

Geochemical and reactive transport modeling of the injection of cooled Triassic brines into the Dogger aquifer (Paris basin, France)

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ABSTRACT

As another option for exploitation of the low-enthalpy geothermal resources of the Paris basin (France), currently limited to the carbonate Dogger aquifer, brine could be extracted from deeper Triassic sandstone reservoirs and re-injected into the Dogger aquifer, which has higher injectivity. The objective of the geochemical modeling work presented here is to identify the physical–chemical processes that are likely to be induced by the re-injection of the cooled Triassic brines into the Dogger aquifer and to predict their possible consequences on the Dogger porosity. The results suggest that this re-injection process may induce precipitation/dissolution reactions. However, the impact on porosity should be limited in magnitude (a few percent) and in extent (tens of meters around the well).

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1. Introduction

Geothermal exploitation in the Paris basin (France) started in the early 1970s. Since, the Paris basin has become the most developed low-enthalpy field in Western Europe with 40 geothermal plants presently in operation. 90% of these plants exploit the carbonate Dogger aquifer (1500–2000 m deep, <http://www.geothermie-perspectives.fr/>). A recent hydrodynamic and thermal modeling study of the Dogger formation predicted an impending decline in the temperature of produced waters (Hamm et al., 2011). However, this energy decline has not been observed: only one of the operating production wells shows a small drop in temperature (3–4 °C). Nevertheless, the geothermal resource of the Dogger aquifer will not be sufficient to meet the Grenelle Environment demand for increasing the geothermal energy share of total renewable energy from 2% (2006 data) to 12% by 2020 (AFPG, 2012). Therefore, finding new geothermal resources in the densely populated Paris basin is a crucial issue. A previous study (CLASTIQ-1 project, Bouchot et al., 2008) has shown that the underlying Triassic sandstone reservoirs (2000–3000 m deep) have attractive geothermal potential for district heating as an alternative to the Dogger aquifer. However, previous attempts of exploitation of these sandstone reservoirs (e.g. Melleray site, close to Orleans city, Loiret)

have revealed re-injection problems preventing further geothermal operations. The re-injection problems are mainly due to the mechanical entrainment of fine particles which settle on pore surfaces and eventually clog the pores (Lopez and Millot, 2008). To overcome this technical difficulty, one possible solution envisaged would be to inject (totally or partly) the exploited Triassic brines into another aquifer with better injection properties, namely the Dogger aquifer.¹ However, this solution might trigger geochemical reactions that could risk damaging the properties of the Dogger, in particular its porosity.

The objective of the modeling work presented here is to identify the physical and chemical processes that are likely to be induced by the re-injection of the cooled Triassic brines into the Dogger aquifer and to assess a first quantification of their possible consequences on the Dogger porosity. This study was conducted in the framework of the CLASTIQ-2 project (Bouchot et al., 2012) and co-funded by the French Environment and Energy Management Agency (ADEME) and BRGM. The CLASTIQ-2 project is a sequel of the CLASTIQ-1 project.

¹ This might be an issue referring strictly to the French regulation which generally prohibits the mixing of waters arising from distinct aquifers. However, since both the Dogger and the Triassic aquifers are not strategic for drinking water supply, a derogation from the administration could reasonably be expected.

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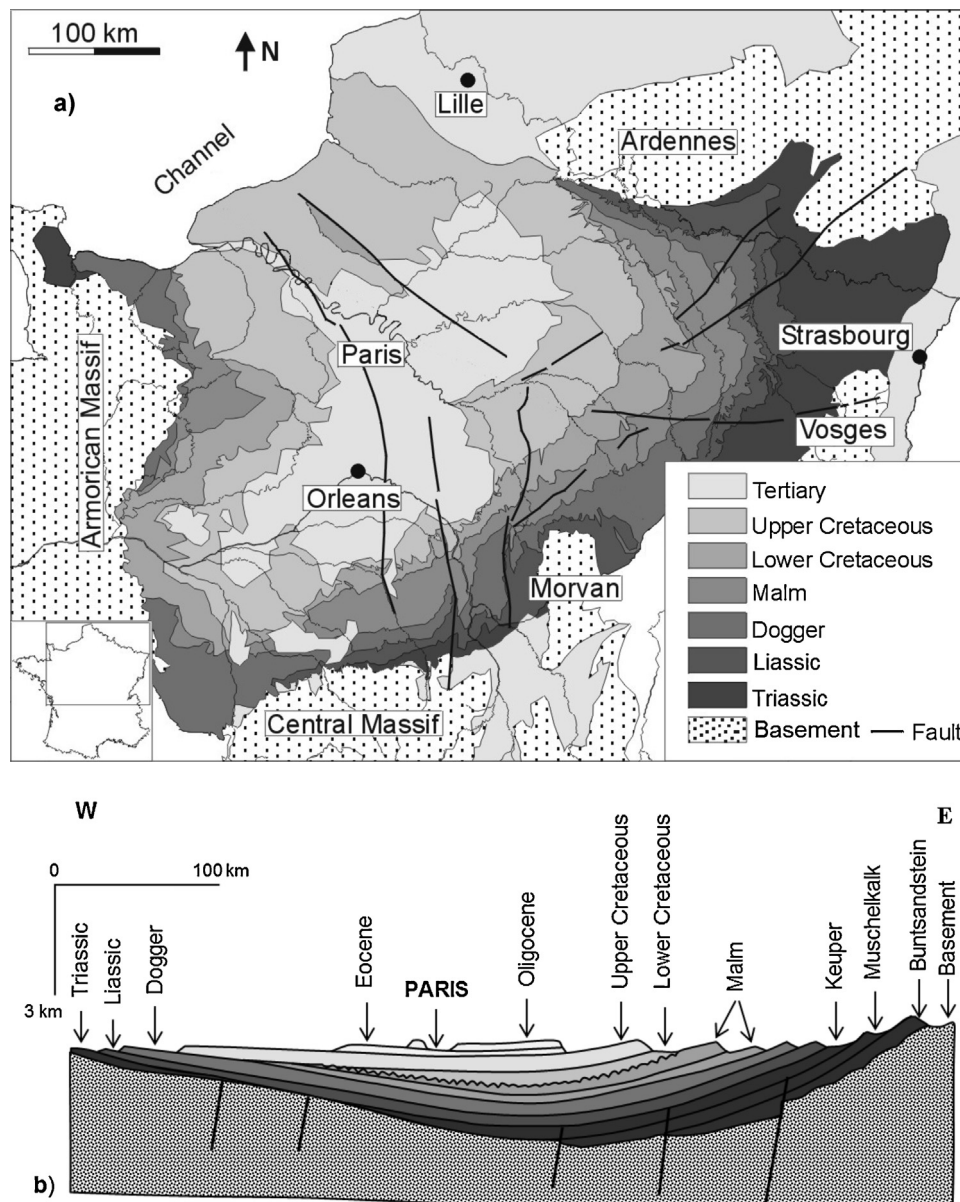


Fig. 1. (a) Simplified geological map of the Paris basin and (b) schematic geological WE cross-section of the Paris basin (a) Modified from Gonçalves et al. (2003) and (b) modified from Perrodon and Zabeck (1990).

2. General considerations

2.1. Geological context

The Paris basin is a large sedimentary basin (110,000 km²) which occupies the Northern part of France (Fig. 1). Nearly circular, it is surrounded by four Paleozoic massifs: the Armorican Massif to the west, the Central Massif to the south, the Vosges to the east and the Ardennes to the northeast. The Paris basin was generated during a Permo-Triassic extensional phase and it developed during the Meso-Cenozoic. Thus, it is filled with up to 3000 m of sediments (mainly Mesozoic) lying on a Paleozoic basement (Guillocheau et al., 2000; Delmas et al., 2002). The Paris basin contains numerous aquifers, including geothermal (Fig. 2). The geothermal gradient has been estimated to be about 35 °C/km in this basin with a surface temperature fixed at 10 °C (Bonté et al., 2013). Thus, water temperatures in the deepest parts may be relatively high (up to 125 °C, Fig. 3). The Triassic sandstones (2000–3000 m deep) and the

Dogger limestones (1500–2000 m deep) are the deepest geothermal reservoirs of the Paris basin (Fig. 2).

2.2. Historical setting

A great interest in the Dogger aquifer began in the early 1970s, when incentive public policies and insurance policies favored the development of new energy concepts. The Mid-Jurassic (Dogger) carbonate rocks of the Paris basin were thus identified as the most promising target for a geothermal use around the densely populated city of Paris itself, due to their reasonable depth and their characteristics (mainly temperature and permeability), leading to potential warm water flow rates compatible with the Parisian district heating network at the surface (Lopez et al., 2010). The Dogger aquifer was reached by a first drilling in 1962 in Carrières-sur-Seine (Yvelines). Since, the geothermal resource of the Dogger aquifer is exploited using mainly the geothermal well doublet technology, where the warm water is extracted at the production well and

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