

Groundwater dating using dissolved helium and $^{36}\text{Cl}/\text{Cl}$

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Correlation between dissolved helium concentration and $^{36}\text{Cl}/\text{Cl}$ ratio in groundwater

We observed two different types of correlation between dissolved helium concentration and $^{36}\text{Cl}/\text{Cl}$ ratio in groundwater at Äspö in Sweden and the Great Artesian Basin (GAB) in Australia. The ratio of $^{36}\text{Cl}/\text{Cl}$ increased from 3×10^{-15} to 6×10^{-14} with increasing dissolved helium concentration in groundwater in very old granite rock at Äspö. As we estimated the average secular equilibrium ratio of $^{36}\text{Cl}/\text{Cl}$ in the rock to be 5×10^{-14} , some groundwater samples containing more than 2×10^{-2} ccSTP/g of helium may have reached this level. The increased ^{36}Cl atoms are produced by in-situ neutron activation in the rock.

We also observed an inverse correlation between a decline in the $^{36}\text{Cl}/\text{Cl}$ ratio and increase in helium concentration in groundwater at GAB. The ratio of $^{36}\text{Cl}/\text{Cl}$ declines from 1.8×10^{-13} to 13.5×10^{-15} along the exponential function of dissolved helium concentration as a variable. The decreased ^{36}Cl atoms have atmospheric origins in the groundwater of GAB.

We can interpret the dissolved helium concentration in groundwater as equivalent to the function of time if helium accumulation is totally constant in the basin, and find a correlation between growth of ^{36}Cl and radiation time in activation in groundwater at Äspö, and a correlation between the decay of ^{36}Cl and elapsed time at GAB. We can also estimate the rate of helium accumulation from the relation between helium concentration and the apparent length of half-life of ^{36}Cl .

Conclusion

We were able to estimate helium accumulation rates of 5×10^{-3} ccSTP/g at Äspö and 5×10^{-5} ccSTP/g at GAB respectively for 3.01×10^5 years. The oldest groundwater is probably more than two million years at Äspö, while in the Great Artesian Basin, it is possibly less than 0.6 million years, though there is considerable uncertainty about this.

References

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C-isotope composition of Delhi Supergroup, India: Implications for Mesoproterozoic oceanic C isotope evolution

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The C-isotope fluctuations in the Mesoproterozoic has received less attention because C-isotope trends are so muted in comparison to those observed in the Paleoproterozoic and Neoproterozoic. However, with an increasing database and understanding of the global marine C-isotope record, it has been established that from ~ 1.8 Ga (after the ~ 2.0 Ga large positive $\delta^{13}\text{C}$ excursion) to ~ 1.3 Ga, the C-isotope composition of the oceans remained near $0 \pm 1\text{‰}_{\text{PDB}}$. This is a global phenomenon, with common signatures found in early Mesoproterozoic rocks of North America, Russia, China and Australia, among others.

There appears to be a shift to moderately positive C-isotope values ($3.5 \pm 1\text{‰}_{\text{PDB}}$), between 1.3 and 1.25 Ga, with a few minor excursions between 0 and -1‰_{PDB} . This transition has been documented in Canada and Siberia.

The Mesoproterozoic Delhi Supergroup of Aravalli Mountain Range, Rajasthan, Western India, is mainly comprised of quartz arenite and limestone that have undergone greenschist- to amphibolite-facies metamorphism. A marginal marine depositional environment has been envisaged from sedimentary sequences of the Delhi Supergroup. No detailed geochronological study is available for this Supergroup. However, based on field evidence, it is assumed that sedimentary rocks of this Group were likely deposited during the 1.6 to 1.0 Ga interval.

Thirty one carbonate samples have been analyzed for carbon isotopes. These results show that carbonates from the lower succession of the Delhi Supergroup represented by Raialo and Ajabgarh Groups yield $\delta^{13}\text{C}$ values around $0 \pm 1\text{‰}_{\text{PDB}}$, typical of Mesoproterozoic marine carbonates. Carbonates of the younger Delhi Supergroup rocks, however, exhibit $\delta^{13}\text{C}$ of around 4‰_{PDB} .

The positive $\delta^{13}\text{C}$ values in the metamorphosed carbonates are assumed to represent C-isotope composition of the carbonate protoliths, since there is no known process to enrich carbonate in ^{13}C during regional metamorphism. $\delta^{13}\text{C}$ is much more difficult to change than $\delta^{18}\text{O}$ in a rock system-as the relative masses of C in rock vs diagenetic fluids is typically such that $\delta^{13}\text{C}$ compositions will be buffered to rock values. As such, oxygen isotopic compositions of the carbonate will be altered upon diagenesis at a much quicker rate than carbon isotopic compositions.

The Delhi Supergroup carbonates are characterized by $\delta^{13}\text{C}$ values as observed for Mesoproterozoic carbonates worldwide.