3D Delaware Basin Petroleum System Evoluton: Solution of the Basin Inverse Boundary Value Problem

John D. Pigott[1], Kulwadee L. Pigott[1], Esra Yalcin[1,2], and Michael T. Williams[1,3]

[1]University of Oklahoma
[2]TPAO
[3]XTO

ABSTRACT

Basin deconstruction precedes basin construction in basin evolution model building. But significant absences of information owing to erosion commonly obscure the quantification of initial conditions. Irreversible entropic increases in organic maturities further mitigate the ability to determine pathways. However, solution of the basin inverse boundary value problem is possible if sufficient redundant criteria are used for geovalidation and the models are constrained stratigraphically. As an example, the post Silurian evolution of the Delaware Basin and its interior petroleum systems is complex and not amenable to a single maturity model. Integration of 1D, 2D and 3D basin models incorporating stratigraphic-lithologic-geochemical-thermal information gathered from 150 wells in the basin reveal four major tectonic episodes: (1) A Tobosa Rifting Phase (488-320 Ma), (2) A Permian Basin Phase (320-250 Ma), (3) A Stable Platform Phase (250-80 Ma), and (4) A Cenozoic Tectonic Uplift Phase (70-0 Ma). Heat flow values determined from borehole temperatures and lithologic conductivities range from 0.6 to 1.4 HFU, with an average of 1 HFU, and show higher heat flows in the western relative to the eastern side of the basin. However these present day heat flow values cannot be uniquely inverse geovalidated by vitrinite reflectance (Ro%) and pyrolysis maximum temperature (Tmax) measurements, as the basin's evolving thermal history and affected petroleum systems are not the product of simple crustal extension events. Instead the Delaware Basin's evolution results from episodes of stretching and flexure which have varied spatially throughout the basin. Whereas rapid subsidence during the Permian is caused by tectonic crustal stretching on the western side, subsidence on the southeastern side which is proximal to the Marathon-Orogenic belt and Central Basin Platform thrust fault is a product of lithospheric flexural downwarping. The effects upon hydrocarbon maturities are profound. The 1D and 2D models illustrate the western side of the basin to have higher vitrinite reflectance maturity values with respect to the oil window: the Simpson is late mature, the Woodford and Barnett mid mature, and the Wolfcamp early mature. By comparison, in the southeastern the Simpson is mid mature, and the Woodford and Barnett shales are in the early mature oil window. Consequently, 3D maturity-migration pathway mapping suggests extensive oil and gas traps to be located on local highs within the depocenter of the basin and to the northeast and toward the Central Basin Platform for the Woodford, Barnett and Wolfcamp. In contrast, the Bone Spring, the youngest source rock defined in this study, exhibits migration pathways which vector both toward the western edge of the basin and pond in possible sweet spots to the East. This approach to solving the basin inverse boundary value problem for the polyhistory Delaware Basin reveals a heterogeneity of potential stratal-dependent fairways for existing and future conventional – unconventional petroleum exploration strategies.