Radon, radium and helium isotopes in water sources along the Jordan–Dead Sea Rift Valley

T. Moise
Y. Kolodny
Y. Starinsky
Institute of Earth Sciences, The Hebrew Uiversity of Jerusalem, Jerusalem Israel

H. Friedrichsen
K. Hammerschmidt
FR Geochemie, Freie Universität Berlin, Boltzmannstr. 18-20.14195, Berlin, Germany

Radon (^{222}Rn), radium activities and activity ratios (^{226}Ra, ^{228}Ra/^{226}Ra, ^{224}Ra/^{228}Ra) as well as ^{3}He/^{4}He ratios were measured in spring and well waters from the Jordan–Dead Sea Rift Valley (DSR). Our sampling centered around Lake Kinneret (the Sea of Galilee) in the Northern Rift Valley, and on the west shore of the Dead Sea, in the southern part of the rift. ^{222}Rn and ^{226}Ra were measured by emanometry, Ra isotopic ratios by γ-spectrometry, ^{3}He/^{4}He ratios – by mass spectrometry. The ^{228}Ra/^{226}Ra activity ratio varies in DSR waters between 0.03 and 0.9. Such isotopic ratios are very low compared to most analysed waters in the world. These probably reflect a very uraniferous (as opposed to Th rich) lithology with which these brines have interacted. The lower ratio in the Dead Sea region probably reflects the lower Th/U ratio in phosphorites and bituminous marls and chalks of that region. The ^{224}Ra/^{228}Ra activity ratio in the analysed waters ranges between 0.8 and 4.35.

Ra and Rn in the Lake Kinneret area

The salinity of Lake Kinneret is at present about 220 mg Cl/L. The major source of these salts are the saline, some of them hot springs which surround the lake, as well as some probably similar, but un-gauged springs on the lake's floor. The salinity of these springs varies between less than a 1000 to about 20,000 mg Cl/L.

Chemical and isotopic analyses (Fig. 1) confirm the notion that the springs are mixtures of a concentrated brine and fresh water. Starinsky (1974) explained the formation of this brine (Ca-chloridic in character) by evaporation of Neogene sea water which entered the DSR, evaporated beyond precipitation of halite, and interacted with the rift wall rocks, dolomitizing limestones and reducing sulphate.

Our observation that both ^{226}Ra and ^{228}Ra activities are often (especially in the Fuliya springs), also linearly correlated with chloride content (Fig. 2), suggests that the mixing between brine and fresh-water is a very recent (on a time scale of years or decades at most) event.

Ra is associated with the *brine* because in saline waters adsorption of Ra onto the wall rocks is sharply reduced. In contrast to Ra, ^{222}Rn is not correlated with chloride content. The Rn behaviour is explained as resulting from the formation of Ra-rich linings in the water conduits rather close to the surface. It is these Ra rich linings that contribute Rn to the water. Thus contrary to the frequently made assumption, Ra and Rn enter the brines from two different sources.

Additional evidence of Ra removal is provided by

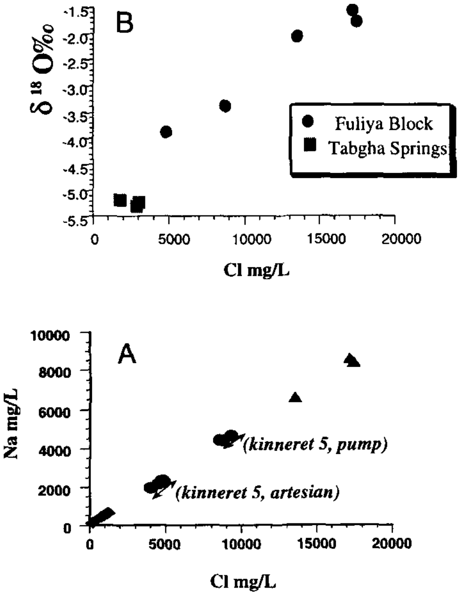

FIG. 1. Na *vs*. Cl (A) and δ^{18}O *vs*. Cl (B) in the Fuliya group waters.

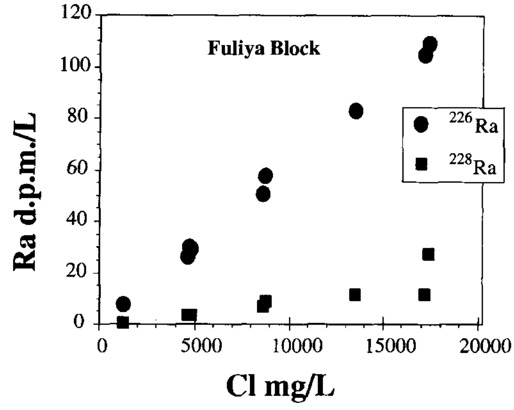

FIG. 2. ^{226}Ra and ^{228}Ra *vs* Cl in the Fuliya Group.

the ^{222}Rn/^{224}Ra relationship in the water of the Fuliya-5 well (Fig. 3). Here the site with the highest Rn activity of that group of springs, is also the site with the lowest ^{224}Ra, a nuclide with a similar half life to ^{222}Rn. Independently on the residence time of water, this proves that Ra is being actively removed from solution onto the rock. The geochemistry of Ra in brines is dominated by two processes: radioactive recoil, and rock dissolution-desorption. The relative significance of the two processes is determined by: a. The longer the half life of a nuclide, the greater the relative importance of dissolution in its supply from rock to water. b. The more saline the water, the more significant dissolution with respect to recoil.

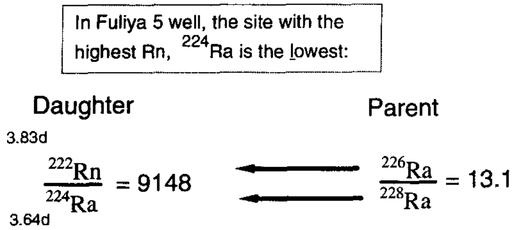

FIG. 3. Scheme of Ra isotope relationships in the Fuliya-5 well.

Helium isotopes

Water samples from along the Rift Valley have a higher ^{3}He concentration compared to the shallow meteoric groundwaters from outside the DSR. R_s/R_a ratios decrease from north to south. They are about 2.5–1 in the Lake Kinneret area and drop to 0.4–0.8 in the Dead Sea region. Even the low ^{3}He sources must reflect a participation of a significant ^{3}He 'mantle' component (Oxburgh *et al.*, 1986), which counterbalances the extremely high ^{4}He contribution to these sources.

References

Oxburgh, E. R., O'Nions, R. K. and Hill, R. (1986) He isotopes in sedimentary basins. *Nature*, **324**, 632–5.

Starinsky, A. (1974) *Relationship between Ca-chloride brines and sedimentary rocks in Israel*, The Hebrew University of Jerusalem, Ph.D. thesis (in Hebrew, English Abst., Unpublished).