Radium geochemistry in a hypersaline lake: The role of Dead Sea water circulation in the aquifer

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The Dead Sea water system is unique in terms of its very high salinity, its geochemical composition (Ca-chloridic and very low Na/Cl ratios), rapid lake level drop (currently, 1 m/yr) and the brines discharging along its shoreline.

The activities of the short-lived isotopes ^{224}Ra and ^{223}Ra and of radon (^{222}Rn) in the Dead Sea water are higher in near shore water and in surface compared with deep water, which is the result of groundwater discharge to the lake. While the radon is enriched only in fresh water and in brines discharging to the lake, the radium isotopes are also enriched in saline lake water circulating in the aquifer. Thus, the use of both radium isotopes and radon allows the distinction between lake water circulation and fresh groundwater discharge along the lake shores.

The longer-lived ^{226}Ra activity is very high in the Dead Sea water (160 to 200 dpm/L), with the main source being brines discharging to the lake, with activities as high as 1,500 dpm/L. On the other hand, activities of radium in saline water in the aquifer, identified as circulating Dead Sea water, are significantly lower than in the lake (~60 dpm/L) as a result of the adsorption of radium onto the sediment grains.

The activities of ^{228}Ra in the lake were also reported to be very high (0.2-1.5 dpm/L, ^{228}Ra/^{226}Ra ~ 0.01, Somayajulu and Rengarajan, 1987). The relatively high ^{228}Ra/^{226}Ra ratios (~0.01) are hard to explain. Considering the typical ratios of 0.03-0.1 in the water discharging to the lake, the large difference in their half lives (5.7 and 1600 yrs, respectively) and the absence of any major sink of radium, one would expect significantly lower ^{228}Ra/^{226}Ra ratios in lake water. We suggest that the circulation of Dead Sea water in the aquifer along the shore and through submerged faults is a major sink for ^{226}Ra, as indicated by its reduced activities in the aquifer. This, possibly together with enrichment of ^{228}Ra in the circulating water, could cause the relatively high ^{228}Ra/^{226}Ra ratios.

The Lomagundi-Jatuli Event, Louis Pasteur, and the geological record of aerobic respiration

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All published early Earth carbon cycle models assume that aerobic respiration is as ancient as oxygenic photosynthesis. However, aerobic respiration shuts down at oxygen concentrations below the Pasteur Point, (~10^{-2} of the present atmospheric level, PAL). As geochemical processes are unable to produce even local oxygen concentrations above ~10^{-3} PAL, it follows that aerobic respiration could only have evolved *after* oxygenic photosynthesis, implying a time gap. The evolution of oxygen reductase-utilizing metabolisms would have occupied this interval. During this time the PS-II-generated O_2 would have been largely unavailable for remineralization of dissolved organic carbon and so would have profoundly shifted the burial ratio of organic/inorganic carbon. We argue that the sequential geological record of the Makganyene Snowball Earth (~2.3-2.22), the excessively aerobic Hekpoort and coeval paleosols, the Lomagundi-Jatuli carbon isotopic excursion (2.22-2.056 Ga), and the deposition of concentrated, sedimentary organic carbon (shungite) mark this period of a profoundly unbalanced global carbon cycle.

Our literature compilation indicates that there are now over 4,000 carbon isotopic measurements which confirm and define the Lomagundi-Jatuli excursion. The Kopp *et al*. (2005) model for oxyatmoversion agrees with phylogenetic evidence for the radiation of cyanobacteria followed closely by the radiation of gram-negative lineages containing magnetotactic bacteria, which depend upon vertical oxygen gradients. These organisms include α-Proteobacteria from which the mitochondrial ancestor originated. The Precambrian carbon cycle was "rebalanced" after a series of biological innovations allowed utilization of the high redox potential of O_2. Aerobic respiration in mitochondria required the evolution of a unique family of Fe-Cu oxidases, one of many factors contributing to the ~210 Myr delay between the Makganyene and the end of the Lomagundi-Jatuli event. We speculate that metalliferious fluids associated with the eruption of the Bushveld complex facilitated evolution of these proteins, allowing mitochondrial endosymbiosis and ending the Lomagundi-Jatuli event at ~2.056 Ga.