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Diagenesis and fluid flow history in reservoir carbonates of the Cordilleran foreland fold and thrust belt: The Cordoba Platform (eastern Mexico).

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The Cordoba Platform in eastern Mexico belongs to the eastern border of the North American Cordillera, which constitutes a Laramian foreland fold and thrust belt (FFTB), and hosts a number of large oil fields. The reservoirs consist of platform carbonates that are Middle and Upper Cretaceous in age. The area has been investigated in the framework of the SUBTRAP-consortium in order to reveal the deformation and fluid flow history and diagenesis of the area, the coupling between these processes and finally, to define the controlling parameters on reservoir development and the petroleum maturation, migration and trapping scenario.

To address these objectives an integrated approach is required. The deformation history is examined by the reconstruction of regional cross-sections based on available surface and seismic data, by structural mapping and microtectonic studies and ultimately, by kinematic and thermal modelling exercises with the THRUSTPACK-software. The result of these exercises is a stepwise model of deformational or thermal stage on discrete time-intervals, reflecting the burial history and the onset and progradation of tectonic deformation through the foreland. To shed light on the fluid flow history different diagenetic phases have been studied by several analytical techniques (classical petrography, cathodoluminescence, scanning electron microscopy, stable isotope geochemistry and fluid inclusion microthermometry). The coupling between deformation agenda and fluid flow history has been realized based on crosscutting relationships of diagenetic phases and the different sets of stylolites. Compaction-related stylolitic planes develop parallel to bedding during burial and are therefore named Bed Parallel Stylolites (BPS). Pre- and syn-BPS phenomena are consequently part of the burial and foreland flexural history. Another set of stylolites develops during layer parallel tectonic shortening (LPS) of the strata and is henceforth named Layer Parallel Shortening Stylolites (LPSS). Syn- and post-LPSS events are interpreted as syn- or post-Laramian deformation.

The central question to be examined is what kind of diagenetic processes and which reservoir potential may be expected in a certain setting (i.e. in a certain position and in a given deformational stage of the foreland) or in other words, is it possible to predict (successful) scenarios based on the present knowledge of geological processes in FFTB settings in carbonates?

The reconstructed evolution from this study comprises the following major episodes: (fig.1)

The pre-BPS history of the Cordoba Platform starts with Upper Cretaceous sedimentation and early diagenetic dissolution and cementation affecting the matrix porosity. Here the original sedimentary environment exerts a major control on porosity preservation/destruction (Ferket *et al*., 2002). Several fracturing episodes are followed by cementation (partly) in equilibrium with the host rock (same mineralogy, cathodoluminescence characteristics and isotopic signature) in an extensional regime. Subsequently, pre-BPS hydrofractures filled with host rock buffered cement are developed and succeeded by the development of a pre-BPS local karst system. The latter scenario is interpreted as an early flexural bulge development, whereby formation water is driven out in a local compressional regime and subsequent local emersion causes karst development. In the same time-interval, slope breccias are deposited at the platform-edge.

With the onset of the tectonic deformation within the hinterland, flysch is deposited in the foreland flexural basin and burial compaction leads to BPS-development (Maastrichtian – Lower Paleocene).

In the short time-interval between BPS- and LPSS-development, several hydrofracturing - brecciation episodes affect the strata locally. Hereby, formation waters are driven towards the foreland and indicate host-rock buffering or slightly higher temperatures and sometimes other mineralogies (dolomite in limestone, fluorite, …).

Since LPS-deformation in FFTB-settings typically indicates the onset of deformation in the foreland (here during Paleocene) and predates folding and thrusting of the strata (e.g. Averbuch *et al*., 1992; Mitra,1994; Tavarnelli, 1997; Storti & Salvini, 2001), LPS-features can be opened during subsequent folding of the strata (here starting from Upper Paleocene) and consequently form fluid pathways.

Post-LPS fractures are cemented by meteoric fluids, as deduced from cathodoluminescence characteristics and isotopic signatures, and a telogenetic karst system develops in the western part of the Cordoba Platform due to post-orogenetic exposure.

At the thrust front, thrust-emplacement is associated with intensive hydrofracturing-brecciation of the dolomitic lithologies above the major thrust plane. These fractures are partly cemented with bacterial mediated crenulated calcite crystals, possessing a depleted isotopic signature (around –30‰PDB for $\delta^{13}C$) that points towards methanogenesis. These curious precipitates are the result of the concurrence of several circumstances: oil-maturation in the adjacent foreland basin (~ Eocene), thrust-emplacement with associated intensive fracturing and the inflow of meteoric water from a nearby emersion surface. An important increase in porosity and permeability occurs at this stage, but the risk is that the seal can also be affected by this intensive fracturing.

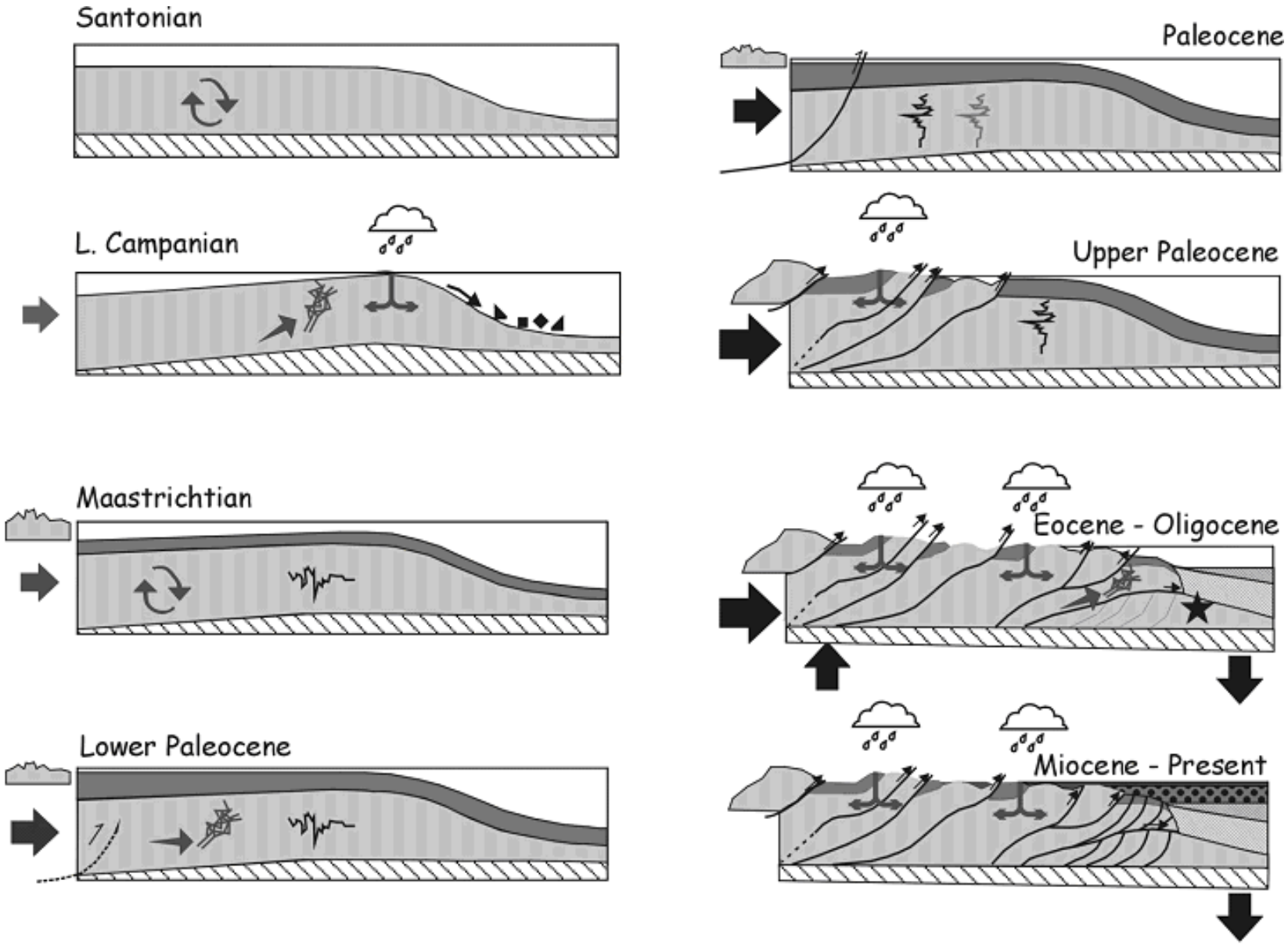

Figure 1: Reconstructed foreland deformation and fluid flow history in the Cordoba Platform and adjacent Veracruz Basin.

Oil-migration is one of the latest phases in the FFTB-evolution, because temperatures did not rise high enough in the superficial thrust sheets, maximum burial of adjacent foreland units being delayed until post-Laramian, Oligocene to Neogene subsidence of the Veracruz Basin to reach the oil window. Oil then starts to migrate either towards foreland structures or towards the adjacent frontal thrust sheets. The occurrence of many oil-stained stylolites shows that these initially impermeable features can also play a role as fluid pathways and porosity connectors after LPS-reopening and subsequent fluid flow.

An integrated approach whereby diagenesis and fluid flow history can be placed in the deformational context of FFTB evolution gives some new and important insights that may be extrapolated to other FFTB settings in carbonates.

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