

## Geochemical and isotopic investigation of thermal fluids – Thau lagoon (Hérault, South of France)

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The Thau basin, in the South of France, close to the mediterranean sea, is the location of several ground-water flows. Two distinct karstic areas interfere with thermal waters in the eastern part of the pond. This area is also a highly touristic place, which enhances its economic part. Conflictual use of the groundwater arises from the proximity of thermal, fishery and tap-water activities. Previous study of the thermal waters did not allow to clearly define the origin of the fluids. In order to go further in this way, fluids from the thermal station and several boreholes from the two karstic areas have been sampled and thoroughly analysed for chemical and isotopic characteristics (Aquilina *et al.*, 1997).

### Origin of thermal waters

The salinities of the thermal drill-holes show a large range of variation from 1.7 to 14 g/l. Na, SO<sub>4</sub> and Br are clearly correlated to Cl and the correlation is identical to a mixing line defined between seawater and meteoric water. On the other hand, NO<sub>3</sub> concentration is inversely correlated to Cl. Ca and Sr show higher concentrations than the seawater–meteoric water relation. Stable isotopes, in agreement with Na–SO<sub>4</sub> and Br–Cl correlation show that the thermal waters define a mixing line between the meteoric waters from the karstic areas and a seawater end-member.

The seawater to meteoric water ratio can be computed from both stable isotopes and Cl. Values are in good agreement, which allows to rule out any dissolution effect, and range from 6 to 39 %. From the mean concentration of <sup>3</sup>H and NO<sub>3</sub> in the karstic fluids, the percentage of meteoric water in the thermal fluids can also be computed. The results are much lower than those from the Cl and stable isotope computation. It indicates that the meteoric end-member in the thermal fluids is not constituted of recent fluids. Thus the thermal fluids result from a complex mixing between (1) seawater and palaeo-

meteoric waters from a deep and hot reservoir, and (2) recent meteoric waters presently flowing into the karstified limestone formations.

### Residence time

In order to estimate the residence time of the thermal waters, <sup>3</sup>H, <sup>14</sup>C, <sup>13</sup>C and <sup>36</sup>Cl have been determined. For the most saline fluids, <sup>3</sup>H activities are close to or below detection limit. A good inverse-correlation is observed between <sup>13</sup>C and <sup>14</sup>C. This result indicates dissolution of marine carbonate and/or the contribution of deep CO<sub>2</sub>, which prevents from using the <sup>14</sup>C for dating the waters. <sup>36</sup>Cl isotopic ratios are very low (below 12 × 10<sup>-15</sup>), lower than the surface waters, and decrease with increasing salinities. This correlation is interpreted as the result of the decrease of the atmospheric contamination of the palaeometeoric waters in an environment which produces a very low flux of neutrons. It can be concluded that the residence time of the thermal fluids is, at least, several thousands years.

### Water–rock interaction

As noticed previously, an excess (as regards seawater content) of Ca and Sr is observed in the thermal fluids. In agreement with the isotopic ratios of C, it seems due to a strong effect of dissolution of calcite. Strontium isotopic measurements are quite homogeneous with a ratio close to 0.7085 (Fig. 1). Analysis of the fluids from the karstic areas indicate that this signature originates from the upper Jurassic–limestone reservoir. This result agrees with the <sup>36</sup>Cl results which indicates that the reservoir has a low U and Th content.

Geothermometers were computed for the thermal fluids. Silica geothermometers are close to the surface temperatures. On the other hand, Na/K temperatures show a very narrow range of variation (98–113°C). using the geothermal gradient defined

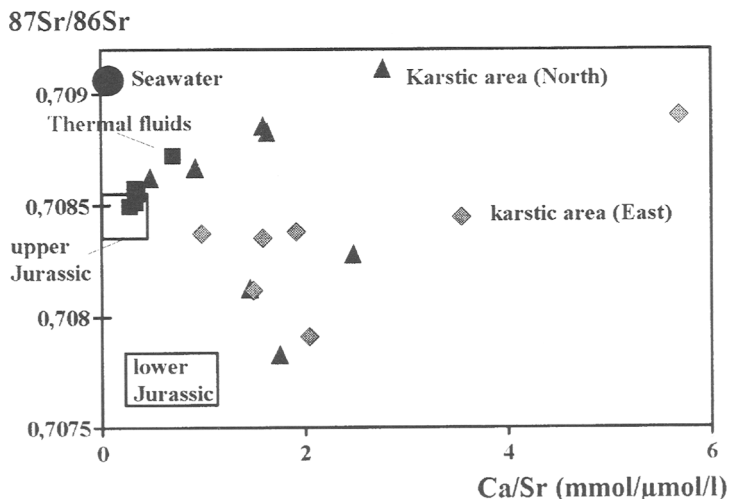


FIG. 1. Isotopic ratio vs Ca/Sr ratio. Dissolution of carbonates leads to two distinct domains depending on the origin of the fluids. The thermal fluids are close to the upper Jurassic domain.

from the points of the karstic areas, a minimum depth of 2–2.5 km can be computed.

### Conclusion

Chemical and isotopic investigation of thermal fluids around the eastern part of the Thau lagoon, indicates that the thermal fluids are composed of a mixing between seawater and palaeometeoric waters, which originate from a reservoir deeper than 2–2.5 km. These fluids flow towards the surface where they mix with present meteoric waters flowing through karstic aquifers.  $^{36}\text{Cl}$  isotopic measurements are interpreted as the result of long-term residence time which allowed decrease of the atmospheric imprint. From

Ca and Sr concentrations, and Sr isotopic ratios, the fluids are assumed to have had a long-term interaction with upper Jurassic limestones.

Geological investigations indicate that the upper-Jurassic limestone reservoir lies at great depth to the South of the thau lagoon, below the Mediterranean sea. It also indicates that the thermal fluid may flow along a deep fault related to the 'Nimes Fault'.

### References

- Aquilina, L., Deluchat, V., Brach, M., Bakalowicz, M., Le Strat, P. and Giraud, F. (1997) BRGM Report R 39530.

## Correction of interferences caused by oxide and hydroxide analyte species in ICP-MS: development and limits of a new method applied to transition metals

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See page 1711 for abstract