Hydrogeochemical investigation of the passive margin of the Southeast Basin of France: GPF Programme

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Introduction

The objective of the Ardèche Project of the GPF programme ('Géologie Profonde de la France') is to model mass transfer in the passive margin of the Southeast Basin of France along a transect located in the Largentière mining district. Two boreholes, the Balazuc borehole and the Morte-Mérie borehole, were drilled on either side of the Uzer fault, a border fault rooted in the Carboniferous substratum Geological formations consist of carbonated Jurassic, continental Triassic which can be divided into upper and lower sandstone units and a middle evaporitic unit, and continental Carboniferous-Permian siltstones. Formations regionally recognized as aquifers are Hettangian dolomites, and upper and lower Triassic sandstone units. During the drilling of both boreholes, intensive fluid sampling was carried out. This included sampling of water inflow, core leaching and a special on-line drilling fluid chemical characterization procedure (Aquilina *et al.*, 1993*a,b*). This procedure involves continuous measurement of gas content and physico-chemical parameters of the drilling fluid and discontinuous chemical analysis of drilling fluid samples.

Results from Balazuc borehole

During drilling of the Balazuc borehole, no water inflow was noticed since sulphate diagenesis strongly reduced porosity to values ranging from 2 to 4%. Under these conditions, chemical monitoring of drilling fluids was particularly suitable. It was possible to compute fluid input to the drilling fluids from the rocks (dissolution and mixing of interstitial fluids) and determine the interstitial fluid composition, although compositions can only be regarded as estimates (Aquilina *et al.*, 1994).

The most striking feature of the gas content of drilling fluids is the lack of general trends at the drilling scale. Each formation has a unique signature. In the upper part, there is a gaseous hydrocarbon source located in a black shale formation. Below 1450 m, there are two helium rich sources, one corresponding to the lower sandstone unit and Carboniferous formations.

The major conclusions which can be drawn from the interstitial fluid chemistry confirm this lack of vertical gradient. From the top to the bottom of the cored phase (1220–1725 m) we can distinguish: (1) Hettangian limestone: modified connate water; (2) Hettangian dolomite: fluid circulation related to dolomitization (basinal fluids); (3) upper part of the upper Triassic sandstone unit: sandstone bed fluids are of meteoric origin; (4) lower part of the upper Triassic sandstone unit: brines originating from underlying evaporitic formation; (5) middle Triassic evaporitic formation: evaporated sea-water; (6) lower Triassic sandstone unit and Carboniferous: hydrothermal circulation of continental brines.

Results from Morte-Mérie borehole

The geologic setting of this borehole is very different from that of the Balazuc borehole. The top of the Triassic is reached at a depth of 125 m while it is found at 1350 m in Balazuc. Gas record during drilling mainly shows 2 different regimes, the Permian showing numerous helium anomalies.

Water influxes were encountered during drilling at depths of 70 m (Hettangian dolomites) and 634 m in the Permian series. In the Triassic sandstone units, only a small gas inflow was noticed at 410 m (conglomerate at the base of the Triassic formations). This is due to the proximity of the fault, since in mine shafts located slightly to the west, these formations are still aquifers. To complete the information, 7 irrigation wells and a mining borehole were sampled at depths ranging from 35 to 250 m. Four kinds of water can be distinguished: (1) HCO_3, Ca type, conductivity of

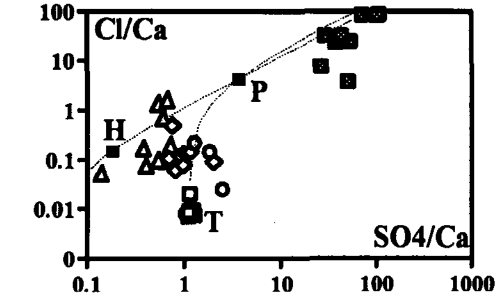

FIG. 1. Diagram of Cl/Ca *vs.* SO_4/Ca. Black squares indicate well samples (H: Hettangian, T: Triassic, P: Permian). Interstitial waters: Triangles: Hettangian, diamonds: upper Triassic, circles: middle Triassic, squares: lower Triassic, grey squares: Permian.

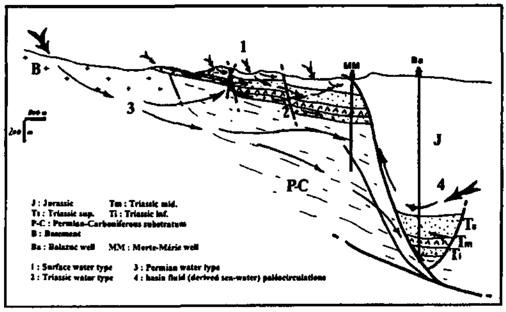

FIG. 2. Geological and hydrological section of the Largentière area transect.

700 μS; (2) Ca, SO_4, HCO_3 type, conductivity from 1070 to 1200 μS; (3) SO_4, Ca type, conductivity from 1860 to 2160 μS; (4) Na, Cl type, conductivity of 15.6 mS. These 4 types corresponds to 3 different aquifers: Hettangian (type 1 and 2), Triassic sandstone units (type 3) and Permian (type 4). Statistical analysis (CPA) shows that 95% of the variability of the water can be explained by two axis, which represents three poles of mixing.

In figure 1, these three poles (black squares) have been represented with the mixing lines and the results of the core leaching. Type 4 water corresponds to the Permian interstitial water group and type 3 is also very similar to the lower Triassic interstitial water. The water that circulates within the Hettangian dolomites and the water of the upper Triassic sandstone unit (types 1 and 2) are composed of mixed waters which implies a connection between surface water and lower Triassic and Permian aquifers.

Comparison of the two boreholes

Although the analyses and the interpretation of the data are still in progress, several features of the hydrological system of the transect can be outlined. They are summarized in figure 2.

(1) The Uzer fault completely separates two different hydrological domains. Since no water inflow was observed in the eastern compartment, water circulation in the upper aquifers of the western compartment is mainly north-south.

(2) The fault network allows the circulation of basement and lower Triassic fluid towards the upper Triassic sandstone unit and the Hettangian carbonates.

(3) The aquifer of the lower Triassic sandstone unit seems to be protected from pollution by the other types of water.

(4) The water inflow at 634 m in the Permian is similar to springs located in the metamorphic basement (Leleu *et al.*, 1982) which seems to indicate a large scale downward circulation from the outcropping basement.

(5) This type of water is a likely candidate for the hydrothermal origin of the water encountered in the lower Triassic unit and the Carboniferous in the Balazuc compartment. This circulation could have occurred before these formations reached the present depth.

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References

Aquilina, L., Cecile, J. L., Sureau, J.F., and Degranges, P. (1993*a*) *Scientific Drilling*, **4**, 5–12.

Aquilina, L., Boulègue, J., Pinault, J.L. and Sureau, J.F. (1993*b*) *Scientific Drilling*, **4**, 13–22.

Aquilina, L., Boulègue, J., Sureau, J.F. and Bariac, T. (1994) *Applied Geochemistry*, in press.

Leleu, M., Oustrière, P., Sarcia, C. and Sureau, J.F. (1982) *European Economic Community*, 084-79-7-MPP-F, 180pp.