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Extended Abstracts

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title: **Characterization of the hydrogeological boundary separating two aquifers: a multi-disciplinary approach combining geological, geochemical and hydrodynamic data (Aix-les-Bains, France)**

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Aix-les-Bains (Savoie-France) is located on the eastern shore of Lake Bourget in the "département" of Savoie. Three establishments within a few kilometers of Aix-les-Bains currently exploit the area underground water resources: the Marlioz and Thermes Nationaux spas and the Société des Eaux d'Aix-les-Bains bottles mineral water at Raphy Saint Simon (RSS). The spas draw their water exclusively from deep boreholes, whereas the RSS bottling plant has a natural spring (RSS well) and two boreholes (RS4 and RS5), both of which are more than 500-m deep (Figure 1). Although the spas and mineral water plant are only a few kilometers apart, their waters have distinct physico-chemical characteristics, suggesting that they are derived from two different but adjoining aquifers. The present study used geological, geochemical and hydrodynamic data in order to determine the boundary between the thermal water and mineral water aquifers, and to investigate the relationship between them. It is important to determine the boundaries between the aquifers especially at depth because the waters are abstracted exclusively by boreholes.

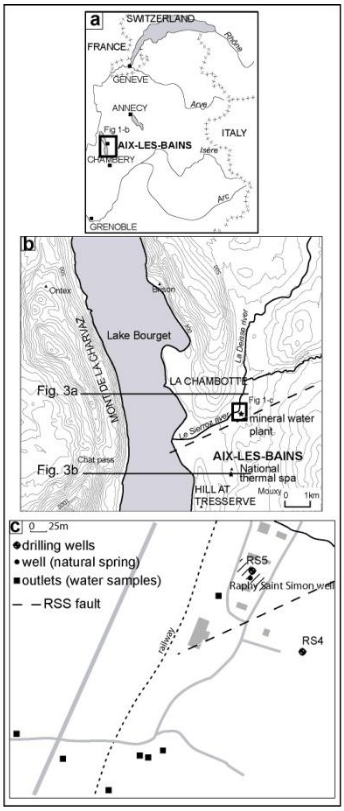

Figure 1. Location of the study area: a): regional map; b) local map; c) RSS well field.

GEOLOGICAL DATA

Geological mapping and a reinterpretation of seismic profiles produced in the 1970s for oil exploration were used to investigate the structure of the area between Aix-les-Bains and La Chambotte (8 km north of Aix). This relatively small area was found to contain two very different types of anticlinal structure: a fault-bounded anticline to the north (Figure 2a) and a box fold to the south (Figure 2b). Dip measurements for both anticlines revealed sub-vertical western flanks, less steeply dipping eastern flanks and sub-horizontal central sections. The central section of the northern anticline is much narrower than the central section of the southern anticline. Both anticlines have been thrust over their adjoining synclines; however, the thrust plane is much steeper in the north than it is in the south. As a result, equivalent strata are at a higher altitude to the north of Aix-les-Bains than they are to the south of the city. In addition, the eastern flank of the northern anticline is intersected by two backthrust faults and the southern anticline is affected by a peel thrust. Given the extremely rapid transition from one anticlinal form to another, these two structures cannot be contiguous; however, their juxtaposition can be explained by the presence of a fault oriented N065°E. This fault is not visible at outcrop but it must lie between the end of the La Chambotte anticline and the hill at Tresserve. It has been named the Raphy Saint Simon Fault (RSSF).

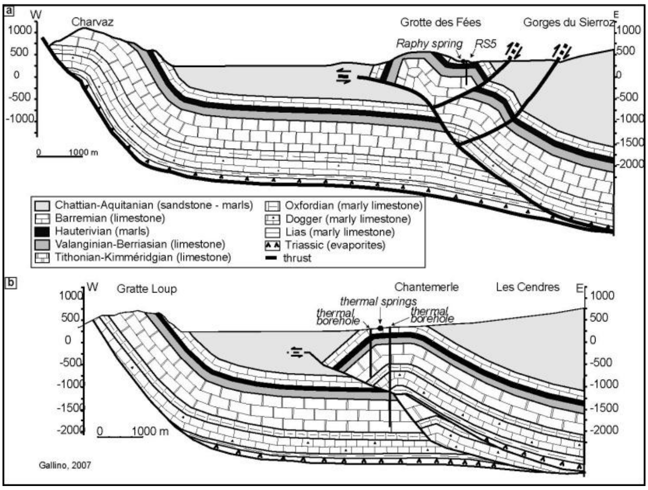

Figure 2. Geological structures to the north (a) and to the south (b) of Raphy Saint Simon field.

GEOCHEMICAL DATA

Water samples from wells and springs within a 300-m radius of the RSS well field had identical or similar major ion concentrations to the mineral waters; nevertheless, two distinct chemical facies were recognized on the basis of differences in magnesium and sulfate concentrations. For example, the sulfate concentrations of water samples from RS5 and the RSS well were five times lower than those of RS4 (20 $mg \cdot L^{-1}$ vs. 100 $mg \cdot L^{-1}$) (Figure 3). Differences were also found in the sulfur isotope signatures of samples from the two boreholes, even though both boreholes abstract their waters in the Upper Kimmeridgian limestone. The sulfur isotope signature of RS5 (8.9‰ vs. CDT) is closer to that of pyrite (-0.8‰ vs. CDT), whereas the signature of RS4 (18.9‰ vs. CDT) is closer to that of the thermal water (31.5‰ vs. CDT). These differences in sulfur isotope and major ion concentrations show that the recharge waters for the two boreholes have different sources and that the boreholes must therefore be in different geological blocks separated by the RSSF.

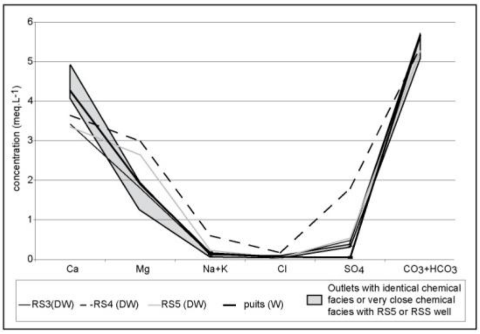

Figure 3. Schoeller Berkaloff diagram of the outlets of the RSS well field, wells and springs around the well field.

HYDRODYNAMIC DATA

Monitoring of the dynamic water levels in the boreholes and the flow rate of the RSS well allowed us to determine the hydrogeological and geological limits. Variations in the water yields of the boreholes in one block were observable in the adjoining block. Although the fault allows the transfer of pressure between the two blocks, it also leads to the water level in the northern block being 30 meters lower than the water level in the southern block.

Some phenomena were only observed in the northern, mineral-water block. For example, during rainfall events water levels were seen to drop suddenly in RS5 (Figure 4) but not in RS4.

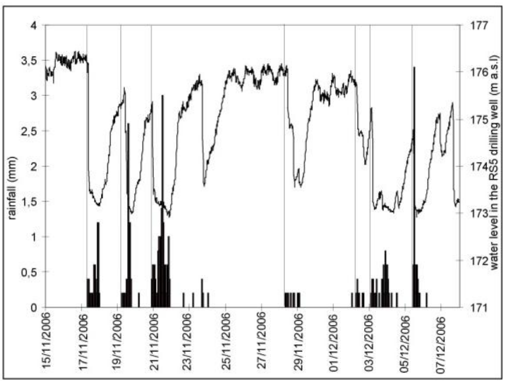

Figure 4. Variations in the dynamic water level of RS5 during rainfall events.

In addition, we observed cyclical variations in the flow rate of the RSS well, as well as variations related to atmospheric pressure (Figure 5).

These phenomena were not observed at the natural thermal water outlets in the southern block.

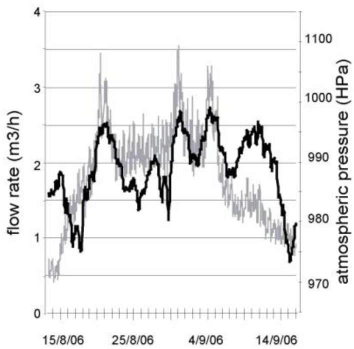

Figure 5. Variations in the RSS well flow rate related to atmospheric pressure.

CONCLUSION

The present study produced the following evidence for the existence of two distinct structural blocks:

- the different geological structures indicate the presence of two blocks separated by a fault oriented N065°E.
- Hydrogeochemical analyses revealed two distinct borehole water facies: one closer of mineral water facies and the other one closer to the thermal water facies.
- Hydrodynamic tests revealed differences between water levels in the boreholes and the existence of phenomena that only occur in the northern block. These results also indicate the presence of two aquifers with different water recharges and different ways of functioning.

Geological, geochemical and hydrodynamic data all indicate the existence of a N065°E-trending fault near the RSS well field. This fault marks the boundary between the mineral water aquifer to the north and the thermal water aquifer to the south. It maintains a difference in the water levels of the two aquifers, but allows the transfer of pressure between them.

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