Hydrodynamics and geophysical characteristics of the overpressure system in the Permian basin: Implications for hydrocarbon migration

By
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This study combines numerical modeling techniques with field data to establish the hydrogeologic framework of the Delaware basin and the Central Basin Platform (CBP). Geophysical well data including sonic, porosity, and resistivity logs were used to interpret the distribution of overpressure and the characteristics of pressure seals in the Delaware basin. The overpressure zone is generally associated with geophysical anomalies of low resistivity, low bulk density, high seismic transit time, high porosity, and high seismic frequency. Above and below the overpressure zone, the presence of high neutron porosity and low-density porosity anomalies implies that gas capillary seals may exist and limit the dissipation of overpressures. Large number of small earthquakes (M<3) occurred within the overpressure zone and near the transition zone between the overpressured shales and normally pressured facies. Although it is difficult to determine the mechanism of these earthquakes, their occurrence suggests that hydrofracturing and large pressure gradients in the transition zone would episodically facilitate fluid migration away from the overpressured zone. Variation of permeabilities in the West Platform fault zone accompanying fault block motion was investigated to study regional fluid flow between the Delaware basin and CBP. Our numerical model predicts that the permeability of West Platform fault zone could significantly affect maintenance and dissipation of overpressure, regional flow pattern, and long-distance hydrocarbon migration. An extremely low-permeability fault zone could maintain overpressure to the present-day whereas a permeable fault zone would act as a main pathway for fluid migration. Episodic dewatering through hydrofracturing processes induced by hydrocarbon generation in the Mississippian-Pennsylvanian shales could better explain primary and secondary migration of hydrocarbons from the deep eastern Delaware basin to the shallow CBP reservoirs. This hydrologic model is consistent with field geophysical anomalies and seismic activities.