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Geological characterisation of the Oliana anticline, an analogue of a geothermal reservoir (South Pyrenees)

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The Oliana anticline in the Southern Pyrenees has been characterised as a potential outcrop analogue of a geothermal reservoir using field, petrographic and petrophysical analyses of fifty-two samples collected in the folded sequences that comprise conglomerates, sandstones, limestones, marls and gypsum. Five lithofacies (i.e., conglomerates, hybrid arenites, lithic arenites, carbonates and evaporites) were established based on the petrographic characteristics of sixty-three thin sections. Petrophysical measurements of forty samples from plugs oriented parallel and perpendicular to bedding indicate mineral densities varying from 2.334 to 2.767 g/cm^3, bulk densities from 2.107 to 2.710 g/cm^3, porosities from 0.42 to 22.14 %, permeabilities in the order of 10^{-19} to 10^{-13} m^2 (0.001 to 393 mD, respectively) and velocity of compressional acoustic waves ranging from 2236 to 6322 ms^{-1}.

These results evidence a negative linear correlation between porosity and bulk density and between compressional waves velocity and permeability. The lithofacies characterisation explains the petrophysical variability of the Oliana anticline. Thus, mineral composition, matrix content, and grain size were the most critical petrologic factors affecting porosity development and the consequent bulk density and permeability variability. In addition, petrophysical variability is also produced by diagenetic processes such as fracturing and dissolution. Fracturing significantly affected the rocks of the anticline's northern limb, producing high permeabilities. In contrast, dissolution was the principal porosity-forming mechanism at the southern limb, producing punctual and disconnected porosity with low associated permeability.

The thermal conductivity measured in thirty-five samples using a TCi analyser and the Transient Plane Source (MTPS) method reveals a slight positive correlation between thermal conductivity and mineral density and between the samples stratigraphic position and thermal conductivity. Slight compositional heterogeneities between samples from different syn-orogenic units explain the last correlation. A low conductive (from 1.846 to 3.232 Wm^{-1}K^{-1}) area matched carbonatic and evaporitic succession, mainly located in the core of the anticline. In contrast, a high conductive zone (from 2.549 to 3.646 Wm^{-1}K^{-1}) is associated with the detrital syn-orogenic succession found in the fold limbs.

Our observations also suggest that thrusting in the north of the Oliana anticline conditionate the distribution of facies and precipitation of calcite cement. Proximal facies (i.e., conglomerates) are located at the northern limb, whereas distal facies (i.e., sandstones) are predominant at the southern limb of the anticline. Furthermore, higher fracture density and cementation have been observed at the north than at the south, probably associated with intense tectonic stress and fluid circulation through the principal thrust planes.

Based on rocks' thermal properties and permeability values, the Oliana anticline is classified as a petrothermal system because low permeabilities would disable convective heat transfer through sedimentary succession. Future research should study fracture permeability, as it could significantly improve the overall permeability of the structure.