Evolution of the Dead Sea Brines

Israel Zak
Institute of Earth Sciences, The Hebrew University, 91904 Jerusalem, Israel

Since the beginning of its subsidence in late Neogene times, the Dead Sea Rift has accumulated up to 10,000 m of evaporites and clastics. The sea-flooded part of the Rift, the Gulf of Sedom, and accumulated in its distal part a thick sequence of rock salt known as the Sedom Formation. The entire intra-Rift sequence is defined as the Dead Sea Group.

The Dead Sea Group and the surrounding pre-Rift formations contain large volumes of stagnant and migrating interstitial brines, much of which interacting with neighbouring formations. The so-called Dead Sea brine is the commonest, of Ca-chloridic composition, with over 330 g/l of dissolved salts and with a uniquely high Br content (over 5 g/l). The lake, composed of this brine, fills the over 300 m deep basin of the Dead Sea and may be considered an outcrop of the surrounding underground fossil brine. This water body, and brines known from springs and boreholes around the lake, can all be derived from the mixing and chemical evolution of three basic brines. The first is a diagenetic brine, originally evaporated seawater of the Gulf of Sedom and later modified by Mg-Ca exchange into Ca-Mg-Na-K-Cl-Br water (with Ca2+> HCO3-+SO42-). In this brine, the original (marine) Mg has been exchanged for the Ca of carbonates of the Dead Sea Group and of the surrounding Cretaceous and older carbonate rocks, and most of the original sulfate has been lost through gypsum and anhydrite precipitation with this sequestered Ca. The 87Sr/86Sr ratios in the Dead Sea brine and in evaporates of the Dead Sea Group demonstrate their evolution from original Pliocene open-sea water, through restricted gulf waters and finally to the land-locked Ca-chloridic diagenetic brines. The second type of brine consists of meteoric waters, dilute to mesohaline, with seawater affinity (airborne sea-salts). The third type is a mix of metamorphic brines, which evolved by incongruent alteration and dissolution of hydrous evaporate minerals (e.g. carnallite and gypsum) of the Dead Sea Group. The highly soluble salts are selectively and alternatingly retained in solution, in successive lakes, or recycled from solid deposits formed during periods of desiccation.

The composition of the present-day lake waters, which are Dead Sea brine in the strictest sense, is continuously modified and retained by interacting with these other solutions and by multiple evaporation cycles, with occasional desiccation. The processes are also contolled by mixing along vertical hydraulic pathways along the rift's marginal faults, whose porosity enables brines to sink to depths of geothermal heating. Brine properties and behavior are explained, illustrated, and predicted by application of Jaenecke's version of Gibbs diagrams. The evolution of the Dead Sea brines provides a characteristic hydrochemical model for continental rift basins temporarily connected with the ocean.

Geological analogues: The geochemical evolution of the Dead Sea may be a meaningful model for continental rift basins that are formed in the course of the early, preoceanic rifting of a continental plate. The geochemistry is comparable to the Cachloride evaporites of the proto-Atlantic Sergipe basin (northeast Brazil) and the Congo-Gabon basin (west Africa), and with the recent Ca-chloridic Hot Brine pools of the Red Sea. Indeed, continental rifts are predisposed to endorheic drainage, and as such they are typical, morphotectonic evaporite environments. The often anomalously deep subsidence of continental rift basins favors thick evaporate accumulation and water-rock interaction, and their fault systems enable strong local thermal influences.