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A multi-tracers mixing-cells model identified and quantified active recharge into a deep Nubian sandstone "fossil" aquifer

PROF. EILON M ADAR, PHD[1], BETZABE ATENCIO[1], ROI RAM[1,2], AVIHU BURG[2], REIKA YOKOCHI[3], YOSEPH YECHIELI[1,2], ROLAND PURTSCHERT[4], ZHENG-TIAN LU[5] AND WEI JIANG[5]

[1]Zuckerberg Inst. for Water Research, Ben Gurion University of the Negev
[2]Geological Survey of Israel
[3]The University of Chicago
[4], Physics Institute, University of Bern
[5]University of Science and Technology of China
Presenting Author: eilon@bgu.ac.il

For about half a century, it has been accepted that the Nubian sandstone aquifer (NSA) beneath the Saharan and Arabian deserts contain ancient water. In light of the lack of precipitation and high potential evaporation, it has been commonly accepted that the Nubian sandstone aquifers are hardly renewable and have therefore been referred to as "fossil aquifers" [e.g., 1].

Being the NSA mostly confined and in places even artesian beneath the Sinai and the Negev deserts, the expectation is that groundwater age will gradually increase downstream from the recharge zone in central Sinai toward the discharge in the southern Dead Sea. However, a ^{81}Kr age distribution along two primary flow paths revealed substantial fluctuations in groundwater ages deployed downstream with ups and downs of tens of thousands of years along a few kilometers (Fig. 1). An age difference of more than 200 kyr (127 ± 15 and 328 ± 27 kyr) was observed between wells located less than 10 km apart, indicating the mixing of ancient and younger groundwater [2;3].

Triggered by ^{81}Kr age distribution, yet independent of the krypton isotopes data, multi-tracers mixing-cells modeling based on a set of mass balance equations of dissolved minerals and environmental isotopes [4] confirmed the following (Fig. 2): the intrusion of old salty groundwater from a deep-seated aquifer, and rejuvenation of groundwater in the NSA is due to substantial active recharge in places where the confinement of the NSA had been breached.

[1] Issar, Bein & Michaeli (1972), J. Hydrol. 17, 353–374.

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[4] Adar, Rosenthal, Issar & Batelaan (1992), J. Hydrol., 136, 333–352.

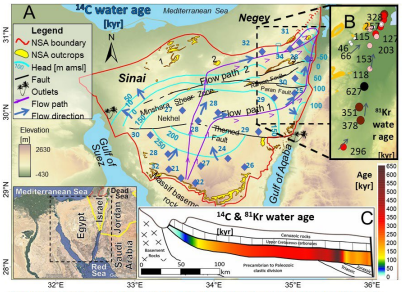

Figure. 1: Homogeneous groundwater age distribution in the Nubian sandstone aquifer based on ^{14}C (A) versus ^{81}Kr ages (B) showing an increase in groundwater age from the aquifer's recharge area in the southern Sinai toward the edge of the Arava Rift valley in the southern Negev, with intermittent rises and falls further north toward the Dead Sea (C). [Modified after Ram et al., 2020].

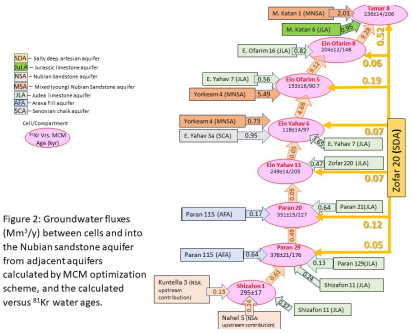

Figure 2: Groundwater fluxes (Mm^3/y) between cells and into the Nubian sandstone aquifer from adjacent aquifers calculated by MCM optimization scheme, and the calculated versus ^{81}Kr water ages.