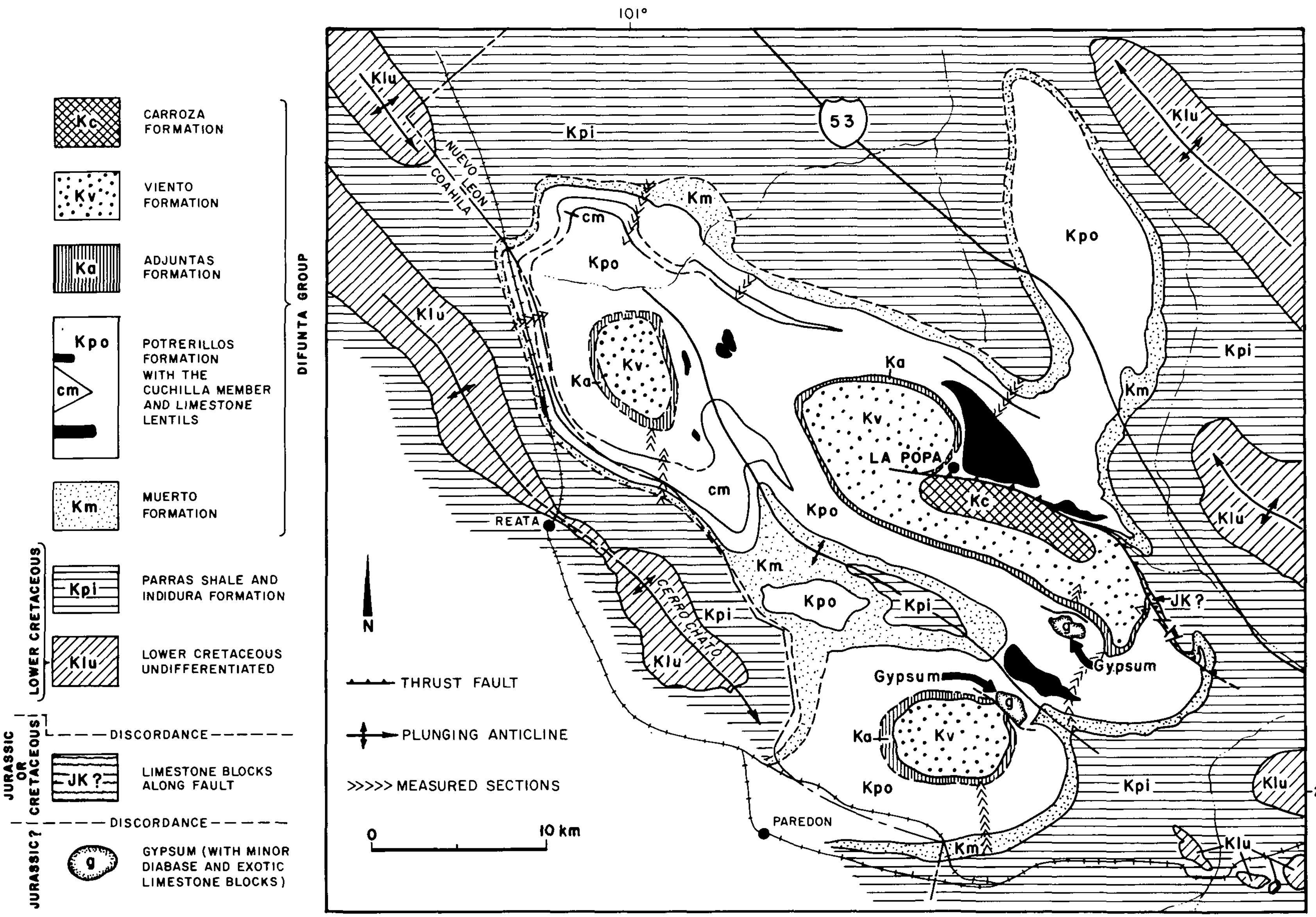

Figure 4. Geologic map of the La Popa basin showing the location of gypsum piercement features (modified from McBride and others, 1974, and Laudon, 1975).

Figure 5. Aerial photograph showing the two gypsum piercement features and surrounding sedimentary rocks. See Figure 6 for key.

crops. For a summary of the pre-Mesozoic history, refer to Flawn and Diaz (1959). During the Triassic and Jurassic periods, block faulting occurred across most of northern Mexico, and thick red-bed sequences were deposited in fault troughs and grabens (Mixom and others, 1959). Jurassic evaporites of the Olvido and Minas Viejas Formations are probable basinward equivalents of these red-bed formations (Weidie and Murray, 1967).

Early Cretaceous time was marked by a transgression onto the Cretaceous Coahuila peninsula. By Comanchean time, all of northeastern Mexico was inundated, and a thick sequence of shallow-marine limestone was deposited across all of northeastern Mexico. By middle Late Cretaceous time (Coniacian and Santonian), differential subsidence had occurred, and the Parras and La Popa basins developed as a foredeep in front of the rising highlands of the Sierra Madre Oriental to the south and southwest. Approximately 5,000 ft (1,500 m) of marine Parras Shale was deposited in this foredeep (Weidie and Murray, 1967). During Campanian and Maastrichtian time and into early Tertiary time, large amounts of clastics were shed to the northeast from the Sierra Madre highlands, and as much as 16,000 ft (5,000 m) of paralic and shallow marine sedimentary rocks belonging to the Difunta Group filled the Parras and La Popa basins (McBride and others, 1974, and Laudon, 1975). The basins were filled by an over-all regressive sequence represented by four progradations of deltaic and delta-related sediments and three intervening transgressive phases. In the Parras and La Popa basins, the Cretaceous-Tertiary boundary is indistinct, as the final regression occurred during Late Cretaceous to early Tertiary time.

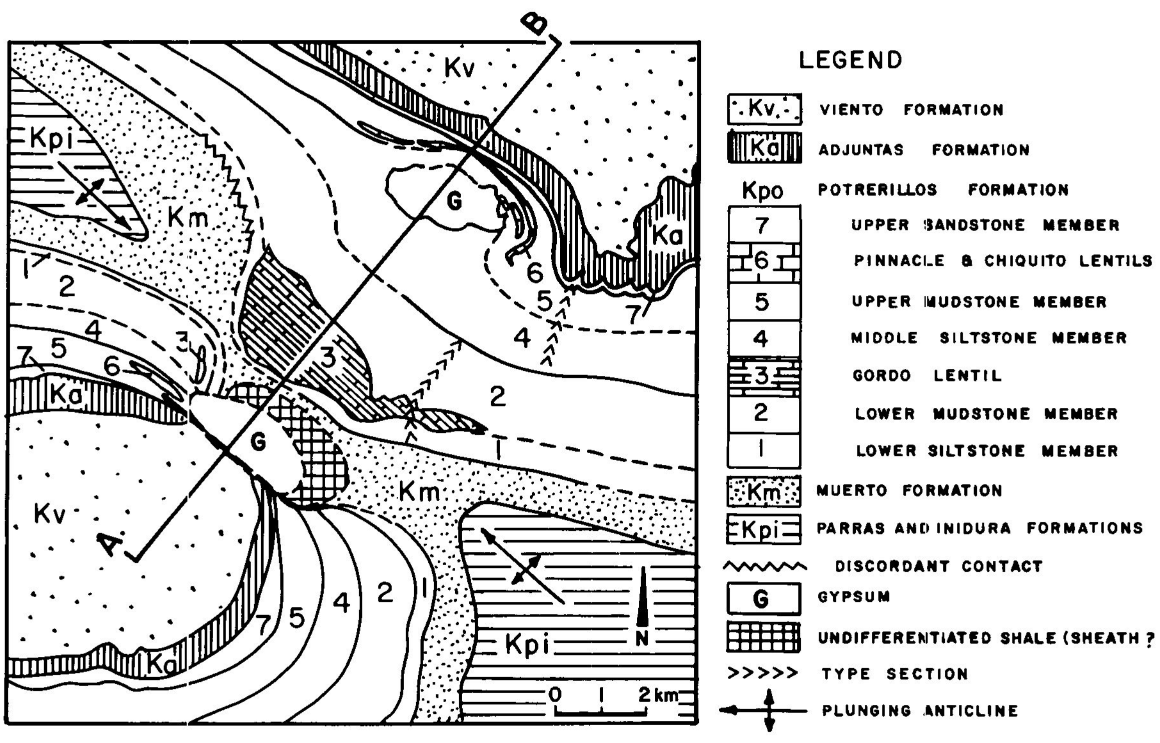

Figure 6. Geologic map of photograph in Figure 5 and location of cross section A–B in Figure 8.

DESCRIPTION OF THE PIERCEMENT FEATURES

Figure 3 shows the stratigraphic column for the Difunta Group in the immediate vicinity of the piercement features. In their present state of erosion, the features are completely surrounded by folded rocks of the Potrerillos Formation (Fig. 4). In plan view, both features are elliptical in shape and are approximately 8,000 by 4,000 ft (2.5 by 1.2 km) (Figs. 5, 6, and 7), with the long axes oriented northwest-southeast. Outcrops consist of a crumbly, white crust composed primarily of gypsum and anhydrite. Contacts between the evaporite cores and the Potrerillos Formation are poorly exposed. Inclusions of highly epidotized diorite and exotic limestone blocks are present within the evaporite cores and also on the flanks of the gypsum. K. P. Young (personal commun.) identified *Exogyra* sp. cf. *virgula* DeFrance, which is of Kimmeridgian age (Zuloaga or Smackover equivalent), from one of the limestone inclusions. Although only the one inclusion has been dated, the other exotic limestone blocks are clearly different from any limestones belonging to the Difunta Group.

These exotic blocks are probably of Jurassic to Early Cretaceous age and were brought to the surface as inclusions in the evaporites. Many of the exotic limestone blocks ring the evaporite cores (Fig. 7). Through differential erosion and continued extrusion, these exotics have migrated to the sides of the evaporite cores.

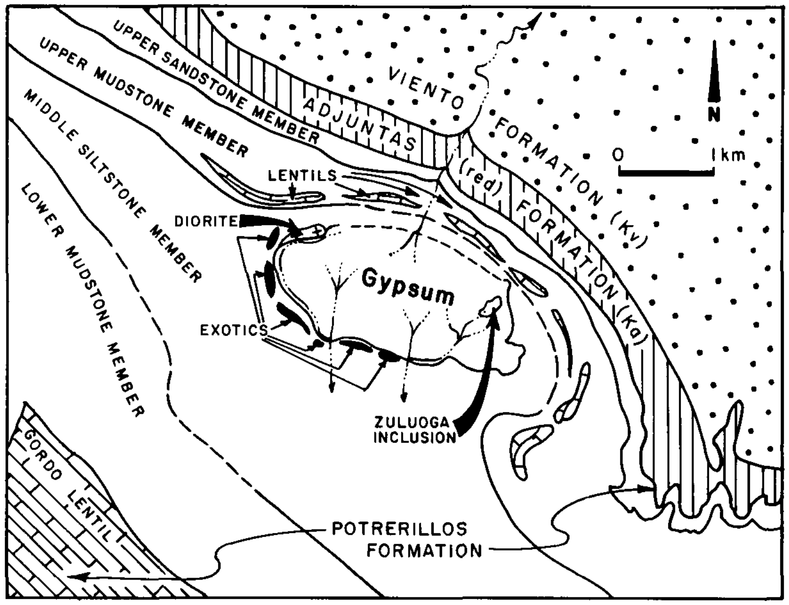

Figure 7. Detailed geologic map of the northern piercement feature showing location of lentils and exotic limestone blocks.

The southern diapiric feature occurs at the crest of a northwest-southeast–trending anticline that folds all of the Potrerillos Formation (Figs. 4 and 8). The northern diapir forms only a local doming and occurs entirely within a part of the Potrerillos Formation that otherwise dips uniformly to the northeast.

A shale mass of uncertain stratigraphic position, which is possibly diapiric shale, is also present on the east flank of the southern piercement feature (Figs. 6 and 8). Figure 8 is a northwest-southeast schematic cross section through the two piercement features. Sandstone units are shown to pinch out in the vicinity of the features, because all sandstone units that are visible on the surface pinch out within a distance of 3,000 ft (1,085 m) of the evaporite cores. Most of the limestone lentils are geographically associated with the piercement features and pinch out away from the features (Figs. 5 and 6).

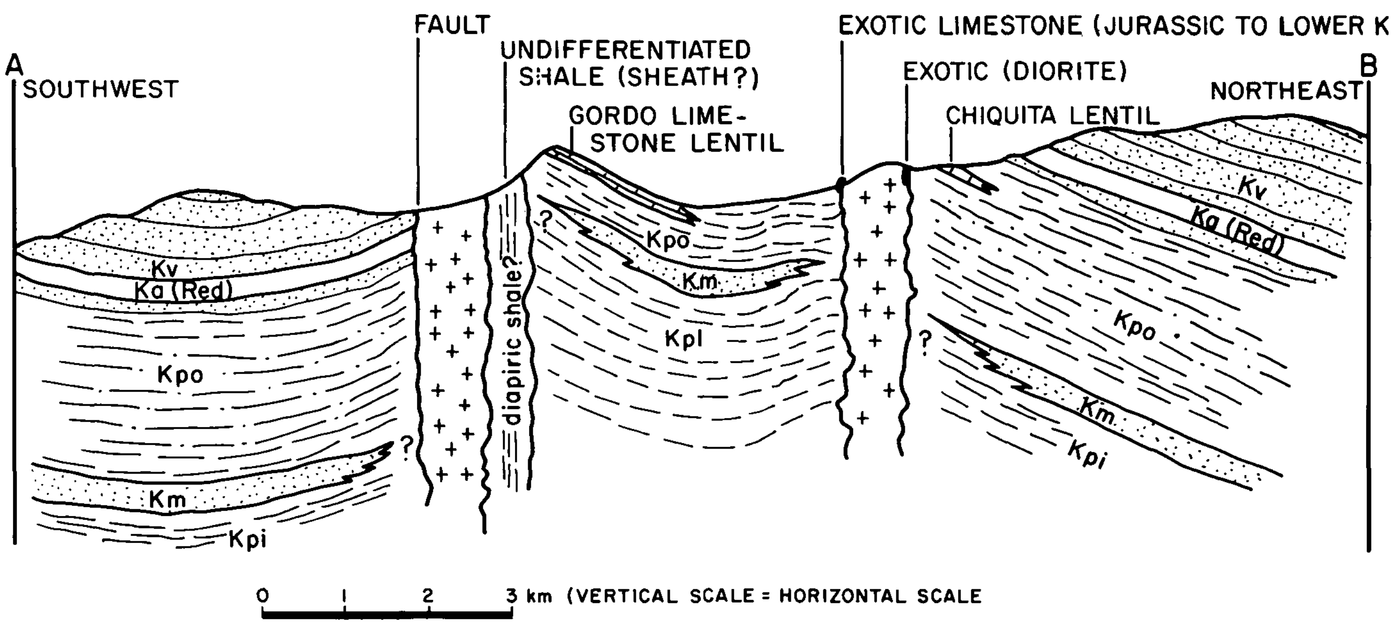

Figure 8. Schematic southwest-northeast geologic cross section through the two gypsum piercement structures. Cross section location and abbreviations shown in Figure 6.

Figure 9. The Gordo limestone lentil as viewed from the southwest across the southern gypsum body. See Figure 6 for location of the Gordo lentil. (Photograph courtesy of E. F. McBride.)

The limestone lentils are not exotics. They are concordant and interbedded with shales of the Potrerillos Formation. Each of the limestone lentils was named and described by McBride and others (1974). Some of the lentils show both unbedded reef cores and well-bedded interreef carbonate clastics (Fig. 9). The majority of the carbonate masses appear to be rudistid reefs, algal mounds, and associated carbonate clastics. The limestone lentils occur at two stratigraphic positions within the Potrerillos Formation, both of which are laterally equivalent to mudstone members of the Potrerillos Formation. All facies variations associated with the piercement features occur within 1 mi (1.6 km) of the domes, and most occur within 5 mi (0.8 km).

No salt (halite) has been found in either of these piercement features. There is no clear evidence in the Potrerillos Formation for the development of a peripheral sink (rim syncline), and evidence for Cretaceous extrusion is equivocal. No direct evidence for Cretaceous extrusion such as salt glaciers or breccias has been identified.

ORIGIN OF THE PIERCEMENT FEATURES: INTERPRETATION

The geographic distribution of carbonate lentils and sandstone pinch-outs relative to the evaporite diapirs in the La Popa basin indicates that these sedimentary-facies variations are genetically related to the evaporite features. The evaporite diapirs must have penetrated close enough to the surface to have created some sort of topographic expression during Late Cretaceous time. The features probably formed subtle topographic highs both on the sea floor during high sea-level stands and on the land surface during low sea-level stands. The proximity of the facies variations to the piercement features suggests that the features were local phenomena and not related to turtleback structures or to the pillow stage of salt-dome growth.

The limestone lentils occur within mudstone members or at stratigraphic positions that correspond to maximum transgressive phases within the transgressive-regressive cycles. This was a time when the shoreline was farthest to the west, clastic influx was at a minimum, and the water depth in the basin was at a maximum. Although the evidence for water depth is weak, the water was probably not deep. Although other interpretations are possible, the reefs are interpreted to have grown preferentially in shoal areas and probably at very close to sea level in association with the topographic highs that were related to the evaporite features. The sediments that may have been deposited over the top of the domes during Cretaceous time are now eroded away. It thus is not known whether the reefs formed over the very tops of the domes or only on the flanks.

During regressive phases, prograding delta and fluvial systems tended to avoid the topographically elevated areas associated with the domes. Delta-front sandstone units, as well as fluvial channel sandstone units, simply pinch out against the highs.

The sedimentary patterns observed suggest that these evaporite domes formed through a process that Barton (1933) called downbuilding. Downbuilding implies that the domes did not physically force their way upward through overlying rock. Instead, concurrent with intrusion and possibly extrusion, clastic sedimentation occurred on the flanks of the domes (only the reefs may have grown on top of the domes), and, through time, the surrounding sediments subsided or "downbuilt" around the dome. Whereas this relative movement distinction may not be important mechanically, it can be very important sedimentologically. Downbuilding implies that primary stratigraphic variations should be expected on the flanks of the dome and relatively close to the dome. Recognition of downbuilding in other areas can be an important clue both to the possible existence of stratigraphic trapping mechanisms near the dome and to the scale on which to explore for such traps. Recognition of any syntectonic sedimentation can be critical in the search for hydrocarbons associated with stratigraphic traps.

There is no direct evidence for salt in the piercement structures of the La Popa basin. Wall and others (1961), however, reported that a well drilled in the core of the Sierra del Fraile, an evaporite-cored anticline that occurs 20 mi (33 km) to the southeast of the La Popa evaporite features, encountered gypsum, anhydrite, and eventually salt of unknown structural and stratigraphic relationships. It thus can be speculated that the gypsum and anhydrite cores of the La Popa basin features are probably underlain by salt. Future gravity work in the area may resolve this uncertainty.

In the La Popa basin, the Minas Viejas Formation is overlain by an estimated 12,000 ft (3,700 m) of Jurassic and Lower Cretaceous rocks that are chiefly carbonates. These are overlain by the Parras Formation and the Difunta Group, which have a combined maximum thickness of >21,000 ft (6,500 m). In the La Popa basin area, therefore, the Minas Viejas Formation may be buried by 33,000 ft (10,000 m) of sedimentary rock. At the time of deposition of the first syndiapiric sediments of the Potrerillos Formation, the Minas Viejas Formation was buried at an estimated depth of 17,000 ft (5,200 m). The thick pre-Laramide cover, the syntectonic sedimentary features of pre-Laramide age, and the location of stocks away from major anticlines suggest that the domes were not formed by Laramide compression. Geostatic loading is considered to be the most important mechanism for emplacement of these diapiric features.

CONCLUSIONS

Nettleton (1934), Trusheim (1960), Halbouty (1967), Bishop (1978), and many others described mechanisms for salt movement and the emplacement of piercement structures. Many described the expected stratigraphic variations that may be associated with the features, including thickening or thinning toward the domes, particularly in relation to peripheral sinks (rim synclines). Nowhere, however, have these features been described where they are visible in the lateral continuity of excellent surface outcrops, and, to this writer's knowledge, syndiapiric carbonate reefs have not previously been reported in the literature.

Facies relationships in Cretaceous rocks near the features indicate that the evaporite cores penetrated close enough to the surface during Cretaceous time to create topographic relief both on the sea floor during high sea-level stands and on the surface of the land during low sea-level stands. The topographic relief was maintained for a period of time corresponding to at least 2 regressive-transgressive cycles over a vertical thickness in the rock record of >4,000 ft (1,200 km). To have remained near the surface for such a length of time suggests that the evaporites were effectively extrusive, although direct evidence for extrusion, such as salt glaciers or breccias, has not been identified in the surrounding rocks. This evidence indicates that the domes grew, not by physically piercing overlying rocks, but rather by downbuilding of sediments surrounding the domes. Although downbuilding may be difficult to recognize in the subsurface, the concept is very important. If it can be identified in other areas, it can be an important clue to the existence and scale of potential primary stratigraphic traps in the subsurface of that area.

The pre-Laramide age of some of the syndiapiric sedimentary features and the location of the diapirs away from major anticlines suggest that the emplacement of the diapirs is not related to Laramide compression. Geostatic loading is considered to be the most important mechanism for emplacement of the diapirs.

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