Conceptual model of low-enthalpy Lower Cretaceous aquifer in Lisbon urban area (Portugal)

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Abstract: A conceptual model was elaborated through an inter-disciplinary approach in order to develop a sustainable and integrated water/geothermal reservoir management of the low-enthalpy Lower Cretaceous aquifer in Lisbon urban area. Strong aquifer compartimentation, progressive salinization processes of extracted groundwater and very long residence times, suggest both a very limited rate of modern recharge and narrow groundwater reserves. All these evidences recommend the reinjection of the groundwater in a potential low-enthalpy geothermal exploitation of this urban aquifer to ensure reservoir optimal conditions from water and geothermal perspectives.

Keywords: conceptual model; integrated water/geothermal reservoir management; Lisbon urban area

Introduction

In the context of growing use of low CO_2-emission energy sources, groundwater in urban areas, instead of an essential resource for water supply (Howard, 2002), eventually has been considered as a potential low-enthalpy geothermal resource (Norden, 2007, and reference therein). In district heating networks (e.g. Paris Basin, Panonian Basin, etc.), groundwater of moderate to high temperature (>60ºC) extracted from deep sedimentary aquifers are often highly mineralized (TDS>150 g/L), discarding its use for water supply or agricultural purposes (ibídem). However, in Lisbon urban area (Portugal), hypothermal (20-50ºC) groundwater in deep Lower Cretaceous sedimentary formations, could be suitable as drinking water and as potential low-enthalpy geothermal resource (Correia et al., 2002). A conceptual model was developed to help drawn a sustainable and integrated water/geothermal reservoir management of this low-enthalpy aquifer in Lisbon urban area. The present communication shows some of the main conclusions currently achieved.

Methods

In order to create a conceptual model, the first step was to consolidate and integrate all available geological, geochemical, geophysical and hydrogeological information, provided in different data formats, in a GIS based database. To help to understand the geometrical configuration and extensions of Lower Cretaceous formations at the study area, a 3D geological model was developed based in the former database. A field survey was carried out in 2013 providing, from hydrogeochemical and isotopic determinations and aquifer tests, relevant data about groundwater (temperature, salinity, major and minor ions) and reservoir characteristics (porosity, transmissivity, diffusivity).

Results and Conclusions

Less than 20 groundwater wells were identified exploiting the Lower Cretaceous formations in Lisbon urban area, mostly for industrial purposes along the Tagus estuary seaport (see Fig.1). Due to its roof depths (usually >300m) and confined properties of the aquifer over the whole extension of the urban area under study, discharged into the aquifer of typical sources of water recharge and pollutants derived from urban activities (e.g. leakage from water supply networks or sewage systems) (Howard, 2002) seem to be almost negligible.

From the hydrogeochemical point of view, water from this aquifer is mainly HCO_3-Cl-Na-Ca type with mean TDS value less than 1 g/L (Fig.2), and relatively high Fe concentration probably due to dissolution of ferruginous minerals coupled with reduced conditions at depth. Therefore, after Fe removal and assuming absence of pathogenic agents, groundwater could be suitable as tap water. However, some progressive salinization processes of extracted groundwater after a relatively short exploitation period have been also identified (see Fig. 2); mixing processes with mineralized fluids coming from partial dissolution of evaporite rocks probably deep underground can be the most plausible explanation (Almeida et al., 1991).

Collected data suggests a high level of compartmentation of this aquifer, probably related to the existence of folds, faults and intrusion of dykes and sills from Lisbon Volcanic Complex (Carvalho et al., 1990). Groundwater residence time of 12 Ky obtained by A.Cavaco-CFG (1989) in AC1-Balum geothermal well (Carvalho and Cardoso, 1994), through radiocarbon analyses after ^{13}C corrections, suggests a very limited rate of modern recharge. This could become a constraint for the exploitation of the water/geothermal reservoir, since the amount of fluid may not be enough to address economic requirements in some hypothetical projects.

On the evidence of these results we recommend groundwater reinjection in a potential low-enthalpy geothermal exploitation of this urban aquifer in order to ensure reservoir optimal conditions from water and geothermal perspectives. Aquifer compactation seems to be a real threat (Heleno et al., 2011). However, the exploitation of this water/geothermal urban reservoir can be sustainable if the approval of the exploitation plans is dependent of the improvement of the appropriate integrated monitoring and management plans.

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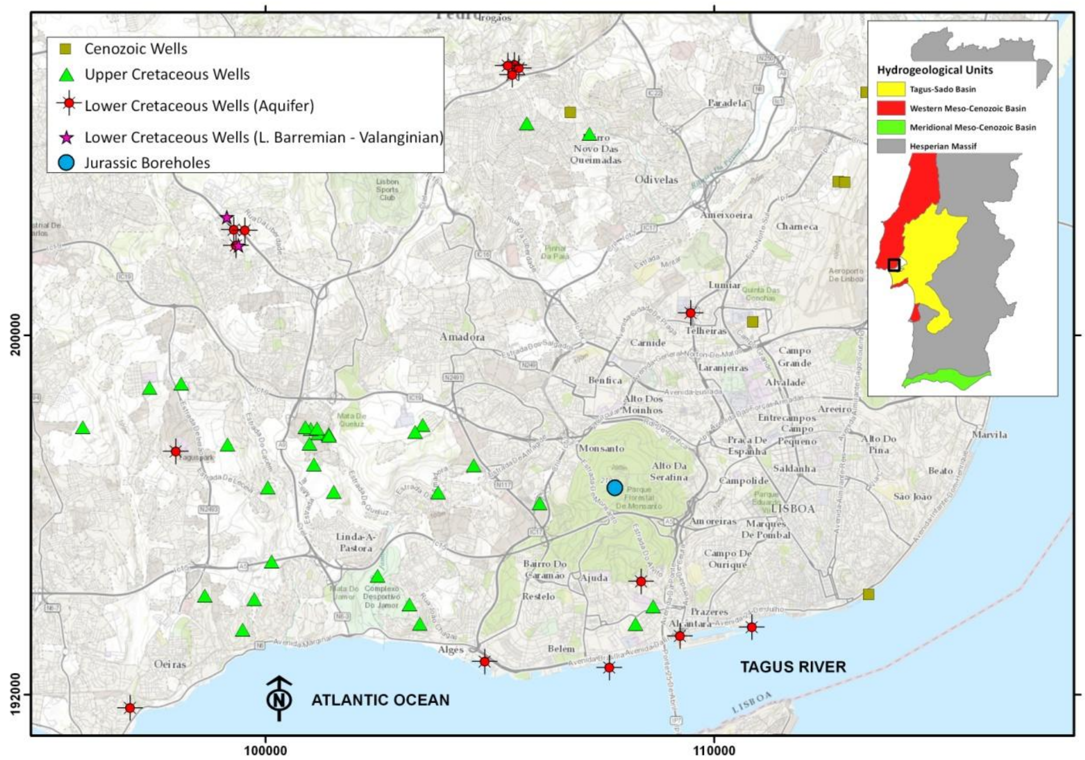

Figure 1 Topographic map of the Lisbon urban area, highlighting groundwater wells (in function of the aquifer level reached) and Monsanto-1 borehole (blue circle). Upper right: simplified hydrogeological map of mainland Portugal, distinguishing the study area with a black rectangle.

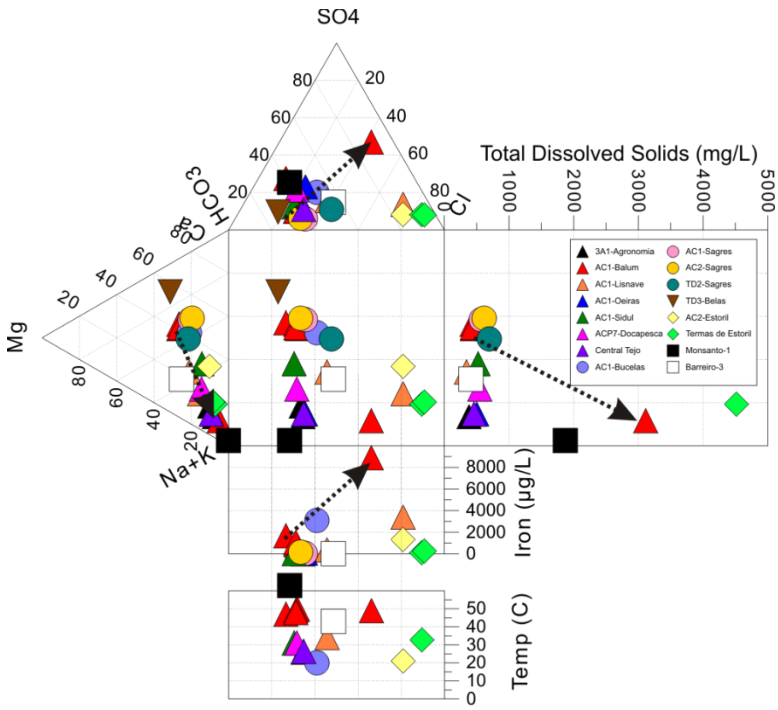

Figure 2 Modified Durov diagram of main physical-chemical characteristics of groundwater from Lower Cretaceous aquifer in Lisbon urban region. Black arrows show salinization processes observed in AC1-Balum geothermal well.