Simulation of the hydrochemical evolution of the Ledo-Paniselian aquifer in North Belgium using the PHAST simulator

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ABSTRACT

The Ledo-Paniselian is a tertiary aquifer system in the north part of Flanders (Belgium), where it is a frequently used groundwater source for industrial and smaller scale applications. Considering the importance of the aquifer, it has intensively been studied in the past. These studies comprised both hydrodynamical, hydrochemical and isotopic aspects. Consequently the hydrogeological functioning of this aquifer system is well understood. This paper shows the results of a last addition as the hydrochemical evolution of the aquifer has now been reconstructed with the hydrogeochemical simulator PHAST.

The aquifer consists of Eocene marine mainly sandy deposits that originally contained salt water. The Ledo-Paniselian layer is dipping to the north where it is covered under the significant clay layer of the Bartonian clay which makes the aquifer semi-confined in this region. Only in the south, where it outcrops, has the layer a phreatic regime. In the upper part of the aquifer, salt water has been replaced by freshwater, infiltrated during the holocene and pleistocene periods. Isotopic evidence has shown that this freshening cycle has only been interrupted temporarily during the last glacial maximum, around 20000 years ago, likely because of the presence of the permafrost layer which prevented infiltration of recharge water. A gap in the ^{14}C ages is indicating this. The main recharge of the aquifer is in its upstream section, but not in the phreatic part (Fig 1). The compact Bartonian clay forms a topographical cuesta near its southern border, with associated high water table levels. The local head difference between the upper water table and the Ledo-Paniselian piezometric level (up to 15 m difference) makes that the percolating fluxes are high enough to induce a groundwater divide (this is observed) in the Ledo-Paniselian. Groundwater flow in the semi-confined part of the aquifer is in the northern direction. As a result of the freshening progress and its associated cation exchange processes, a whole chromatographic series of watertypes has been generated, ranging from $CaHCO_3$ in the upstream part, over $MgHCO_3$ and $NaHCO_3$ types midway to the original saline NaCl waters in the deepest part. Because of the rather uniform south-north groundwater flow direction, the occurrence of the diverse watertypes shows a nice banded pattern.

In the past attempts have been made for modelling the evolution of the fresh/salt water distribution in this aquifer. This was typically done in cross-section in the north-south direction with single component solute transport models. But simulation of the hydrochemistry was, until now, restricted to a rather simple one-dimensional approach using the PHREEQM model. With the advance of multi-dimensional PHREEQC compatible simulation programs like PHAST, it is possible to extend the simulation in a two-dimensional approach along cross-sections, and in the near future maybe also in full 3D. Here the cross-section approach was used to limit calculation times. Among the included processes are mixing, cation exchange, calcite and gypsum dissolution. Starting from an initially completely salt groundwater body, the freshening process is followed over thousands of years and the resulting groundwater types are derived from the calculated concentration distributions. The observed chromatographic watertype series is regenerated by the PHAST model.

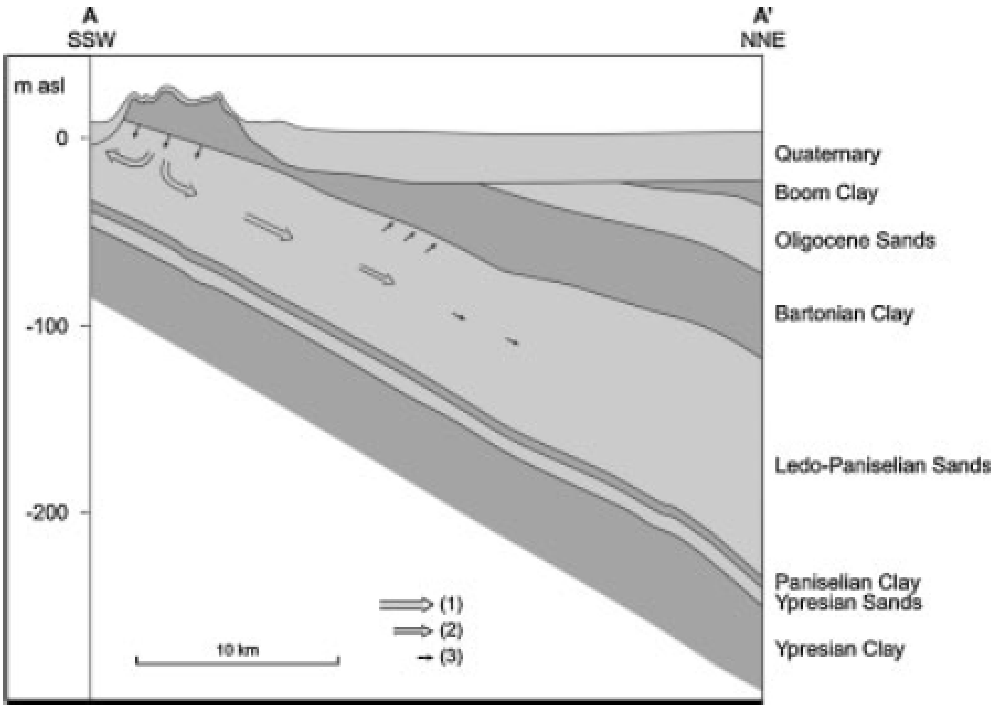

Fig 1 Hydrogeological cross-section of the Ledo-Paniselian Aquifer (after Blaser *et al.*, 2010) Groundwater flow pathways are shown. The Ledo-Paniselian Aquifer is recharged by a downward flow through the Bartonian Clay. The groundwater is mostly leaving the Ledo-Paniselian Aquifer by an upward flow through the Bartonian Clay. Darcy flow velocities (indicated by arrows): (1) 1.6 m a^{-1}; (2) 0.4 m a^{-1}; (3) 0.09 m a^{-1} or less derived from the mathematical modeling of the groundwater flow in Walraevens, 1988).

REFERENCES

Blaser, Petra; Coetsiers, Marleen; Aeschbach-Hertig, Werner; Kipfer, R., Van Camp, M. , Loosli,H. and Walraevens, K. (2010). A new groundwater radiocarbon correction approach accounting for palaeoclimate conditions at recharge and hydrochemical evolution : the Ledo-Paniselian aquifer, Belgium. *Applied Geochemistry* 25 : 437-455.