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Effects of tectonic structures, groundwater pumping, and mining activity on evaporite subrosion and resulting land subsidence

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Subsurface dissolution (subrosion) of evaporites such as halite and gypsum can lead to widespread land subsidence. Observed karst development of evaporites proceeds at the boundary of halite and gypsum and depends, among other factors, on the inclination of the top of rock salt layer and the presence of normal faults, which form pathways for the undersaturated water. The natural process of subrosion may be accelerated if (1) a tectonic setting facilitates vertical groundwater exchange, (2) hydraulic boundary conditions of groundwater flow are altered, and if (3) the study area has a history of salt mining activities. The tectonic setting of the study area is characterized by horst and graben structures delimited by normal faults. A constructed 3D geological model is based on the existing geological information (borehole descriptions, geological maps, and cross-sections) and includes 47 faults and 4 faulted horizons of the main aquifers-aquitards boundaries. Large-scale pumping activities within the shallow carbonate aquifer likely transmit along normal fault zones into the deeper evaporatic formations, causing a density difference dependent upconing of saltwater into the shallow aquifer. In addition, salt mining within the study area has constantly increased over the last 150 years. Field observations and laboratory experiments of salt mining caverns have shown that subsurface cavities form tip-down triangular cavities, which, depending on the presence of embedded clay layers, may enlarge in horizontal direction. Largest observed land subsidence rates over the last 100 years mostly coincide with locations of mined salt fields, and are typically separated by a temporal delay of up to 25 years.