Impact of Basin Architecture on Diagenesis and Dolomitization in a Fault-Bounded Carbonate Platform: Outcrop Analogue of a Pre-Salt Carbonate Reservoir, Red Sea Rift, NW Saudi Arabia

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ABSTRACT

The early Miocene Wadi Waqb Member of the Jabal Kibrit Formation, NW Saudi Arabia, is of great interest both because of its importance as an archive of a pre-salt syn-rift carbonate platform but also as a major hydrocarbon reservoir. Despite this importance, little is known about the diagenesis and reservoir heterogeneity of this succession. This study uses petrographic, elemental chemistry, stable isotope ($\delta^{13}C$ and $\delta^{18}O$) and clumped isotope ($\Delta 47$) analyses to decipher the controlling processes behind the formation of various diagenetic products, especially dolomite, from two locations (Wadi Waqb and Ad-Dubaybah) that have experienced different diagenetic histories. Petrographically, the dolomites in both locations are similar, and characterized by euhedral to subhedral crystals (50–200 µm) and fabric-preserving dolomite textures. Clumped isotope analysis suggests slightly elevated temperatures occurred in the Ad-Dubaybah location (up to 49°C) and a sea surface temperature (~30°C) at the Wadi Waqb location; additionally, dolomitizing fluids at Wadi Waqb had higher $\delta^{18}O_{SMOW}$ values (up to +4‰) compared to those at Ad Dubaybah (up to -3‰). Two different dolomitization models are proposed: a seepage reflux, evaporative seawater mechanism at Wadi Waqb, and a fault-controlled, modified seawater mechanism at Ad-Dubaybah. At Ad-Dubaybah, seawater was modified through interaction with an immature basal sandstone aquifer, the Al-Wajh Formation. The spatial distribution of the dolostone bodies formed at these two locations supports the models proposed here, with the Wadi Waqb location exhibiting massive dolostone bodies while dolostone bodies at Ad-Dubaybah are mostly clustered along the slope and platform margin. Porosity is highest in the slope sediments due to the interplay between higher precursor porosity, grain size of the

Al-Ramadan, K., A. Koeshidayatullah, D. Cantrell, and P. K. Swart, 2019, Impact of basin architecture on diagenesis and dolomitization in a fault-bounded carbonate platform: Outcrop analogue of a pre-salt carbonate reservoir, Red Sea Rift, NW Saudi Arabia: GeoGulf Transactions, v. 69, p. 445–446.

original limestone, and dolomitization. Ultimately, this study provides insights into the impact of carbonate diagenesis in an active tectonic basin and the resultant porosity distribution of a pre-salt carbonate reservoir system.