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Origin of mineral and thermal waters

title: **Flow and groundwater chemical evolution in exposed salt diapirs and adjacent country rocks (Zagros Mts., Iran)**

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Zagros Mts. host numerous salt diapirs, which differs in activity, relief, surficial deposits etc. Some diapirs are exposed to arid conditions in low elevation, some are situated in higher altitude in less arid climate. While some diapirs are formed by vast surfaces build predominately by halite, at others the rock salt is covered by 20 m thick residuum, which even enable planting of crops (Bruthans et al., 2009). High variability of environments enabled to select distinct areas for study of water flow a chemical evolution in subsurface of diapirs. The wider surroundings of the salt diapirs are suffering by the scarcity of sources of low TDS water.

To understand the groundwater and soil water flow in various diapirs, its chemistry evolution and source of the high TDS in springs in country rocks adjacent to diapir several methods were applied:

- ^2H , ^3H , ^{18}O and ^{13}C isotopes and solute chemistry of water from saturated and unsaturated zone of diapirs and springs from country rocks were studied to estimate the residence time of water and its origin.
- Rain gages and no tension lysimeters were placed below some surfaces to study the flow via soil zone (isotopes and chemistry) and estimate the subsurface denudation rate.
- Infiltration rate on various surfaces was measured.
- To explain the water chemistry evolution along flow path, the composition of the soil, surficial deposits and rock salt was studied by means of XRD and XRF and solute chemistry was studied from water leaches of soil samples taken in various depth.
- Rain event causing flood was observed directly in the field including direct sampling on solute chemistry and ^2H and ^{18}O isotopes (Fig. 1).



Figure 1. Collection of the water immediately after heavy rain on the bottom of karst sinkhole causing focused recharge, which support the trees growing just ca 10 m above the halite.

Based on ^2H and ^{18}O isotopes, the water in all but one studied spring has meteoric origin. The residence time of groundwater in diapirs is generally short, with springs having tritium activity close to tritium activity of present rainwater. Brines from various diapirs have very similar composition, originating mainly from dissolution of the halite and gypsum. The salt exposures are virtually impermeable and water quickly drains out, causing flash floods. Given the high TDS in drainage the salt exposures are source of large amount of brines, which deteriorate the water quality in wide surroundings of the diapirs. On the contrary the surfaces build by thick soil show infiltration rates, which exceed common rain event except the most intensive ones. On some surfaces the TDS of the soil and surface water is very low (80 mg/L). As most of the water evaporate from these surfaces the amount of generated brine by deep percolation is very low. This enable to distinguish (based on aerial imaginary) the areas, which will be likely heavily polluted by brines from those potentially interesting for groundwater abstraction.

Comparison of $\text{Cl}^-/\text{SO}_4^{2-}$ ratio of diapir brines and springs in country rocks shows that brines derived from diapirs are not responsible for increasing TDS of country rocks springs. Instead, the dissolved solids either originate from Gachsaran formation, which contain evaporate minerals or from dissolution of marginal parts of diapirs (formed mainly by gypsum) by groundwater from country rocks.

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