Tectonic Controls on Porosity of Cretaceous Siliciclastic Oil and Gas Reservoirs of the Rocky Mountains

Covault, Jacob A.[*1]; Craddock, William H.[1]; Blondes, Madalyn S.[1]; Houseknecht, David W.[1] (1) U.S. Geological Survey, Reston, VA.

Assessment of carbon dioxide and hydrocarbon storage opportunities in saline aquifers is difficult in settings that lack context from petroleum exploration and production. Predictions of reservoir porosity generally are not well constrained, but they are particularly important factors in calculations of resource volumes. We employ a database of 645 mean porosity measurements from Cretaceous siliciclastic oil and gas reservoirs of the Rocky Mountain region (Nehring Associates) to interpret geologic controls on porosity. In Wyoming, Cretaceous strata have been buried to depths between ~2-14 km and, assuming a conservative geotherm of 15°C/km for the region, were exposed to temperatures between ~40-220°C (surface temperature of 10°C). Cretaceous siliciclastic reservoirs were deposited in a breadth of environments of the Western Interior foreland basin. In spite of varied thermal and depositional histories, we document a formation-independent relationship of diminishing mean porosity with depth to reservoir top.

The decrease of porosity with depth appears to be controlled in two fundamental ways by the tectonic setting at the time of deposition. First, tectonics controlled framework grain composition, with mostly lithic arenites deposited in the Cretaceous foreland basin setting. Second, tectonics controlled the rate of subsidence and sediment influx, thereby exerting an important influence on the nature and duration of the stress regime during burial. Lithic arenites deposited in the foreland basin were buried rapidly, facilitating compaction of ductile framework grains during shallow burial before precipitation of significant volumes of chemical cements. In contrast, Paleozoic-Jurassic passive-margin quartz arenite reservoirs of the Rocky Mountain region exhibit more variability in porosity-depth relationships within similar aged strata and between formations, especially at shallower depths. Quartz arenites deposited on the passive margin generally were buried slowly, permitting time for occlusion of porosity by chemical cement precipitated within a framework of rigid grains during shallow burial before significant compaction could occur. During deeper burial, quartz arenites are susceptible to chemical compaction and related cementation whereas the development of overpressure resulting from compaction disequilibrium and hydrocarbon generation may inhibit compaction and cementation in lithic arenites. Our results suggest that the tectonic setting of a sedimentary basin, which influences rates of accommodation creation and sediment supply, dictates the relative importance of original depositional processes, compaction, and cementation in determining reservoir porosity. Insights provide predictions of porosity in retroarc foreland basins characterized by quartz-rich reservoir strata, rapid burial, and overpressure.