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The role of mobile shale in forming fold belt anticlines and hydrocarbon accumulations in Sabah Basin, Malaysia

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The Sabah Basin consists of a thick, clastic sedimentary succession deposited as a consequence of Miocene uplift and rapid erosion of the Sabah land massif, where sediment input greatly exceeded accommodation space along a narrow shelf, causing shelf-margin instability. This resulted in episodic massive slope failures generating mass transport deposits and prolific turbidite deposition from Middle Miocene to Pliocene times. The high sediment loading on the shelf resulted in overpressuring of the Setap Shale at depth which, coupled with episodic regional compressional tectonics of the South China Sea, generated fold belt anticlines outboard of the shelf margin that form major hydrocarbon traps in the study area.

The distinction on seismic between overpressured shale and the effects of gas is often difficult to differentiate in these deepwater structures, as the acoustic velocity of overpressured shale is comparable to gas saturated formations (as low as 1500-1700m/sec). This necessitates careful analysis of mobile shale analogues in the vicinity. In general shale ridges have smooth surfaces, while intrusions exhibit pipe-like morphology. The intrusion of mobile overpressured shale typically causes deformation and fracturing of the surrounding sediments, which may affect the underlying source rock interval, thus facilitating hydrocarbon migration.

In this study, we model the movement and intrusion of shale bodies by assuming a constant shale volume during structural deformation, and by applying the algorithms for intrusion and fracturing in PetroMod 3DTM software. Three “shale facies” including stable shale, mobile shale and mud-volcano are established for mobility modeling with different physical parameters such as density, viscosity, frictional angle and cohesion. During pore pressure evolution, it is noted that when pore fluid pressures reach up to 80% of lithostatic stress, hydraulic fracturing will occur and fluids expelled from stable shale. On the other hand, the light, highly viscous and less frictional angle shale will start to mobilise. In the model, the effects of forces due to Pliocene tectonic inversion were also modeled by adjusting the boundary conditions including pressure, displacement and shearing.

The resulting hydrocarbon generation model shows that gas expulsion could contribute to mobile Setap Shale movement. The modeling results provide a better understanding of pore pressure regime, shale diapirism, likely migration pathways and hydrocarbon phase type and distribution associated with the fold belt anticlines of the Sabah Basin.