In situ natural radionuclides transport and retardadation in coastal groundwater of the southern China

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^{238}U and ^{232}Th decay-series disequilibria in groundwater naturally occur as a result of water-rock interactions. The studies connected with them provide site-specific, natural analog information which improve the understanding of migratory behavior of radionuclides in groundwater. In these studies, a mass balance model was used to relate the distributions of decay-series radionuclides among solution, sorbed and solid pools in an coastal aquifer system to processes of water transport, sorption-desorption, radioactive ingrowth-decay and α recoil. Isotopes of Ra (^{226}Ra, ^{228}Ra, ^{224}Ra) and Rn (^{222}Rn) were measured in coastal groundwater from Xiamen, China, where both seawater intrusion and submarine groundwater discharge are found which make the rock-water interaction probably more remarkable there .

The results show that α-recoil supply rates of ^{222}Rn ($P_{r,Rn}$) and ^{224}Ra ($P_{r,Ra224}$) decrease seaward from 206 to 5.4 atoms L^{-1} min^{-1} and from 295 to 7.8 atoms L^{-1} min^{-1}, respectively, which give good explanations for their spatial distributions. $P_{r,Ra224}$ is larger than $P_{r,Rn}$ in each station, suggesting solids in studied aquifer may contain more thorium than uranium.

$P_{r,Rn}/A_{Rn}$ increases seaward from 0.3 to 0.9 along the path with an average value of 0.6, suggesting the primary source of groundwater ^{222}Rn is α-recoil of ^{226}Ra decay in solid pool, and it is also seen that the ratio increases along the path. ^{226}Ra decay in the sorbed pool ($R_{f,Ra226} \cdot A_{Ra226}$) attributes about 40% of total source of coastal groundwater ^{222}Rn. $P_{r,Ra224}/A_{Ra224}$ ranges from 14.0 to 333.0, with an average value of 177.8, almost two orders higher than that of $P_{r,Rn}/A_{Rn}$, while α-recoil supply rate (Pr) from the aquifer rocks of both nuclides are within the same order. This shows that retardation of different nuclides by groundwater are differ greatly: α-recoil supply rate of ^{224}Ra by aquifers rock is much faster than other radionuclides in Xiamen costal groundwater, revealing aquifers rock have strong retardation on radium isotopes, while the immigration scale of ^{222}Rn is longer than radium isotopes in groundwater.

The retardation factor of radium isotopes ($R_{f,Ra}$) in groundwater decrease seaward from 2.19×10^3 to 0.04×10^3, with average value 0.8×10^3, while its liveliness extent increase gradually, which result in the decreasing of ^{222}Rn of groundwater in a certain degree.

Calculation by the mass balance model also suggest that observed ^{224}Ra/^{228}Ra)a.r. of groundwater are mainly controlled together by α-recoil in aquifer solid pool and retardation by rocks. Both of effects decline gradually from land to sea, and make ^{224}Ra/^{228}Ra)a.r. increase gradually seaward the cooperatively.

# Phanerozoic ocean chemistry and anthropogenic ocean acidification

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Phanerozoic ocean carbonate chemistry

Phanerozoic ocean carbonate chemistry can be estimated using estimates of surface ocean carbonate mineral saturation states, calcium concentrations, temperature, and atmospheric carbon dioxide content. Any Phanerozoic carbonate chemistry reconstruction must be interpreted at best as indicating likely trends and magnitudes of past variation and not as a quantitatively accurate record.

Figure 1: Ocean pH computed assuming constant surface-ocean carbonate mineral saturation
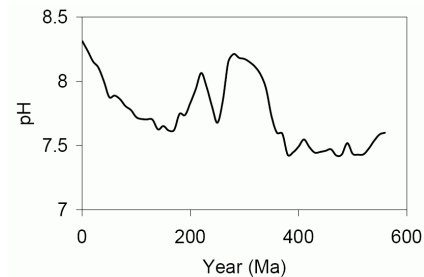
Phanerozoic carbonate mineral saturation

There is no direct record of surface ocean carbonate mineral saturation states, but some idea can be gained by looking at the latitudinal extent of carbonate reefs, taking into consideration factors such as paleo-temperature and the dominant lithology of reef builders at any given time. It is likely that orgnaisms have become more efficient at building carbonate skeletons due to the selective advantage bestowed upon organisms able to calcify in less saturated waters.

Variations in saturation states also follow geologic CO_2 degassing rates. High CO_2 degassing means high atmospheric pCO_2 means high silicate weathering means high cation flux to the oceans. Ocean carbonate-ion concentrations must increase in response until the carbonate mineral saturation increases enough to induce carbonate burial that balances riverine inputs. Thus, on multi-million year time scales surface ocean carbonate saturation state tend to parallel atmospheric CO_2 concentration.

Future carbonate mineral saturation

This situation contrasts markedly with what may occur over the next decades and centuries. Because of the rapidity of our CO_2 emissions, over the next decades and centuries carbonate mineral saturation states will be approximately inversely proportional to atmospheric CO_2 concentrations. Unabated anthropogenic CO_2 emissions could produce surface ocean saturation conditions that are lower than any since the Cretaceous-Tertiary boundary extinction event.