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Syn-tectonic sand intrusions - an added complexity to a highly deformed fold and thrust belt and implication for subsurface structural interpretation: Eastern Carpathians Bend Zone, Romania

Dan Mircea Tamas[1], Alexandra Tamas[2], Zsolt Schleder[3], and Csaba Krezsek[4]
[1]Geology Department, Babes-Bolyai University, Cluj-Napoca, Romania (danmircea.tamas@ubbcluj.ro)
[2]Department of Earth Sciences, Durham University, Durham, UK
[3]OMV Exploration & Production GmbH, Vienna, Austria
[4]Exploration B.U., OMV Petrom, Bucharest, Romania

Fold and thrust belts are a notorious challenging environment when it comes to providing structural models for the subsurface, and the Eastern Carpathians Bend Zone (ECBZ) is no exception.

Hosting the largest onshore oil fields in Romania, this is a highly mature hydrocarbon area, with most of the fields producing since the late nineteenth century. Characterise by superimposed tectonic events, most notably the mid-Miocene compression (when most of the shortening occurred) the area is also well known for multiple detachment levels and salt tectonics. As a consequence, the reservoirs, especially the Oligocene - lower Miocene (sub-salt), thought very prolific are structurally complex, heterogeneous and compartmentalised. It is a constant struggle for the geologist to create structural maps of these reservoirs due to complex deformation, inconsistent data and poor seismic resolution. Some of the most significant issues are related to scattering of dip data and the overall difficulties in correlating well logs. In some cases, even the logs of the side-track well do not correlate with the initial log.

In order to get a better understanding of these complex structures, we used the nearby Oligocene - lower Miocene surface exposures. First, detailed fieldwork coupled with drone photogrammetry and interpretation of 3D virtual outcrop models revealed that upright, gently plunging folds as well as overturned and recumbent folding occurs at these stratigraphic levels. Fold limbs are occasionally cross-cut by forethrust or backthrust. Also, parasitic folding and fold-accommodation faults have been identified. Apart from this rather complex but typical tectonic structures, a network of sand intrusions is also present in the Oligocene - lower Miocene sequence. The injectites, dykes, sills or composite intrusions are sourced from the quartz-rich sandstones and injected into the adjacent rocks. The dyke networks are intersecting the adjacent rocks at high angles and appear to follow fold-related fractures. Also, some preserved fluidized layers respond to fold tightening by thickness redistribution and intrusion. Injection is therefore considered to be syn-kinematic with the mid-Miocene tectonic stage when most of the shortening in the area occurred. Intrusion was most likely driven by the fluid overpressures built up due to active

contractional tectonics, with intrusion events potentially triggered by associated seismicity.

Their presence can explain some of the reservoir heterogeneities and challenges in well correlation. For example, one well through a misinterpreted dyke will provide misleading information regarding reservoir architecture, including dip data and highlighting that not every change in dip is due to folding or faulting. Finally, as the dykes commonly follow fold-related fractures, it is highly possible to intrude fault planes as well, thus potentially influencing the shale gouge ratio and fault seal capacity.

The outcrops in the ECBZ are good surface analogues for global examples of hydrocarbon reservoirs affected by remobilized sand intrusions. A better understanding of these complex structures, especially in a compressional setting, can improve both subsurface structural interpretation and reservoir characterisation.