[EA]Pre-Salt Sedimentary Tectonics and Opening of the Gulf of Mexico*

José Rafael Barboza-Gudiño[1], Valentina Castellanos-Rodríguez[4], Yam-Zul Ernesto Ocampo Díaz[2], Irene Guadalupe Pérez-Casillas[3], J. Francisco Pérez-Aguilar[2], Luis Uriel López-Gallegos[3], and Diego Jaime-Rodríguez[2]

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[1]Instituto de Geología, Universidad Autónoma de San Luis Potosí. Manuel Nava 5, zona universitaria, San Luis Potosí, C.P. 78240 (rbarboza@uaslp.mx)
[2]Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí. Manuel Nava 8, zona universitaria, San Luis Potosí, C.P. 78290
[3]Posgrado en Geología Aplicada, Universidad Autónoma de San Luis Potosí
[4]Universidad Tecnológica de Puerto Peñasco, Sonora

Abstract

The stratigraphy of northeastern Mexico was studied since the first half of the 20th. year hundred and the first tectonic models for the early Mesozoic were linked to the opening of the Gulf of Mexico basin. Later most of the region was affected by shortening during the Late Cretaceous-Paleogene. During the last decade development of new analytical techniques allowed to determine maximal depositional ages of siliciclastic successions and their provenances. in addition, geochemical, petrographic and heavy mineral studies offered new possibilities for the stratigraphic correlation, tectonic arrangement and paleogeographic reconstruction. The interpretation of pre-salt stratigraphy and tectonic evolution around the Gulf of Mexico is from a special importance because the great possibilities of new exploration targets and to understand the conditions during early Mesozoic time that lead to opening of the Gulf of Mexico.

Objectives

Several research projects in the last decade were conducted by the "earth crust geodynamic" group of the Autonomous University San Luis Potosí with the goal to reconstruct the Early Mesozoic stratigraphy, tectonic evolution and paleogeography of northeastern Mexico. At this point forthcoming research will focus on the generation of more plausible analytical support and experimentally or numerical development of tectonic models.

Procedures

Our actual model of sedimentation and tectonic evolution of northeastern Mexico is the result of field observations and analytical data, that support ages and correlation of stratigraphic units, as well as provenance and tectonic setting. After cartography and measurement of stratigraphic columns when it was possible because the strongly deformation, we reconstructed pre-Oxfordian successions exposed in northeastern Mexico (Figure 1 and Figure 2).

Ages of volcanism (U-Pb, Zr) of many Early to Middle Jurassic volcanic rocks, were obtained by the LA-MC-ICPMS technique, as well as maximal depositional ages of Paleozoic and Early Mesozoic siliciclastic rocks. For most of the volcanic and siliciclastic units were also performed geochemical analysis, including rare earth elements (REE) and for some volcanic units also Rb/Sr and Sm/Nd relations. In addition, petrographic descriptions including counting of clastic components were performed for use of the classification and tectonic discrimination diagrams, as well as analysis of heavy minerals content, palynological studies and descriptions of the scarce paleontological material contained in continental up to deep marine strata.

Results

Triassic rocks are of fluvial origin in Nuevo León and Tamaulipas (El Alamar Formation, Barboza-Gudiño et al., 2010) and deep marine turbidites in San Luis Potosí-Zacatecas, known as the Zacatecas Formation, as part of a submarine fan system (Potosí fan, Centeno-García., 2005). Results of detrital zircon geochronology allow to estimate Late Triassic maximal depositional ages in all the cases and show through the main age picks: Grenvillian, Panafrican, Peri-Gondwana and Permo-Triassic provenances. During Latest Triassic and Early Jurassic, subduction along the ancient pacific margin caused deformation of the Triassic rocks and posterior development of a continental volcanic arc, known as Nazas arc, whose volcanic products are present in several localities of Durango, Coahuila, Zacatecas, Nuevo León and Tamaulipas. Volcanic rocks of the Nazas arc yielded Early to Middle Jurassic (193-169 Ma) U-Pb ages on zircon by LA-MC-ICPMS (Barboza-Gudiño et al., 2008, Zavala-Monsivais et al., 2012, Lawton and Molina-Garza., 2014).

Several extensional or probably trans-tensional basins were also developed at a back arc position to the same time and were filled by red-beds and volcanoclastic products which are more voluminous to the east, in Tamaulipas, yielding maximal depositional ages based on detrital zircons, between 186 and 165 Ma. Finally, La Joya Formation rests discordantly over the older units in the region as a result of an erosional unconformity and their detrital zircons provide Early to Late Jurassic maximum depositional ages between 170 and 150 Ma (Rubio-Cisneros and Lawton., 2011).

Based on petrography and geochemistry, the volcanic rocks of the Nazas arc can be classified as rhyolite, rhyodacite, dacite and andesite and in all the cases as subalkaline intermediate and acidic volcanic rocks. Regardless the used diagrams for tectonic discrimination based on trace elements, these volcanic rocks plot in the continental volcanic arc fields.

Discussion

At the end of the Paleozoic, the Mexican territory was located towards the equatorial western margin of Pangea. The stratigraphic record in central to western Mexico begins with Triassic siliciclastic deposits (Zacatecas or La Ballena Formation, Chilar Complex) product of sediment feed through fluvial systems (El Alamar) that drained the continent. Precambrian-Paleozoic basement exposures in Tamaulipas and Nuevo León represent uplifted blocks in a continental crust segment influenced by extensional tectonics, mainly during the Latest Triassic to Jurassic Time. During the Middle Jurassic transgression, such uplifted blocks were the last flooded areas, that appear in the paleogeography as islands, on which the extensive cretaceous platforms were developed.

In outcrops of Sierra de Catorce, San Luis Potosí as well as in Sierra de Teyra and Caopas-Rodeo areas in northern Zacatecas, Triassic strata show strong synsedimentary deformation in form of slump structures as well as debris flows and fine to coarse-grained sandstone with floated pebbles up to blocks of quartzite, limestone, chert, as well as abundant siltstone and slate intraclasts. While in these areas volcanic rocks of mafic composition appear as clasts and also as lava flows, interstratified with the uppermost Triassic strata, in all localities placed towards the west, the volcanic succession of the Nazas Formation, rests unconformable on Middle to Upper Triassic turbidites. In this way we interpret the deposits in Real de Catorce as continental slope deposits that change upwards in to distal deltaic and finally a marine marginal facies and the subaerial volcanic succession of the Lower Jurassic Nazas Formation. The predominantly volcanic Nazas Formation known in the Mesa Central, change eastward in to red beds with interlayered volcanic rocks of La Boca Formation in the Sierra Madre Oriental, Being the highest or lowest proportion of volcanic rocks, the only difference between these two lower to middle Jurassic stratigraphic units.

Finally, La Joya Formation represent deposition related to an erosional unconformity. La Joya Formation was proposed as break-up unconformity related to opening of the Gulf of Mexico basin, but it is notable the amount of volcanoclastic materials in La Joya, derived from the volcanic the Nazas and La Boca formations, which show typical petrographic and geochemical features of supra-subduction volcanism, evidently related to the paleo-pacific margin of Mexico, making also evident a link between such active continental margin during the Early Jurassic time and the Gulf of Mexico extensional basin.

We propose in addition to subduction in western Mexico, that the immature and fragmented nature of the crust in the zone led to development of an extensive area of influence of subduction magmatism. The subduction process may have also influenced the extension around the Gulf of Mexico as an atypical back arc, as proposed by Stern and Dickinson (2010). Such authors do not explain the mechanism of development of an extension axis quasi perpendicular to the trench, but we attribute this because of heat flow introduced by subduction in the mantle. The convection currents tend to expand the crust in the direction that represents the minor opposing forces and not necessarily perpendicular to the trench, as it occurs along continental margins of thick and well consolidated cratons, in which the minor forces opposing to expansion of the crust, are perpendicular and close to the trench. Moreover, the rotation of the Yucatan block that has allowed the opening of the Gulf, may be related to a greater expansion rate in the west, related to greater convection forces in the area near the heat source and gradually decreases towards the east, when we move away from the same heat source (Figure 3).

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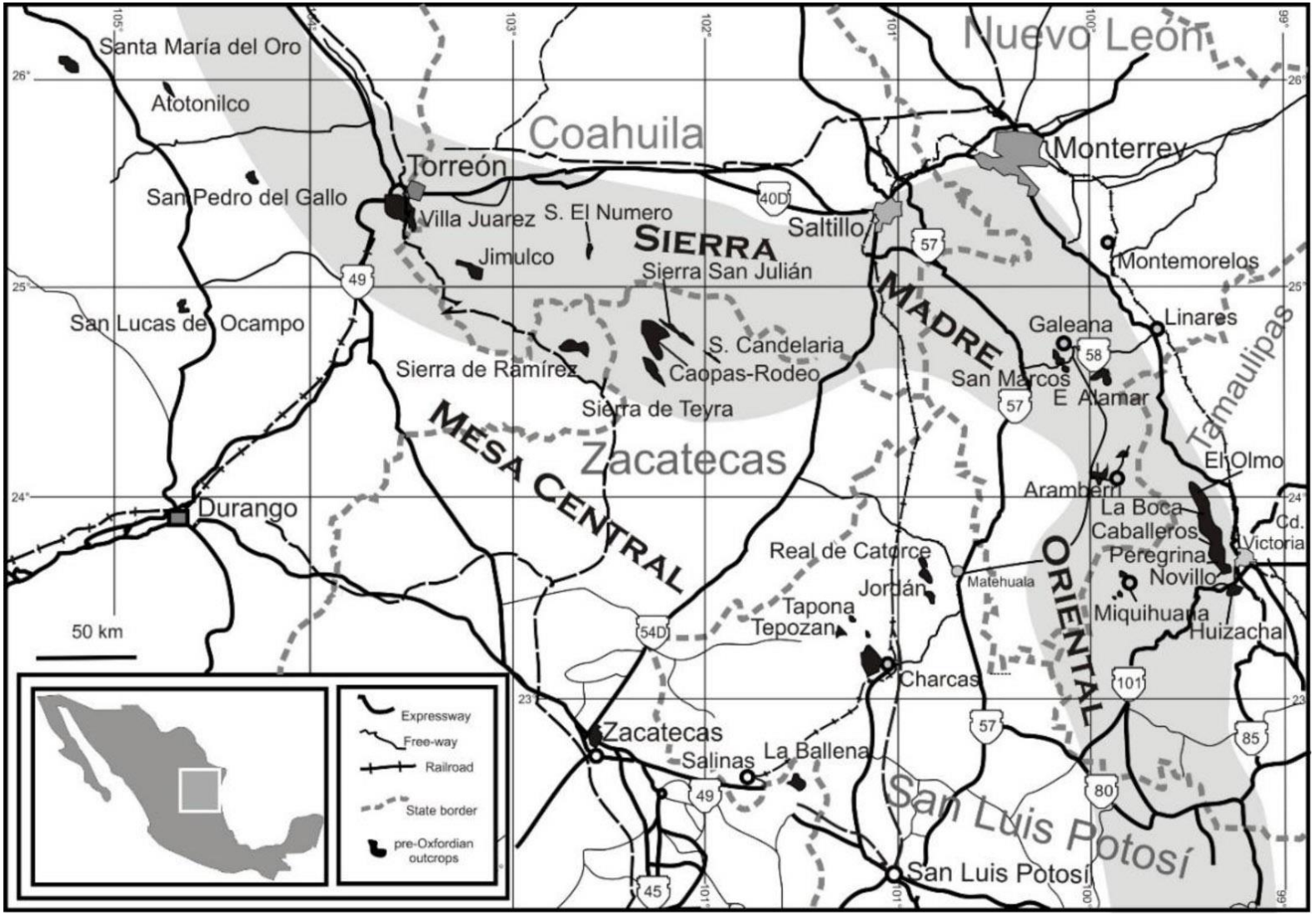

Figure 1. Distribution of pre-salt (pre-Oxfordian) successions exposed in northeastern Mexico.

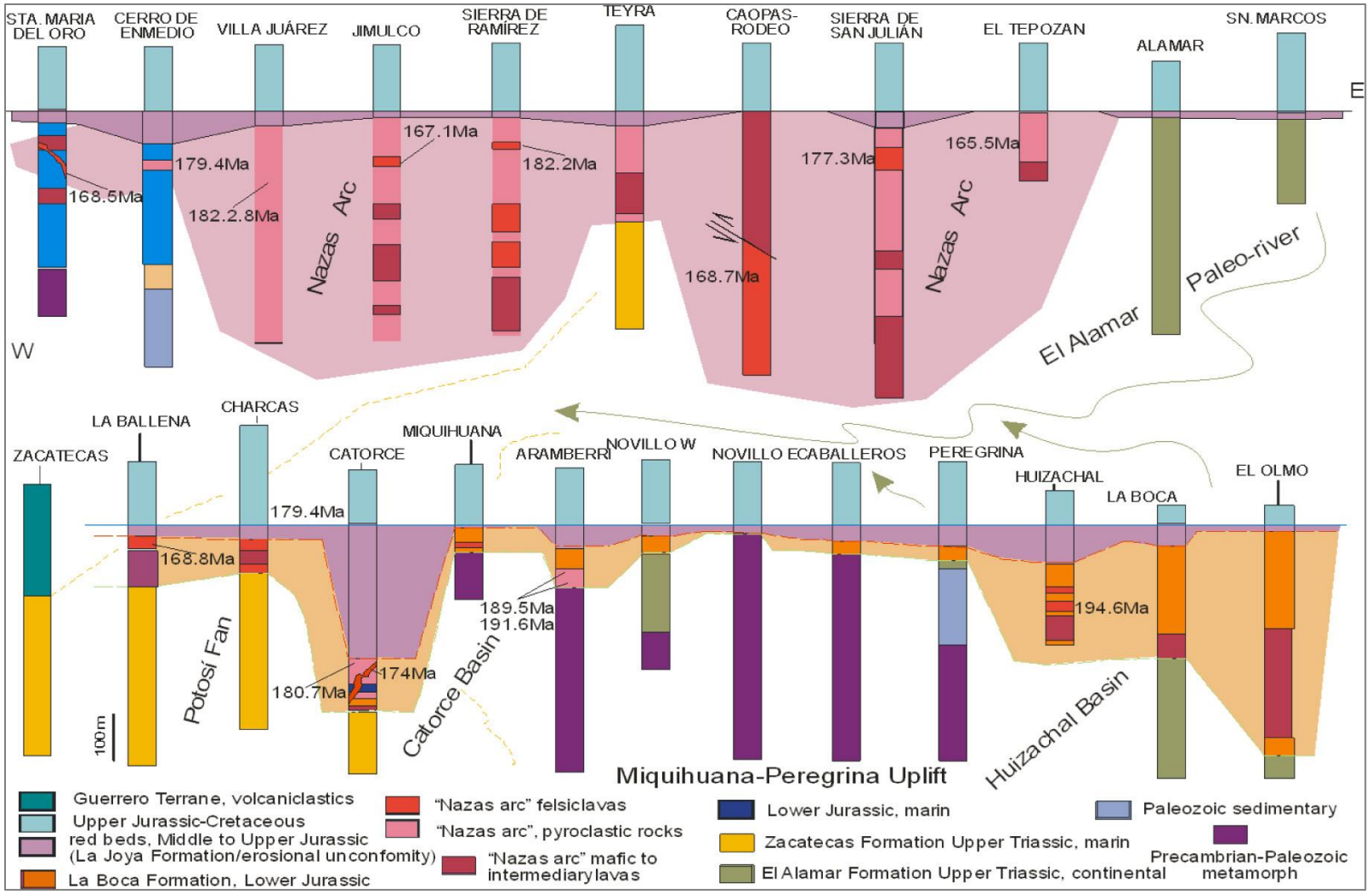

Figure 2. Simplified pre-Cretaceous stratigraphic columns of localities shown in Figure 1.

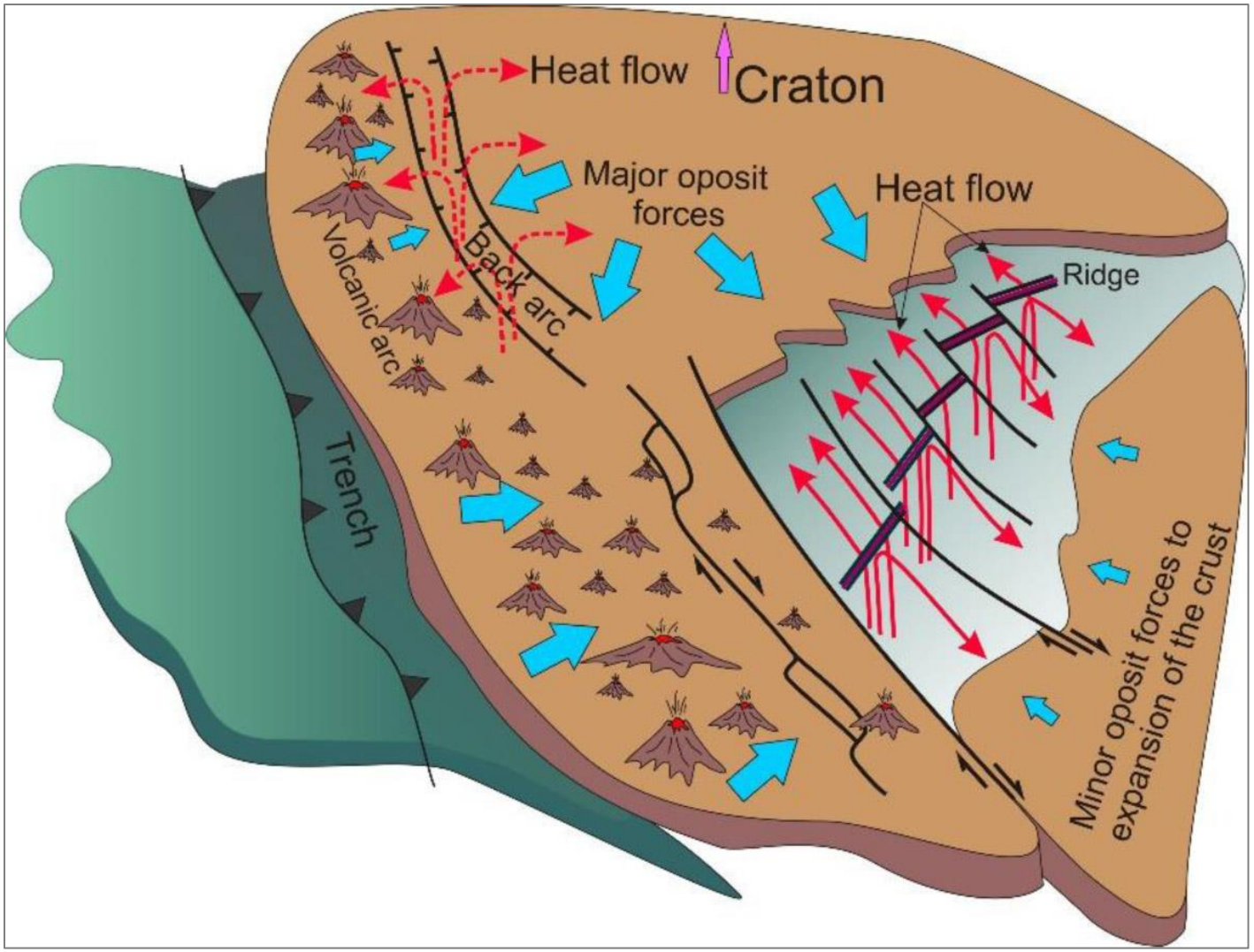

Figure 3. Model of heat flow paths, opposing forces to the expansion of the crust and back arc extensional basins.