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Paleoburial and paleostress history of a carbonate syn-rift reservoir : constraints from inversion of calcite twins and stylolite roughness in the Toca formation (Lower Congo Basin, South Atlantic)

Boubacar Bah¹, Olivier Lacombe¹, Nicolas Beaudoin², Jean-Pierre Girard³, Claude Gout³, and Nicolas Godeau⁴

¹Institut des Sciences de la Terre de Paris (ISTeP), Sorbonne Université, CNRS-INSU, 75005 Paris, France

²Laboratoire des Fluides Complexes et Leurs Réservoirs, Université de Pau et des Pays de l'Adour, E2S UPPA, CNRS, TotalEnergies, LFCR, 64000 Pau, France

³TotalEnergies, Centre Scientifique et Technique Jean Féger - CSTJF, Pau, France.

⁴Université Aix Marseille, CNRS, CEREGE, Aix-en-Provence, France

To construct accurate geological models of reservoirs and better predict their properties, it is critical to have a good understanding of the burial and stress history of the host sedimentary basin over time. Stress and strain are important factors influencing the preservation or reduction of reservoir porosity and permeability. One way to access the orientations and magnitudes of paleostresses is to use paleopiezometers. This study aims at reconstructing the stress and burial history of the syn-rift Barremian (130-125 Ma) Toca Fm in the Lower Congo basin (West African passive margin) using stress inversion of calcite mechanical twins and sedimentary and tectonic, bedding-parallel stylolite. This combined approach was applied to two oriented borehole cores drilled in a poorly deformed oil field, offshore Congo, and provided constraints on both paleostress orientations and magnitudes. The timing of the different paleostress regimes documented was derived from a burial-time model reconstructed by use of TemisFlow™.

The inversion of calcite twins was performed on a widespread early diagenetic cement (dated 127.4 ± 4.9 to 123.1 ± 7.7 Ma by U-Pb LA-ICPMS) and revealed two types of stress regimes. (1) An extensional stress regime with σ_1 vertical and σ_3 oriented either $N50^\circ \pm 20^\circ$ or $N120^\circ \pm 20^\circ$, and mean differential stresses of 45 MPa for ($\sigma_1 - \sigma_3$) and 20 MPa for ($\sigma_2 - \sigma_3$). The NE-SW ($N50^\circ \pm 20^\circ$) extensional direction, which restores to $N100^\circ$ after moving back Africa to its position at Barremian times, marks the syn-rift extension that led to the opening of the South Atlantic. The 120° direction (\sim N-S after restoration) possibly reflects local perturbation and/or $\sigma_2 - \sigma_3$ permutations during rifting in response to tectonic inheritance. (2) A compressional or strike-slip stress regime with horizontal σ_1 oriented \sim E-W (and associated N-S extension) and mean differential stresses of 40 MPa for ($\sigma_1 - \sigma_3$) and 15 MPa for ($\sigma_2 - \sigma_3$). This suggests that the basin underwent a post-rift compressional history during the continuous burial of the Toca formation possibly related to the Atlantic ridge push effects. For the first time, we also reconstructed paleostress orientations from "tectonic" bedding-parallel stylolites, that developed during a tectonic extensional phase. The results point to a NE-SW extension consistent with the direction of

the syn-rift extension revealed by calcite twinning. In order to constrain the sequence of stress evolution, we used the results of sedimentary stylolite roughness inversion paleopiezometry, which documents that the burial-related pressure solution in the Toca Fm occurred in the 400-1700m depth range (dissolution along 90% of stylolites halting between 700 and 1000m). Projection of this depth range onto the TemisFlow™ reconstructed burial-time curve of the Toca Fm indicates that vertical pressure solution was active between 122 and 95 Ma, and therefore that σ_1 switched from vertical to horizontal around 95 Ma. Our study reveals that the Toca Fm has undergone a complex polyphase stress history during burial, with stress regimes evolving from extensional to compressional/strike-slip. It also illustrates the great usefulness of combining stress inversion of calcite twins and stylolite roughness with a burial-time model to constrain the stress history of a deeply buried reservoir.