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Outcrop analogue study of carbonate caprock stringers for CCS and geothermal reservoir: the petrophysical and petrothermal properties of the upper Muschelkalk in the Estopanyà salt wall (South-Central Pyrenees)

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Salt is playing a principal role in the current energy transition. From diapirs to salt walls, salt structures are being proposed for a growing number of non-fossil energy purposes and carbon-neutral projects (i.e., geothermics, hydrogen storage in salt caverns or CCS). However, diapiric structures are not uniform and exhibit significant compositional and structural heterogeneities that prevent an easy characterization and exploration, thus increasing the risk of exploitation. Compositional heterogeneities within salt structures arise by the occurrence of different rocks inherited from the original Layered Evaporite Sequence (LES) and transported during salt flow or created through various diagenetic processes during diapirism (e.g., caprock formation).

One of the most common heterogeneities found in salt bodies is the presence of heterometric rock masses known as stringers. The limestones of the upper Muschelkalk (M3) facies (Middle Triassic) are the primary non-evaporitic lithological unit within the Triassic LES of the South-Central Pyrenees. These limestones are exposed throughout the South-Pyrenean fold-and-thrust belt embedded in mudrocks and gypsums of the Upper Triassic Keuper facies, forming the actual caprock exposures in the region. The Estopanyà salt wall is located in the westernmost part of the South-Central Pyrenean Zone, within the Serres Marginals thrust sheet. This area shows a well-preserved 58 km^2 caprock exposure formed by Middle and Upper Triassic rocks that surround two adjacent salt-embedded basins known as the Estopanyà and Boix synclines. According to the stratigraphic record of these synclines, from the Upper Cretaceous to the Oligocene, the evolution of the area resulted in salt withdrawal leading to salt inflation and the occurrence of several E-W-oriented salt walls that were exposed during the deformation onset in the Lower Eocene (early Ypresian times).

The M3 stringers in the Estopanyà salt wall are embedded in a caprock matrix formed by the

dissolution of halite on the surface, albeit its presence has been proposed at deeper levels based on gravimetric models. The stringers have been identified and mapped, forming decameter-thick and kilometre-long structures showing significant folding and fracturing as well as a well-preserved stratigraphic sequence. The basal part of these stringers is formed by a layered to tabular millimetre-to-centimetre-thick limestones whilst the upper part consists of tabular to massive centimetre to meter-thick limestones. The current contribution presents the petrophysical (i.e., mineral density, connected porosity, permeability and P-wave velocity) and petrothermal (thermal conductivity and specific heat capacity) properties of 40 samples collected throughout the eastern Estopanyà salt wall, covering the basal and upper succession of various stringers. The sample analysis enables us to discuss the factors controlling the studied rock properties and the viability of carbonate stringers as geothermal reservoirs and CCS, which is a novel study that can be replied in similar salt structures worldwide.