3D seismic imaging reveals salt-magma interactions in the Santos Basin, offshore Brazil

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Many sedimentary basins worldwide host extensive evaporite deposits, which through salt tectonic processes can form a variety of complex salt structures and diapirs. Many of these basins also host extensive networks of igneous intrusions. It thus seems inevitable that, in some scenarios, magma intruded into a sedimentary basin will interact with salt. However, we have a poor understanding of how the unique rheological and compositional properties of salt, or the local stress states developed around salt bodies, may influence the emplacement and composition of magma. For example, do evaporites and associated salt structures provide preferential flow pathways for ascending magma, or do they capture magma? We also do not know how the interaction of hot magma with salt, or the presence of crystallised intrusions within salt, may impact halokinesis. To understand how salt and magma interact, it is critical to investigate both their structural and chemical relationships within a framework where the timing of intrusion, evaporite deposition, and salt movement is well-constrained. Key problems with this ideal approach to unravel salt-magma interaction are: (i) field (or outcrop) exposures of intrusions within salt allow chemical and small-scale structural analysis of magma-salt interactions, but provide little insight into how the whole system behaved in 3D; whilst (ii) seismic reflection images of intrusions within salt bodies reveal their 3D architecture and may provide insight into the impact of magmatism on halokinesis, but do not allow chemical or small-scale structural analysis, unless drilled.

Here, we use 3D seismic reflection data from the Santos Basin, offshore Brazil to characterise the structure of, and relationships between, 38 igneous sills emplaced below, within, or above a Lower Cretaceous evaporite layer. Salt movement initiated soon after deposition, primarily driven by gravity-driven extension, and continued throughout most of the Cenozoic but with different kinematics and degree of salt rise and diapirism throughout the study-area. In the area hosting the sills, Late Cretaceous-Cenozoic deformation was dominated by continued extension with limited salt rise and diapirism. Conversely, in the area where no sills are recognized, Late Cretaceous-Cenozoic salt tectonics was characterized by passive/active diapirism and localized shortening.

There is little overall geometrical difference between sills emplaced below, within, and above the
salt, but we note that many intra-salt sills appear more segmented. Seismic-stratigraphic relationships indicate sill emplacement occurred during several episodes in the Cretaceous between the Turonian-to-Santonian. We suggest this phase of magmatism, which separated the major Albian-Cenomanian and Cenozoic periods of salt movement, locally inhibited diapirism and thereby changed the mode of basin deformation. We attribute this local change in salt diapirism to: (i) crystallisation of igneous sills, which locally increased the mechanical strength of salt and overburden, limiting salt rise and acting as buttresses to lateral salt movement; and (ii) melting and assimilation of weak evaporite layers (e.g., carnallite), which usually act to lubricate salt movement, into the magma. These results shed light into the interaction of two common and important structural processes in sedimentary basins that are relatively well studied separately but whose interaction is often overlooked.