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Structural and thermal development of the Atlantic margin offshore Essaouira (Morocco) – evidence of salt extrusion and implications for hydrocarbon exploration

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Along the east–west regional seismic line BGR11-202 (MIRROR campaign, 2011), several distinct salt diapirs and related structures can be identified close to the present day coast line. The subsalt structure is only very poorly imaged. Further offshore, rotated fault blocks are overlain by Mesozoic and Cenozoic sediments. Towards the west, the evidence for past volcanic activity is increasing (necks, dykes, and sills). The magnetic anomaly S1 is roughly situated west of the most western identifiable salt structure. The aim of our study is to describe and verify possible salt tectonic and related thermal models and the evolution of the petroleum systems.

One salt structure in particular shows clear evidence of salt extrusion in the past. We explain the potential scenario of the salt diapir development and extrusion in a series of structurally restored sections: After deposition, probably within the syn-rift Liassic half grabens (not imaged), the salt quickly became instable due to differential loading, assisted by growing density contrast with the overburden. It forced its way up using weak zones—which could have been the active normal faults—while the overburden collapsed into the previously occupied space (salt withdrawal). Even though the salt was constantly rising, it did not reach the surface due to constant burial. Only once the sedimentation rate decreased—during the late Cretaceous and early Paleogene—the salt extruded and crept down the continental slope onto the hiatus unconformity. With the extrusion, the salt partly dissolved in contact with the ocean water, and a cap rock formed. The related paleorelief was buried by the detritical sediments provided by the Atlas orogenesis. At present day, these paleoreliefs still have a bathymetric expression, as they are providing an unstable underground and trigger normal faulting and local resedimentation. Also remobilization of the salt, even though strengthened by the cap rock, might be possible locally.

Three of the four salt diapirs identified on the BGR11-202 profile are situated at the same stratigraphic level. Only the westernmost diapir is stuck deeper and did not seem to have extruded in the past (at least in the 2D section). This suggests that along-dip lateral variability exists in the structural style of the salt diapirs. This could be due to initial composition or deposition amounts, or, as it could be an explanation for the latter case, increasing volcanic content towards the west. The lack of identifiable salt structures in the east (out of section) could be explained by the increasing strength of the Jurassic carbonate platform, preventing the underlying Liassic salt to rise.

We performed basin modelling based on the above described structural scenario to develop and test several thermal scenarios through geologic time. Both the presence and influence of the ocean-continent transition and the related volcanic activity are discussed. The salt extrusion provides excellent trapping and sealing conditions for the truncated early Cretaceous potential reservoirs. By the means of petroleum systems modelling, which uses both the structural and thermal models, we discuss and evaluate the trap versus charge timing of the salt-related plays.