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Tracking flow-paths by REE+Y and stable isotopes: the Golan Heights

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Groundwater from the Golan Heights feed to a high degree the most important freshwater reservoir of Israel, the Lake Kinneret. Hence, knowing their sources and characters is an instantaneous demand. Within the "*German-Israeli-Jordanian-Palestinian Joint Research Program for the Sustainable Utilisation of Aquifer Systems*", hundreds of water samples were taken from all over the Jordan-Dead Sea rift-system to understand groundwater flow-systems and salinisation. For that purpose, each sample was analysed for major and minor ions, rare earth elements including yttrium (REY) and stable isotopes of water ($d^{18}O$, $d^{2}H$).

In well developed flow-systems, REY-patterns of groundwater are established in the catchment area by first water-rock interaction and keep unchanged, even if the lithology of the aquifer changes. Except under high temperatures, $\delta^{2}H$ and $\delta^{18}O$ are less controlled by water-rock interaction than by climatic and geomorphological factors at the time of replenishment.

The combined use of hydrochemical and isotopic methods enabled us to define the areas of replenishment and flow-paths of all investigated groundwaters in the Golan Heights. Despite location, salinity or temperature of spring or well waters, stable isotopes showed, that the main area of recharge is the elevated Hermon-Massif, with high annually precipitation amounts. The REY pattern of fresh water from well Alonei HaBashan 3, situated in the Upper Golan Hights, points to carbonaceous infiltration area and stable isotope signatures are lighter than in the recharge of Upper Galilee, while the major element composition refers to a pre-Neogenic limy aquifer and con-

tact to basalts. Further to the south, in the Yarmouk gorge hot Mezar springs occur, which show stable isotope signatures lighter than in water of Alonei Habshan 3. Both, REY pattern and hydrochemistry show contact to Sr-rich limestone aquifer of Mt. Scopus group. That refers to an infiltration some 50 km to the north, the nearest elevated area where carbonates crop out. Nearby Mezar, hot Hammat Gader springs occur, which show comparable isotopic signatures and hydrochemical composition. However, the REY-patterns indicate infiltration in basalts.

By means of those three samples we could show, that the use of a combined hydrochemical and isotopic approach reveals complex and large-scale groundwater flow-systems much better than a focused view on a specific band of elements.