Coupling processes at basin scale by numerical modelling for geothermal resources: application to the Anglo-Paris Basin

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In the Anglo-Paris Basin, geothermal exploitation has mainly concerned the Dogger aquifer up to now [1,2]. Other horizons such as the Albian aquifer are targeted for future exploitation. Feasibility of these new geothermal plants is often based on models, which focus mainly on the targeted aquifer and its close surrounding area.

However, the past acquisition of measurements of temperature and of thermal conductivity for fundamental or applied purposes has enriched the understanding of the thermal regime of the whole Anglo-Paris sedimentary basin [3,4,5,6,7]. It brought to light spatial and temporal thermal heterogeneities (e.g. temperature, thermal conductivity, geothermal flux) which are crucial for geothermal exploitation. In order to understand them better, these variations need to be integrated into basin scale models, taking into account the whole sedimentary pile rather than focusing on specific aquifer levels.

For instance, we reinterpreted and highlighted vertical variations of geothermal flux at the scale of the Meso-Cenozoic pile [4,5,6]. Simulations show that the system has retained a memory of the effects of palaeoclimates. They were carried out based on diffusive palaeoclimatic scenarios. Roughly half of the reduction in heat flux in the upper part of the basin (0–1500 m) is explained in this way [8].

Transitory thermo-hydraulic simulations of diffusive and advective palaeoclimatic phenomena explain the weak vertical thermal flux anomaly in the upper part of the intracratonic sedimentary basin. The simulations show the development in the sedimentary basin of cold and hot zones according to the ascending and descending areas of groundwater flow respectively. The majority of the low thermal flux anomaly can be explained by advective and paleoclimatic mechanisms with a decrease in geothermal flux simulated up to a little over 30 mW/m^2 for the reference well [9].

An explanation of the temperature anomaly of over 20°C between the geothermal plants located to the north and south of Paris in the Bathonian (Dogger) [10,11,1,2] is also put forward by integrating the whole sedimentary pile. Reinterpretation of seismic data provides new geological information, in particular with regard to the geological model of the Beynes-Meudon anticline associated with an east-west orientated fault. Furthermore, by analogy with observations made in marine geophysics, we suggest interpreting a special seismic facies, identifiable along these reprocessed lines and affecting the whole of the sedimentary column, in terms of fractured zones along preferential vertical conduits. The mixed-convective models clearly show the potential contribution of these structures to the heterogeneity observed in the temperature field of the basin by allowing flow constrained by the regional hydraulic head gradient and variable properties (densities and viscosities) [12].

These examples show that convective long-term models need to be developed at basin scale in order to understand temperature distribution accurately before considering reservoir scale simulations. Moreover, the geological formations in the basin are linked by vertical structures, which may favour groundwater and heat flux exchanges bypassing the aquitards. As these geological formations are exploited for their natural resources, including drinking water [13,14] and geothermal energy [1,2], and used as a storage medium, conflict of use may appear while these flux exchanges are not correctly taken into account. Finally, a multidisciplinary approach is needed, which encourages using numerical simulations for coupling mechanisms.

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