Depofacies and Stratal Geometry of the Viento Formation: Implications for Evolution of the La Popa Weld, Northeastern Mexico

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EXTENDED ABSTRACT

The stratal geometry and facies distribution of the Eocene Viento Formation, a thick, continuously exposed siliciclastic unit in La Popa Basin, northeastern Mexico, indicate that deposition and shortening were simultaneous with salt rise. Seven stratigraphic sections measured along a ~5 km southeast-northwest transect in the downdropped, southwestern side of La Popa weld exhibit facies consistent with deposition in a tide-influenced prograding delta system, and include large volumes of bioturbated siltstone to sandstone, heterolithic bedding, mud-draped ripple and plane laminated sandstone. Abundant, 4-15 cm large, disarticulated oysters, abundant, well-rounded, chert pebbles, and rare, well-rounded, pebbles to cobbles intermediate metaigneous clasts, characterize halokinetic sequence boundaries. Rare, intraformational angular unconformities (≤20°), bedding orientations that range from moderately dipping (35°) distal to the weld to slightly overturned adjacent to the weld, lateral thinning from 880 m to zero within ~4 km of the weld, and presence of diapir-derived metaigneous clasts, all reflect strong influence of evaporite rise on Viento Formation deposition. Metaigneous clasts are interpreted to have been cyclically extruded along with diapiric evaporite of Jurassic Minas Viejas Formation of the La Popa salt wall. Short-lived compressional events associated with Hidalgoan orogeny may have driven cyclical extrusion of evaporites and metaigneous clasts, indicating halokinetic sequence development was strongly influenced by shortening.

Background

Detailed field investigations of well exposed and preserved salt structures is an option to study the relationship between salt movement and sedimentation patterns and can offer a predictive analog model for facies architecture of structures buried deep in the subsurface (Giles and Lawton, 1999; Giles and Lawton, 2002; Rowan et al., 2003; Giles et al., 2004). The stratigraphy and structural development of La Popa Basin was intensely studied and interpreted in the last decade by a number of workers, remarkable being the contribution of the trio Giles-Lawton-Rowan; a succinct list of their significant papers among others can be found in the references.

La Popa Basin, located approximately 75 km northwest of Monterrey, Nuevo Leon, Mexico, is part of the distal foreland basin development of the Sierra Madre Oriental fold-thrust belt associated with the Hidalgoan orogeny (age equivalent to the Laramide orogeny), and is one of the few places in the world where easily accessible, well exposed evaporite structures and associated strata crop out in three dimensions (Fig. 1) (McBride

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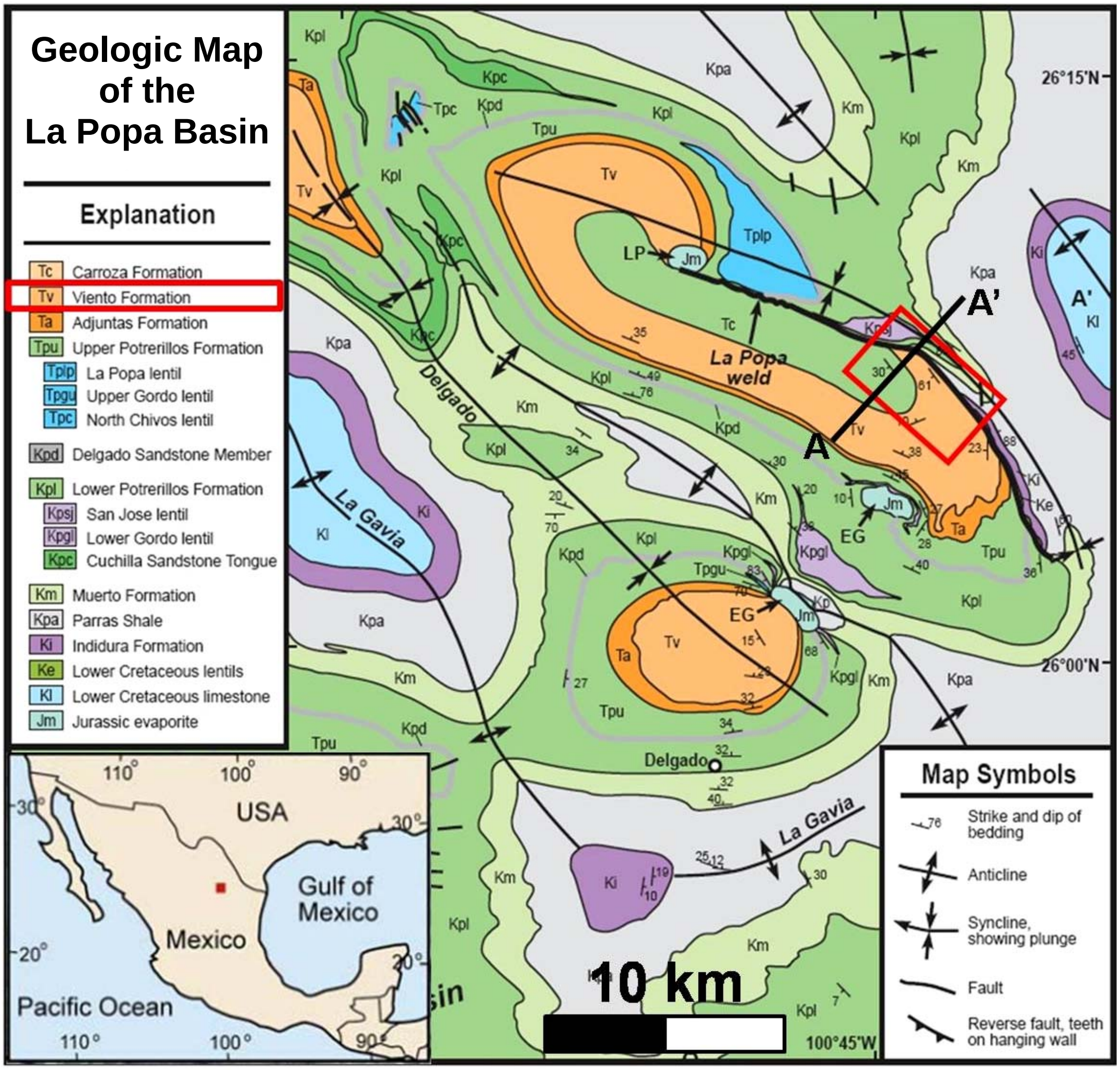

Figure 1. Geologic map of the La Popa Basin, stratigraphic succession indicating the unit studied (Viento Formation), and insert geographic map of Mexico (red square indicates the location of La Popa Basin in northeastern Mexico (modified after Lawton et al., 2001). Note the ~25 km long, northwest-southeast curvilinear surface of the La Popa salt weld. The rectangle indicates the study area within the bend of the weld. The line A-A' is a cross-section within the bend in the weld (not presented at this time).

et al., 1974; Lawton et al., 2001; Dickinson and Lawton, 2001; Rowan et al., 2003; Lawton et al., 2009). The evolution of La Popa Basin was strongly influenced by halokinesis caused by mobilization of the Upper Jurassic–Lower Cretaceous Minas Viejas Formation (Lawton et al., 2001; Lawton et al., 2009). Evaporite structures in La Popa Basin consist of roughly cylindrical salt stocks that are ~4-6 km^2 in outcrop area (McBride et al., 1974; Laudon, 1996), and the sub-vertical La Popa salt weld (Giles and Lawton, 1999) that extends for ~25 km across the basin (Fig. 1). These diapiric structures contain

allochthonous blocks up to 5 m of metamorphosed mafic-intermediate, igneous rocks that yield $^{40}Ar/^{39}Ar$ biotite ages of ~145-146 Ma (Garrison and McMillan, 1999) and Jurassic carbonate in addition to gypsum (Laudon, 1996; Lawton et al., 2001; Giles et al., 2004; Lawton et al., 2009). The metaigneous blocks formed due to partial melting of the continental mantle during Late Jurassic rifting (Garrison and McMillan, 1999) and were subsequently deposited in a hypersaline shallow setting (Lawton et al., 2001; Lawton et al., 2009). Later, the blocks were entrained by the evaporite as it mobilized, carried upward in diapiric structures, and periodically expelled at the surface (Lawton et al., 2001). The basin contains 5-7 km of Lower Cretaceous to Middle Eocene (Hudson and Hanson, 2010) siliciclastic deposits of deltaic and shelf strata and carbonate lenses of the Parras Shale and Difunta Group (McBride et al., 1974; Lawton et al., 2001; Dickinson and Lawton, 2001; Lawton et al., 2009).

Objectives

This study uses the Viento Formation, the youngest marine siliciclastic unit at the top of Difunta Group (Fig. 1), as a proxy to assess the influence of contractile deformation on evolution of the La Popa salt wall/weld. The first objective of this work is to reconstruct the depositional environment and stratal geometries of a ~1,000 m thick package of siliciclastic rocks of the Viento Formation. The second objective is to interpret the distribution of Viento Formation facies in response to rise of the evaporite wall that formerly occupied the site of the La Popa weld. A third objective is to evaluate the influence of regional tectonic compression and thin-skinned shortening on diapir rise and Viento Formation deposition.

Methods

Throughout the study area include exposures of the Viento Formation along the down-dropped side of the La Popa weld and spans the prominent bend that occurs approximately at the midpoint of the weld. Seven stratigraphic sections were measured along northeast-southwest oriented drainages that present very good bedrock exposure and are spread apart of each other 100s of meters. This positioning allowed strong confidence to correlate Viento strata adjacent of the weld surface. Data such as texture, ichnofauna, and sedimentary structures, were collected within each unit and section to aid with interpretations of facies and depositional patterns. Beds forming ridges and the contact of the Viento Formation with the weld were walked-out across drainages to correlate facies and document stratal geometries. Section transects were mapped onto the San Jose De La Popa quadrangle (scale 1:50,000) (G14A84, Nuevo Leon and Coahuila, 1996, Mexico) and using a Garmin GPS (global positioning satellite) system. Bedding orientation data were collected using a Brunton compass along the weld and through the Viento Formation sections.

Depofacies Preliminary Results

Within the Viento Formation exposed adjacent to La Popa weld, ten depofacies are recognized and grouped into three major depositional assemblages: (1) fluvial to deltaic distributary channels, (2) proximal to distal delta front and platform deposits, (3) prodelta to shallow marine deposits. Depositional assemblage 1 consists of three depofacies: pebbly sandstone, conglomeratic sandstone (Figs. 2A-2D), and trough cross-stratified sandstone, which are interpreted to represent downstream fluvial to deltaic

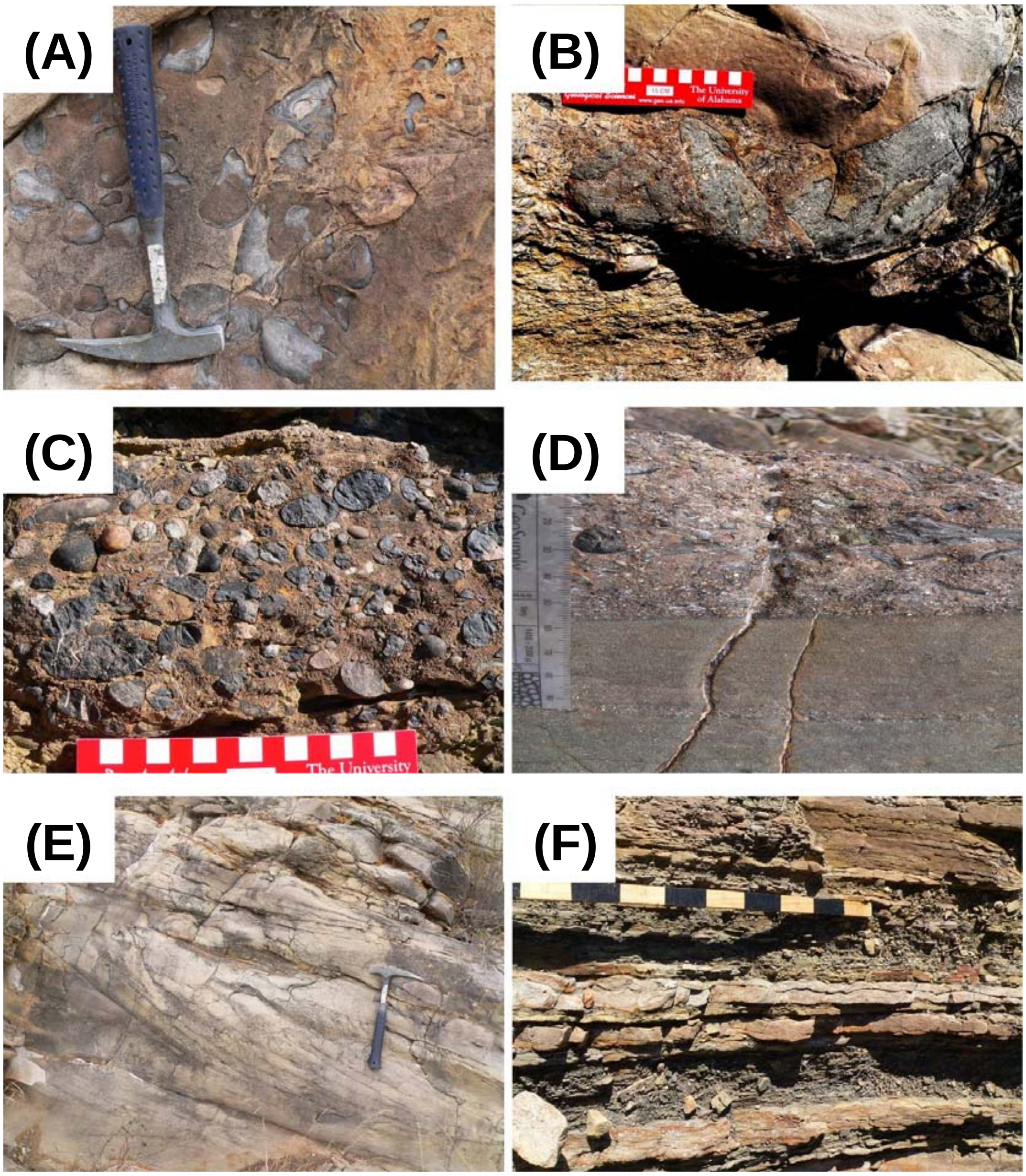

Fig. 2. Outcrop photographs of key depofacies within each depositional assemblage. Photographs A-D are of pebbly sandstone facies of depositional assemblage 1 and represent: (A) abundant, 1-15 cm large, disarticulated, horizontally oysters (rock hammer is 33 cm long); (B) abundant, pebbles to cobbles, subrounded, metaigneous clasts (scale card is 15 cm long); (C) abundant, very-well rounded chert pebbles (scale card is 15 cm long); (D) major erosional surface, with older rock to the bottom, and younger rock to the top—the younger amalgamated pebbly-coarser sandstone eroded the previous trough cross-bedded sandstone facies (grain-size card is 10 cm long). (E) Photograph of low-angle cross bedding in inclined heterolithic stratification facies with ubiquitous mud drapes, representing part of depositional assemblage 2 of proximal to distal, tidally influenced delta platform and front deposits (rock hammer is 33 cm long). (F) Photograph of horizontally-bedded, silt-rich heterolithic fine-grained sandstone and siltstone facies, representing lower part of the prodelta depositional assemblage 3 (Jacob's staff divisions are each 10 cm).

distributary channels and constitute nearly all major sandstone lithofacies and cliff-forming sandstone units in the Viento Formation. Depositional assemblage 2 is composed of the following depofacies: ripple-laminated sandstone, inclined heterolithic stratification sandstone (Fig. 2E), bioturbated sandstone, and oyster bank deposits. The sedimentology of these facies is consistent with deposition in a proximal to distal, tidally influenced delta platform and front. Depositional assemblage 3 consists of depofacies: heterolithic sandstone and siltstone (Fig. 2F), shale deposits, and limestone lentil. These facies were deposited in a prodelta environment.

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REFERENCES CITED

Dickinson, R. W., and T. F. Lawton, 2001, Carboniferous to Cretaceous assembly and fragmentation of Mexico: Geological Society of America Bulletin, v. 113, p. 1142-1160.

Giles, K. A., and T. F. Lawton, 1999, Attributes and evolution of an exhumed salt weld, La Popa Basin, northeastern Mexico: Geology, v. 27, p. 323-326.

Giles, K. A., and T. F. Lawton, 2002, Halokinetic sequence stratigraphy adjacent to the El Papalote Diapir, northeastern Mexico: American Association of Petroleum Geologists Bulletin, v. 86, p. 823-840.

Giles, K. A., T. F. Lawton, and M. G. Rowan, 2004, Summary of halokinetic sequence characteristics from outcrop studies of the La Popa Salt Basin, NE Mexico, *in* P. Post, et al., eds., Salt-sediment interaction and hydrocarbon prospectivity: Concepts, applications, and case studies for the 21st century: Proceedings of the 24th Annual Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists Foundation Bob F. Perkins Research Conference, p. 625-634.

Garrison, J. M., and N. J. McMillan, 1999, Evidence for Jurassic continental rift magmatism in northeast Mexico: Allogenic meta-igneous blocks in El Papalote Diapir, La Popa Basin, Nuevo Leon, Mexico, *in* C. Bartolini, J. L. Wilson, and T. F. Lawton, eds., Mesozoic sedimentary and tectonic history of north-central Mexico: Geological Society of America Special Paper 340, Boulder, Colorado, p. 319-332.

Hudson, M. S., and A. D. Hanson, 2010, Thermal maturation and hydrocarbon migration within La Popa Basin, northeast Mexico, with implication for other salt structures: American Association of Petroleum Geologists Bulletin, v. 94, no. 3, p. 273-291.

Laudon, R. C., 1996, Salt dome growth, thrust fault growth, and syndeformational stratigraphy, La Popa Basin, Mexico: Gulf Coast Association of Geological Societies Transactions, v. 46, p. 219-294.

Lawton, T. F., F. J. Vega, K. A. Giles, and C. Rosales-Dominguez, 2001, Stratigraphy and origin of the La Popa Basin, Nuevo Leon and Coahuila, Mexico, *in* C. Bartolini, R. T. Buffler, and A. Cantú-Chapa, eds., The western Gulf of Mexico Basin: Tectonics, sedimentary basins, and petroleum systems: American Association of Petroleum Geologists Memoir 75, Tulsa, Oklahoma, p. 219-240.

Lawton, T. F., B. A. Ira, F. J. Vega, G. E. Gehrels., and J. M. Amato, 2009, Provenance of Upper Cretaceous–Paleogene sandstones in the foreland basin system of the Sierra Madre Oriental, northeastern Mexico, and its bearing on fluvial dispersal systems of the Mexican Laramide province: Geological Society of America Bulletin, v. 121, p. 820-836.

McBride, E. F., A. E. Weidie, J. A. Wolleben, and R. C. Laudon, 1974, Stratigraphy and structure of the Parras and La Popa basins, northeastern Mexico: Geological Society of America Bulletin, v. 84, p. 1603-1622.

Rowan, M. G., T. F. Lawton, K. A. Giles, and R. A. Ratliff, 2003, Near-salt deformation in La Popa Basin, Mexico, and the northern Gulf of Mexico; a general model for passive diapirism: American Association of Petroleum Geologists Bulletin, v. 87, p. 733-756.