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Fluid/rock interaction in extensional setting: a complex contribution from exhumed mantle and crustal fluids – Case study of the Aptian "Pre-salt" carbonates

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The Lower Cretaceous oil reservoirs of the Santos Basin are subject of many debates concerning the sedimentology, diagenesis, and current fluid compositions (hydrocarbons, water, CO_2). The present study brings some new insights on (1) the origin of modern brines, (2) the spatial distribution of dissolved CO_2 integrated with the structural setting, (3) the modern diagenetic state of the reservoirs and their evolution through time due to complex fluid/rock interaction. This study integrates for the first time in this area element analysis (anions, cations, trace metals), and isotopic data ($\delta^{18}O$, $\delta^{2}H$, $\delta^{7}Li$, $^{87}Sr/^{86}Sr$, $\delta^{34}S_{SO4,}$ $\delta^{18}O_{SO4,}$ $\delta^{11}B$), coupled with rock observations. Additionally, thermodynamic models using PHREEQC allowed (1) to compute the modern CO_2 partial pressure at reservoir conditions, and (2) to simulate the diagenetic evolution through the modelling of fluid/rock interaction. We show that fluid origins and fluid/rock interaction processes can be similar at basin scale. It also shows that isotopic equilibriums are reached for some isotopes ($\delta^{7}Li$, $^{87}Sr/^{86}Sr$, $\delta^{34}S_{SO4}$) with minerals of host formations. Very high values for δD of water and some metals high concentrations may indicate that evaporation is not the only process controlling the water composition, but (1) deep brines of mantellic origin and (2) basinal brines interacting with the continental crust may contribute to the system. The calculation of saturation indexes and XRD analyses shows two opposite situations, one where Mg-clays minerals are still at equilibrium and a second where this phase is undersaturated. The calibration of their structural formula allowed the calculation of specific equilibrium thermodynamic constants. Consequently, we are showing how CO_2 transforms Mg-clay mineral into dolomite and quartz, which is validated by an inverse model. These models are easy to replicate for the diagenetic studies, with strong impact on reservoir quality predictions. Our numerical diagenetic model allows to discuss about CO_2 partial pressure required during diagenesis and its influence on reservoir quality. Several broad implications can be foreseen from this study: (1) CO_2/clay interaction is demonstrated at reservoir scale opening new leads for CO_2 storage by mineralization, (2) high trace metals contents (such as Li) in such setting could open new economic perspectives.