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Isotopic study of a deep groundwater system near the Danube-river / South Germany

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The groundwater flow regime in the jurassic karst and tertiary terrain near the Danube-river in the area of Ingolstadt / South Germany has been well discussed and investigated for years [1, 2, 3]. However, a stringent explanation of the complex deep groundwater system at the meeting-point of young, karstic groundwater from the north (open karst) and old deep groundwater in the south (covered karst) is still lacking. Today, because of the increasing water use for drinking water supply in the high industrialized area of Ingolstadt, reliable hydrogeological answers and a future sustainable groundwater management system are needed. First symptoms of overexploitation are visible by hydrochemical and isotopic measurements. Coming from the actual state of hydrogeological knowledge, the use of isotope techniques provide distinct explanation for the complex genesis of the occurring groundwaters.

The investigation area is the southern part of the karstified Upper Jurassic in the Franconian Alb, region of Ingolstadt. The Jurassic Formation declines from north to south with a dipping angle of more than 3° and dives to the south under the covering tertiary sediments of the South German Molasse and the quaternary sediments of the Danube-river. The Tertiary starts to cover the Jurassic some 5 km north of the Danube river. Here, springs with high discharge are to be found. The covering tertiary sediments often perform a low permeability. With a thickness of up to 100 m below the Danube, the Tertiary forms a local and effective aquitard, which causes an extraordinary hydraulic groundwater flow regime.

The Danube- river is the main drainage system for the investigation area and indicates active groundwater flow regimes. However, an old and mostly stagnant groundwater reservoir below the river was detected by using isotope techniques. The local hydrogeological situation is described schematically in the profile in Fig. 1.

Applications of the isotopes ^{2}H, ^{18}O, ^{3}H, ^{85}Kr, ^{39}Ar, ^{13}C-DIC and ^{14}C-DIC as a part of hydrogeological studies and numerical modeling were performed to gain knowledge of the hydrogeological system interactions (^{85}Kr and ^{39}Ar were measured at the Universität Bern, Prof. H.H. Loosli). The interpretation of existing data of 53 wells and recent measurements at 29 wells were carried out to obtain a quantitative and qualitative assessment of the groundwater system. Three wells with representative isotope results and typical hydrogeological positions are shown in Fig. 1.

The isotope investigations result in three groundwater provinces with different age structure and different recharge conditions. The groundwaters in the northern open karst generally are dominated by tritium containing components. Relatively high $\delta^{2}H$-, $\delta^{18}O$- and ^{14}C-values indicate groundwaters younger then 2000 years . Their recharge area is situated in the open karst and the groundwaters are part of the actual and dynamic water cycle.

The groundwaters in the covered Jurassic karst show generally low $\delta^{2}H$-, $\delta^{18}O$-, ^{3}H- and low ^{14}C-values. The decrease of ^{14}C- as well as $\delta^{2}H$- and $\delta^{18}O$-values from north to south explains the complex interaction of groundwaters with different recharge conditions. Mixing zones, deduced from ^{3}H-, ^{85}Kr- and ^{39}Ar-values are located at the meeting point of the young, dynamic and the old groundwater flow regimes. The latter participate only very little in the actual water cycle. Today, the groundwater flow in this terrain is mostly induced by increasing artificial groundwater discharge and a shift of the mixing zones is significantly notable.

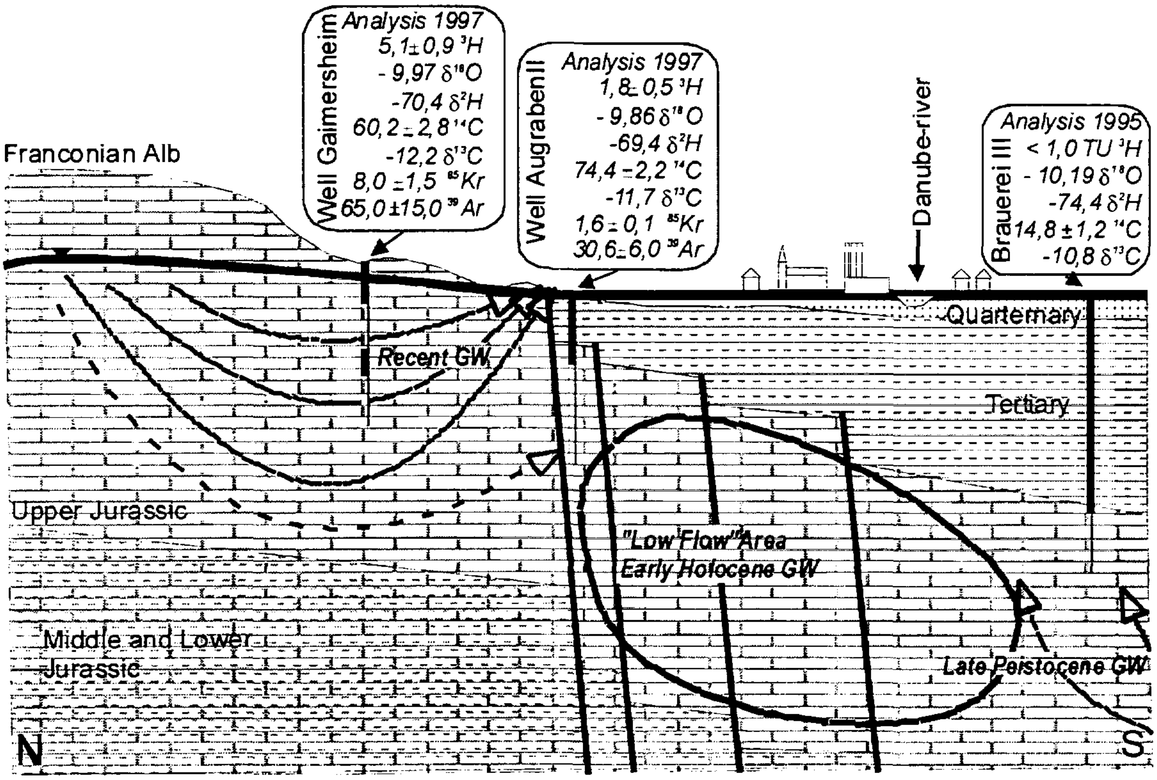

Fig.1: Schematic profile of investigation area with isotope results from three representative wells: δ^{2}H in ‰-VSMOW, δ^{18}O in ‰-VSMOW, ^{3}H in TU, ^{14}C in %-modern, δ^{13}C in ‰-VPDB, ^{85}Kr in dpm/ml$_{Kr}$, ^{39}Ar in %-modern.

The recharge conditions of the deep, old groundwaters were dominated by late Pleistocene climatic conditions. The groundwaters were moved to their recent reservoir, when the recharge condition in the early Holocene lead to an uplift of the groundwater table in the open karst, pressing the former groundwaters out to the east. Today, the hydraulic situation has significantly changed: The groundwater table in the North and the South is higher, the covering Tertiary sediments are low in permeability and the hydraulic gradient to the east, following the Danube gradient, is low.

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