Large-Scale Hypogenic Karst in the Siliciclastic Wasia Group and its Related Reservoir Intervals: A Hypothesis

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ABSTRACT

On the Arabian Plate, the Cretaceous sedimentary succession hosts a multitude of reservoir rocks, both for hydrocarbons and for water. Some reservoirs are among the largest in the world. Reservoirs are present in siliciclastic as well as in carbonate rocks. The Wasia Group is one of the most important groundwater reservoirs in Saudi Arabia and represents a porous sandstone aquifer. Hitherto, the problem why this reservoir has such extraordinary storage capacities has not been tackled. In this contribution, we present a hypothesis to explain these extraordinary properties. The main reservoir interval is the Huraysan – Majma succession with the Huraysan Formation being equivalent to the Khafji and Safaniyah reservoirs in the subsurface, and in Kuwait to the Burgan 4th sand. The Majma Formation has its equivalents in the Wara Formation. We studied this succession in an outcrop analogue study. Lithologs were measured and the corresponding spectral gamma ray emissions recorded. About 150 samples were investigated in the lab, where porosity, permeability, and their anisotropy were studied. Diagenesis was examined petrographically under the microscope and with REM. Many of the sandstone samples have porosities between 30% and 40%; permeabilities vary between 1 and 9 D. Siltstones have high porosities with values between 15% and 25%; however, permeabilities are much lower than in the sandstones with 0,1 to 10 mD. Neither matrix is visible in thin-section nor clay coatings or cements. Remnants of kaolinitic, dolomitic, and calcitic cement are locally preserved. Corrosion is visible on the surfaces of the grains. It also caused structural disintegrity of feldspar clasts in samples 100s of km away from the source area, which would not have survived transport in their present preservation. Additional information comes from drilling companies. For them, drilling and well construction in the Wasia is a major challenge, even in depth of several 100s of meters. During drilling, mainly loose sand is produced and wells are prone to collapse. Special devices are needed during casing and screen installation to prevent rapid backfill with sand and the subsequent incursion of sand through the screens, which would immediately damage the pumps. We interpret these data and observations presented here to be the effect of large-scale dissolution processes. Large-scale dissolution of carbonate cement (karstification) and of feldspars affected the sediments during diagenesis. It is hardly conceivable that this was an early diagenetic process because the resulting lose fabric should have been compacted with increasing sedimentary overburden and with concomitant pressure solution between quartz grains. In addition, karstification affected rocks, which during a (Cretaceous) sea-level fall were well below the depth of surface karst. Hence, we favor a model of hypogenic karst. Hypogenic karstification is increasingly recognized as a major process in subsurface terrains. One variety of this process is sulfuric hypogenic karstification, in which sulfur released from various sources enhances the effects of dissolution through formation of sulfuric acid. Hydrocarbon source rocks are abundant in the pre-Wasia strata of the Arabian Shelf. Degassing of these source rocks is a likely source for sulfur, which in turn in contact with groundwater formed sulfuric acid. In many areas, groundwater in the Wasia aquifer is warm to hot, which additionally might have increased dissolution of carbonate (and other) cements in the sandstones. Ultimately, we believe that (sulfuric) hypogenic karst may also be responsible for the deep-seated karst in the overlying Aruma and Umm Er Radhuma formations.