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Noble gas tracers for characterisation of flow dynamics and origin of groundwater: A case study in Switzerland

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SUMMARY

The Grenchen aquifer system in the Swiss Plateau was extensively investigated in order to determine the extent of groundwater contamination and to assess the natural attenuation capacity. Environmental tracer data were applied to estimate groundwater travel times, mixing ratios, and evaluate groundwater origin. Recharge is basically possible in two distinct topographical areas, the immediate vicinity of the town of Grenchen and the elevated plateau of the first Jura Mountain ridge. Groundwater dating was performed with the $^{3}H/^{3}He$ dating method and supplemented by ^{85}Kr measurements. Stable isotope data ($\delta^{18}O$, $\delta^{2}H$) and dissolved noble gas concentrations allow the determination of the recharge temperature, which is correlated to the recharge elevation. Noble gas temperatures (NGT) decrease in the direction of groundwater flow and range from 10 to 13 °C in the upstream area of the town to 7–9 °C in the downstream river plain. This trend could suggest the admixture of water from the underlying limestone aquifer recharged under cooler infiltration conditions, e.g. at higher recharge elevations. However, it is shown in this study that the difference in NGT does not require such a recharge. Rather, increasing air temperatures over the last 40 years and the urban heat island effect could possibly explain most of the observed temperature shift. Furthermore, it is concluded that the downstream river plain is hydrologically disconnected from the upstream town area. Consequently most water from the town area is drained by the creek Witibach and recharge in the river plain is higher than previously assumed.

Introduction

The investigated shallow aquifer system around the town of Grenchen (Switzerland) was contaminated by chlorinated hydrocarbons (CHC) due to widespread releases of chlorinated solvents by the local watch industry located in the town area (Fig. 1) (Abrecht and Chollet, 2005; Geotechnisches Institut, 1993). For the construction of a motorway tunnel in the downstream part of the contaminated aquifer (Fig. 1, river plain) the groundwater table was temporally lowered by massive water extraction (Soom, 2003). Additionally, groundwater was extracted at four protection wells, stripped of contaminants and discharged in the nearby creek Witibach (Fig. 1).

The final intention of the present research is the prediction of the future behaviour of the contaminant plumes by means of numerical groundwater flow, transport and reaction path models (Berthod, 2005; Steiner, 1999; Stoll, 2007; Sturzenegger et al., 2004). Model calibration and validation used piezometric head measurements and environmental tracer data. To supplement previously available tracer data, new observation wells were drilled at those locations where most knowledge could be gained from new data.

The heterogeneity of the aquifer and the large number of possible recharge paths calls for a comprehensive set of tracers. Extensive tracer measurements all over the field were used to examine the importance of inflows to the aquifer from the underlying limestone aquifer, which receives its recharge on the Jura Mountain ridge, in the overall budget and to quantify the spatial distribution of surface recharge in particular in the downstream part of the aquifer. ^{85}Kr and $^{3}H/^{3}He$ measurements were applied in combination to constrain the groundwater residence times below 50 years (Purtschert, 2008), whereas noble gas concentrations and stable isotopes provide information about groundwater recharge.

Site description

The study area can be divided into three regions with different characteristics in their topography, hydrogeology and land use (Fig. 1):

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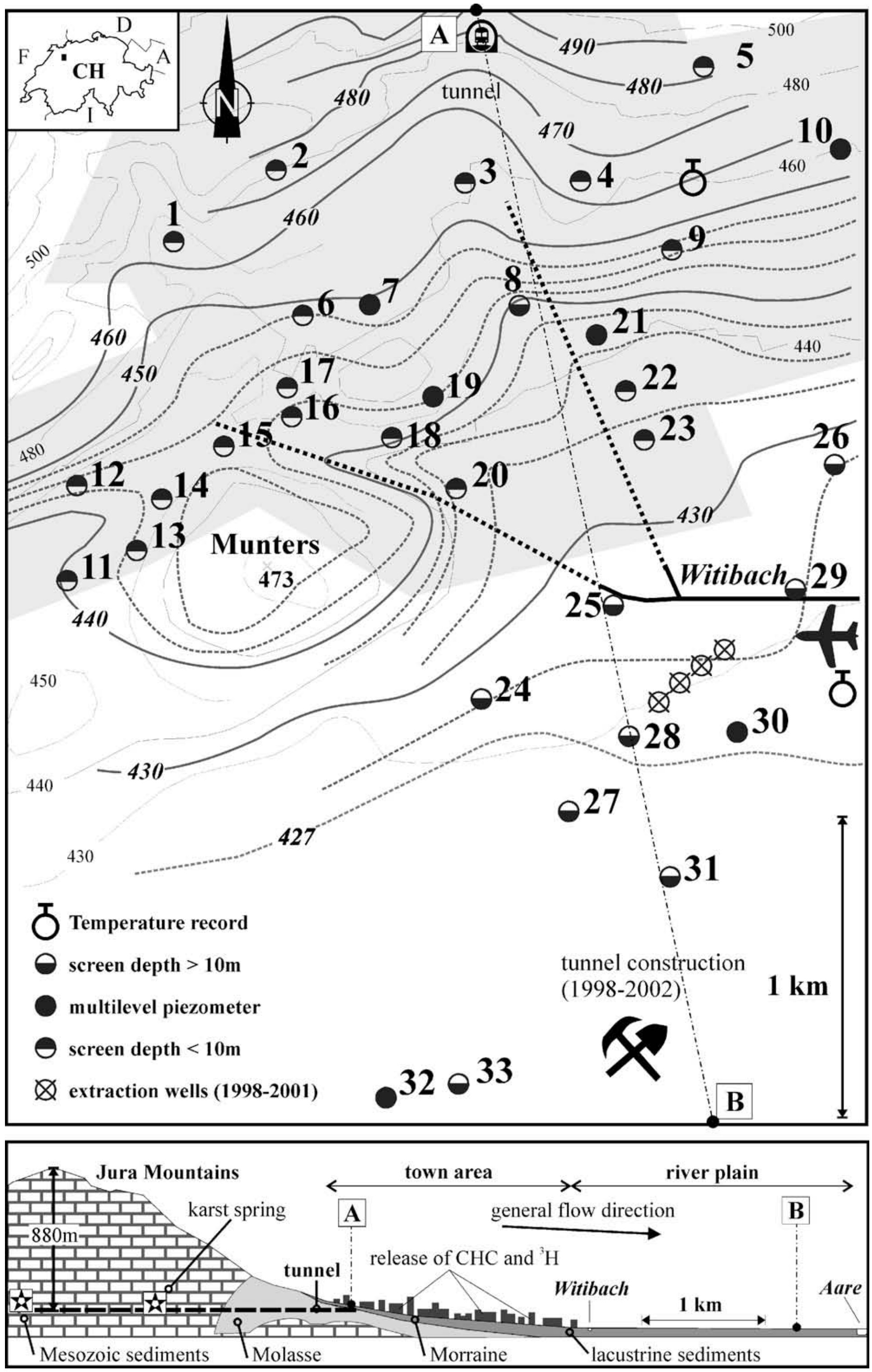

Fig. 1. (top) Distribution of sampled wells in the proximity of the town Grenchen (grey area). Piezometric heads (bold lines) mainly follow the topography and decrease from North to South. (bottom) Cross section through the river plain, the town area and the first Jura Mountain ridge. Sampled karst springs (stars) in the railway tunnel from Grenchen to Moutier are about 880 m below the mountain surface. The town of Grenchen, with emissions of CHC and ^{3}H starts at the slope of the first Jura Mountain ridge.

(1) The Jura Mountain ridge (800–1400 m.a.s.l.) with a mean altitude of the plateau of about 1150 m.a.s.l. forms the Northern boundary. Recharge in this mountain plateau infiltrates into a karst system which has been identified at several locations in the area, e.g. during construction of a railway tunnel crossing the Jura ridge.

(2) The town of Grenchen is situated at the Southern slope of the Jura Mountains (430–600 m.a.s.l.). Groundwater is mainly found in alluvial fans with highly permeable sandy gravels. The heterogeneous hydrogeological conditions are the result of glacial and post-glacial depositions. Alluvial fans with highly permeable sandy gravels are found in the