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High-temperature mono-well aquifer thermal energy storage (ATES) system in a carbonate dominated horizon

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In the Earth's sunbelt a significant part of the electricity consumption is used for cooling. Therefore technologies are investigated, which use renewable energies like wind or sun. These fluctuating energy sources need a storage system to guarantee a continuous cooling process. A promising option is to use the underground. Aquifer thermal energy storage (ATES), where energy is stored in groundwater bearing formations via hot (or cold) water injection in the aquifer system has been successfully proven in Europe as a seasonal storage. However, in arid climates with no or very little seasonal changes and a high cooling demand over the whole year a storage system has to deliver energy on a daily basis. The aim of this study is to use an ATES system, designed as a mono-well with two separated screens in the same aquifer. During the day heat surpluses will be used to charge the storage with a constant injection temperature of 100 ˚C. The stored energy can then be used as an auxiliary energy source during peak demand and night times when no solar energy is available. The study area is located 40 km west of Muscat, Oman where a solar thermal cooling system will be installed in the framework of a project between the Research Council of the Sultanate of Oman and the Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences. The site is situated in the foreland basin of the Oman Mountains, mainly composed of heterogeneous clastic and carbonate sequences. For the analysis of the heat recovery efficiency (HRF) a detailed 3D hydro-thermal finite element model was developed for the carbonate dominated Cenozoic Seeb Formation. The formation is characterised by a carbonate ramp geometry with km-wide uniform facies belts, starting in approximately 350 m depth at the study area. The ramp geometry results in a layer-cake architecture with relatively homogenous hydraulic and thermal properties within each layer but different discrimination between the layers. New precision T-logs in several wells, scattered over the study area, were performed to analyse the initial groundwater temperature. A mean geothermal gradient of approximately 19 ˚C km^{-1} was calculated and implemented to the model. We analysed the sensitivity of the HRF with respect to the vertical heterogeneities, distance between the well screens and different flow rates. This study clarifies that a mono-well storage system is suitable as daily high-temperature ATES. However, heterogeneities within the aquifer have a significant influence on the HRF.