Impact of Magmatic Intrusion on Diagenesis of Shallow Marine Sandstones: Example from Qasim Formation, Northwest Saudi Arabia

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Abstract

Igneous intrusions are common in sedimentary basins, and their occurrence can significantly affect the diagenesis and reservoir quality evolution of sandstone, thereby impacting their hydrocarbons-, geothermal-, and CO_2-storage potentials. The Qasim sandstones in the Tabuk region (NW Saudi Arabia) had experienced shallow burial diagenesis (< 2 km) when Tertiary magma (related to the opening of the Red Sea) intruded to form basaltic sills (0.4 to 4 m thick). The sedimentology, tectono-stratigraphic framework, provenance and chemostratigraphy of the Qasim Formation have been well documented in the literature. However, the impact of the magmatic intrusion on diagenesis and reservoir quality evolution of the sandstones remains enigmatic. This study employed thin-section petrography, QEMSCAN, XRD, SEM, and EDS analyses to investigate the role of magmatic intrusion on diagenesis and reservoir quality of the Qasim Sandstones. Results of the study indicate that reservoir porosity is primarily influenced by primary depositional characteristics (grain size and sorting), diagenetic alterations, and magmatic intrusions. Sandstones with coarser grain size and better sorting have the best intergranular porosity and vice versa. The “normal” diagenetic processes that have significantly affected the reservoir porosity of the sandstones occurred during both shallow burial (eodiagenesis) and uplift (telodiagenesis). The eogenetic alterations include mechanical compaction, early cementation by calcite, pyrite, kaolinite, whereas the telogenetic alterations include the formation of kaolinite, goethite, hematite. Overall, mechanical compaction is the main driver for porosity loss in the sandstones. The intrusion-related diagenetic processes include the dissolution of detrital quartz and calcite cement and the transformation of kaolinite into dickite and chlorite. The transformation of kaolinite into dickite occurred in a dissolution-recrystallization fashion. The magma-induced dissolution of goethite supplied the requisite high Fe content required for chloritization of kaolinite. Additionally, the intrusion has resulted in the dissolution of the early calcite and an increase in porosity towards the sill contact. However, values for compactional porosity loss have relatively remained the same at both close to and away from the sill contact, as the sill is too thin to exert significant vertical loading. This study has relevance to understanding hydrocarbon exploration and exploitation in sediment-lava sequences, and to understanding the development of sediment-lava systems.