

Chlorine isotope ratios of chlorides in deep aquifers in the Paris sedimentary basin

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We have developed a study of chlorides in the fluids of the major deep aquifers of the Paris basin, those of the Keuper (Triassic) and Dogger (Jurassic). For this purpose, we used chlorine isotope ratios ($^{37}\text{Cl}/^{35}\text{Cl}$). In the center of the Paris basin, the Keuper aquifer is very rich in chloride (between 0.8 mol/L and 3 mol/L) and has $\delta^{37}\text{Cl}$ between -0.2 and -2.2 ‰. Chlorinity and $\delta^{37}\text{Cl}$ are organized along a negative trend that connects the most chloride-rich waters with the most negative $\delta^{37}\text{Cl}$ (3 mol/L, $\delta^{37}\text{Cl} = -2.2$ ‰) to seawater (0.558 mol/L, $\delta^{37}\text{Cl} = 0$ ‰). The chloride-enriched endmember ($\delta^{37}\text{Cl} = -2.2$ ‰) cannot be explained by chloride inputs from Triassic evaporites or brines derived from these evaporites, which have chlorides at $\delta^{37}\text{Cl} > -0.8$ ‰. It is therefore necessary to consider a mechanism of isotopic chlorine fractionation of the chlorides to produce these chlorides at $\delta^{37}\text{Cl} = -2.2$ ‰. Diffusion cannot be this fractionation mechanism because it can only produce $\delta^{37}\text{Cl}$ decreases of 1 ‰ when the chloride concentration contrast between upstream and downstream reservoirs is very large, greater than a factor of 10. This condition is not met for fluids with high chlorinity ($[\text{Cl}^-] > 0.5$ mol/l), such as those in Keuper aquifers.

The possibility of isotopic fractionation induced by an ion filtration process must be considered. This mechanism of electrical repulsion between the negative surface charges of clays and chloride ions has been invoked to explain the systematic depletion of chlorides from pore fluids in marine sediments *sensu stricto*.

In the center of the Paris Basin, the composition of chlorides in the Dogger aquifer is more peculiar: chlorinity is between 0.1 mol/L and 0.8 mol/L; $\delta^{37}\text{Cl}$ is between -1.0 and -2.0 ‰, which also illustrates the incompatibility with chlorides from Triassic evaporites or brines derived from these evaporites ($\delta^{37}\text{Cl} > -0.8$ ‰).

It is remarkable that in the center of the Paris basin, practically all the chlorides in aquifers cannot be produced directly from the chlorides in evaporites and their derivatives, nor from those in seawater.