Using Polygonal Fault Systems to Reconstruct the State of Stress Associated with Salt Diapirs

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Salt diapirsim dramatically influences the architecture and fill of sedimentary basins. Reconstructing salt growth is therefore a vital part of hydrocarbon playmaking in salt basins. One of the major risks in diapir flank plays is the role of fault seal, and the geomechanical context of the fault families in these flank areas is thus paramount. Using 3D seismic data from the Central North Sea we show how the geometry of polygonal fault systems (PFS) can be used to reconstruct the state of stress around salt diapirs. Polygonal faults are non-tectonic fault systems that develop during early burial and compactional dewatering. Under passive loading of a horizontal substrate undergoing 1-d consolidation, the maximum principle stress ($\sigma 1$) acts vertically downward. The intermediate and least principle stress ($\sigma 2$ and $\sigma 3$) act in the horizontal plane without any preferred orientation, giving rise to a polygonal fault pattern. In seismic data PFS are organised into a series of stratigraphically confined intervals (tiers) which are representative of distinct periods of deformation.

Seismic data shows that stratigraphic units containing polygonal faults have been pierced by several salt diapirs. Dip maps of horizons within polygonal fault tiers show that closely spaced radial faults exist close to the salt margin and merge into polygonal faults at varying distances from the salt diapir. The width of the radial fault zone approximates the diameter of the salt diapir but is seen to vary throughout different tiers. Critically, fault mapping shows that radial faults are tier bound indicating that radial faults are preferentially aligned polygonal faults, termed here hybrid polygonal faults (HPFs).

HPFs allow us to map the change in orientation of $\sigma 2$ which is parallel to fault strike. We attribute the radial alignment of polygonal faults to the circumferential stretching that occurs in sedimentary units onlapping growing diapirs. By calculating and mapping the palaeo-stress for successive polygonal fault tiers we present an alternative approach for reconstructing salt growth that provides novel constraints on relative magnitudes and orientations of the principal stresses. PFS have been documented in over 100 sedimentary basins worldwide making this technique applicable beyond the North Sea. Additionally, given the sensitivity of PFS to local anisotropy of stress fields this technique may be used to understand other complex structures that develop in sedimentary basins.