Tritium/3He dating of Danube bank infiltration in the Szigetkös area, Hungary

M. Stute 1,5, J. Deàk 2, K. Révész 3, J.K. Böhlke 3, É. Deseö 2, R. Weppernig 1, and P. Schlosser 1,4

1 Lamont-Doherty Earth Observatory of Columbia UniversityPalisades, NY 10964, USA

2 Water Resources Research Centre (VITUKI)Kvassay Jenö út 1, 1095 Budapest, Hungary

3 United States Geological SurveyMS 431, Reston, VA 22092, USA

4 Department of Geological SciencesColumbia University, New York, NY 10027

5 Barnard College, Columbia University3009 Broadway, New York, NY 10027

Abstract

3H, 3He, 4He, and Ne concentrations were measured in samples from a shallow ground water system being recharged by bank infiltration from the Danube river in north-west Hungary. 3H/3He ages increase linearly along flow lines as a function of distance from the Danube. For the deeper ground water (50 to 100 meters below surface), which is not affected by recharge from local precipitation, a horizontal flow velocity of approximately 500 m/year was derived from the age gradient. Variation of 3H plus 3He ("initial tritium") ground water data as a function of the 3H/3He age is consistent with the time series of tritium measurements in the Danube river for the past 30 years, confirming the reliability of the derived residence times. Deviations between measured Danube tritium data and 3H and 3He data from the aquifer can be explained by dispersive mixing and by interaction with local surficial recharge.

Introduction

During the atmospheric atomic bomb tests in the 1950's and 1960's, large quantities of tritium (3H, the radioactive isotope of hydrogen), were released in the upper atmosphere. After oxidation to HTO, 3H takes part in the hydrological cycle. It decays with a half life of 12.43 years to the noble gas 3He. Residence times of shallow ground water in the time range of 0 to 35 years can be determined by measuring the concentrations of 3H and its decay product, 3He (t: 3H/3He age):

$$t = \frac{12.43\mathrm{y}}{\ln(2)} \cdot \ln\left(1 + \frac{^{3}\mathrm{H}}{^{3}\mathrm{He}}\right)$$

The distribution of 3H/3He ages in a ground water system may be used to obtain flow velocities and directions, as well as dispersion coefficients (e.g. *Tolstikhin and Kamensky,* 1969*; Schlosser et al.,* 1989*; Poreda et al.,* 1988). This technique has the potential to verify ground water flow and transport models and to provide a "clock" for biogeochemical processes along flow paths.

The Szigetkös region

The Szigetkös region is an alluvial plain located between the Danube and the Mosoni-Danube in the northwestern corner of Hungary (Fig. 1). In the superficial aquifer, groundwater south of the Danube flows south/ southeastward as indicated by the gradient in the water table elevation distribution (Fig. 1).

MAP has to be inserted

Fig. 1: Map of the area of investigation located in the northwestern corner of Hungary. Stripled lines symbolize the water table elevations (a.s.l.). The arrow shows the flow path along which the samples (identified by numbers; black dots: deep wells, triangles: shallow wells) were taken. The dotted area identifies the diversion canal.

Tracer tests, analysis of the hydrogeology of the aquifer, and H218O/H216O ratios suggest that bank infiltration from the Danube is the main source of groundwater in this aquifer (*Deák et al*., 1995). The superficial aquifer yields groundwater for a population of about one million persons. This resource is threatened by agricultural and communal pollution and by the drastic reduction of the flow in the Danube river as a result of its partial diversion by a concrete lined canal to Slovakia (Fig. 1). A better understanding of the ground water flow is the focus of this study.

Results and discussion

The 3H, and 3H+3He (equivalent to the tritium concentration if tritium were a stable isotope, also "initial tritium") distributions are characterized by a peak at a distance of 12 to 15km from the Danube along a flow line (Fig. 2). Most likely, the peak corresponds to the maximum 3H concentration in precipitation and in the Danube river which was observed around 1963/1964.

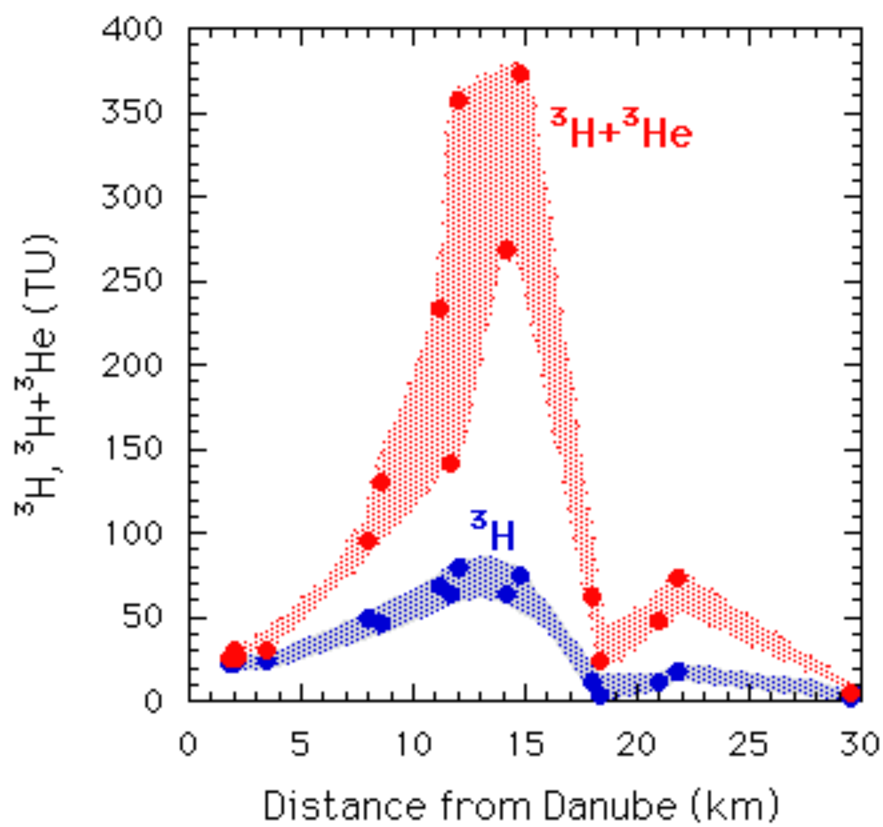

Fig. 2: 3H and 3H+3He concentrations as a function of distance from the Danube. The maximum concentrations occur at a distance

of 12 to 15 km from the Danube.

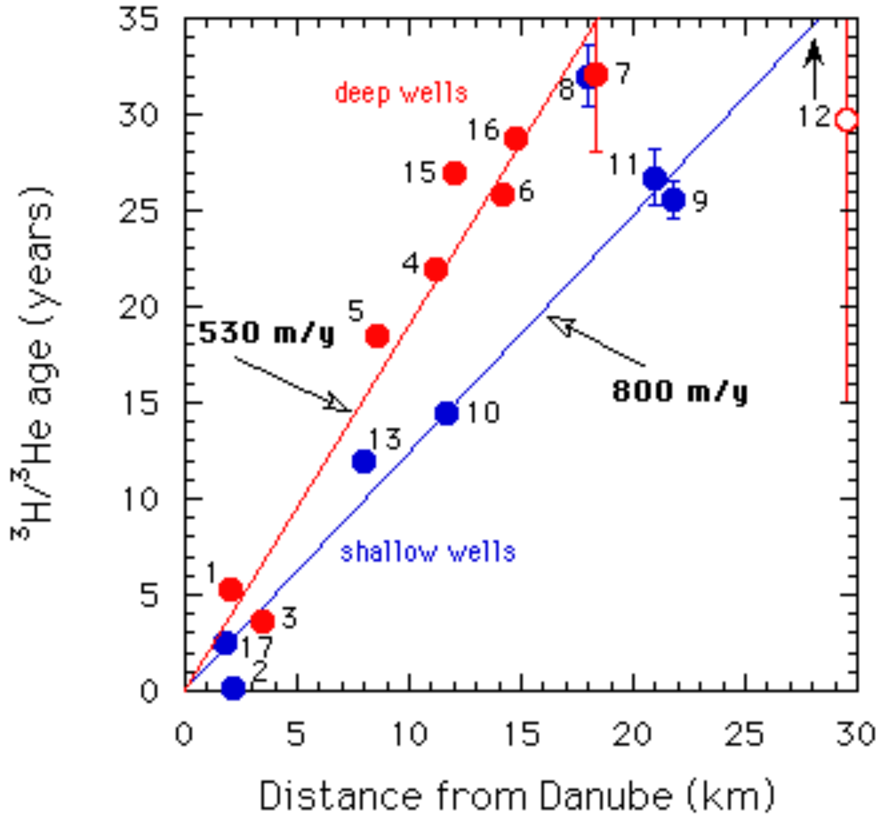

Fig. 3: 3H/3He age as a function of distance from the Danube. The age gradient of the deeper wells can be converted into a horizontal flow velocity of 530 m/y.

This is consistent with the 3H/3He age of these waters which range from about 26 to 29 years (in 1993, Fig. 3). 3H/3He ages (Fig. 3) show a more or less linear increase with distance from the Danube. The shallow wells (depth less than 20 m) are characterized by a steeper gradient than the deeper wells. However, these wells may be affected by mixing with locally recharged groundwater or surface water. The slope of the curve representing the deeper wells can be converted into a horizontal flow velocity of 530m/y.

The consistency of the 3H/3He ages was checked by comparing 3H+3He concentrations as a function of 3H/3He ages with the time series of 3H concentrations in precipitation and Danube water (Fig. 4).

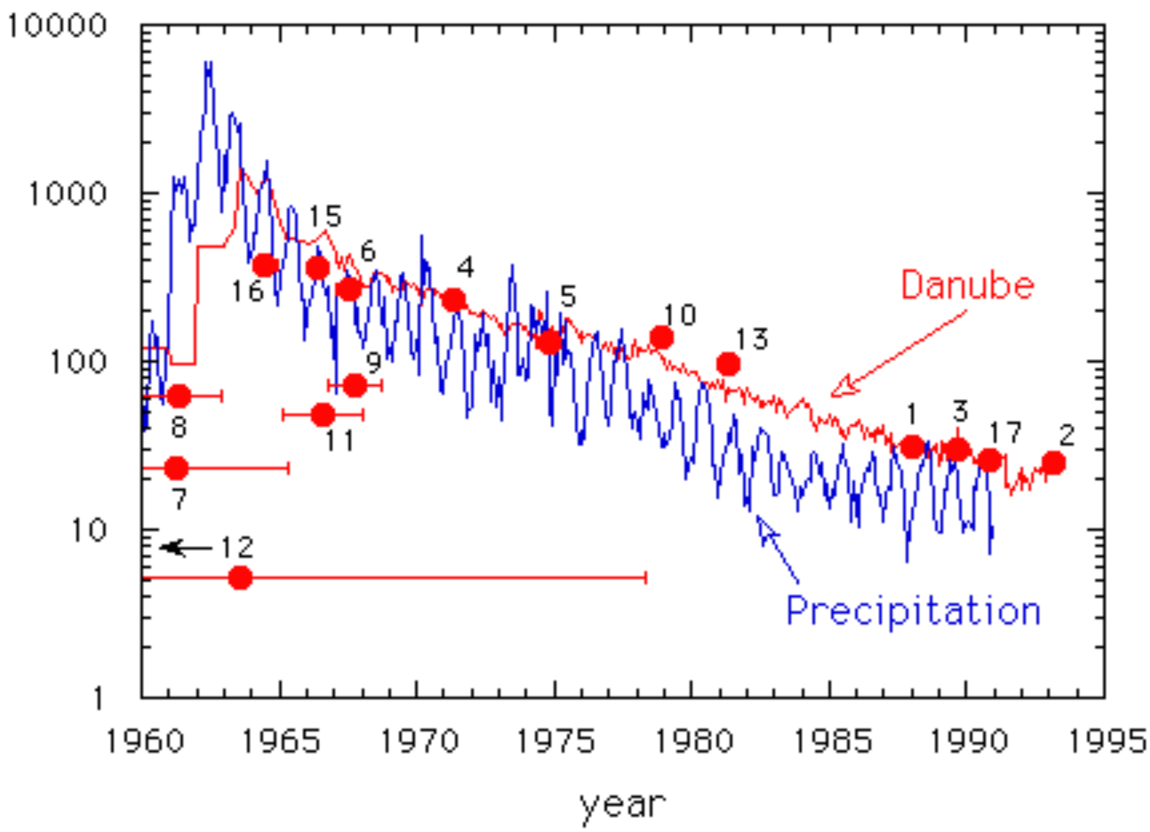

Fig. 4: Tritium concentrations in the Danube (reconstructed from precipitation data for the period prior to 1964, *IAEA/WMO precipitation network*, and measured directly after 1964 *,Rank and Papesch,* 1992, 1993). The red dots symbolize 3H+3He as a function of the time of recharge derived from 3H/3He ages of the groundwater samples.

There is an excellent agreement between our 3H/3He data and the Danube tritium data for groundwater recharged after 1968. Deviations of the 3H/3He data from the river input curve may be due to macrodispersion or large scale mixing in the groundwater system. A one dimensional dispersion/ advection model was used to simulate the influence of dispersive mixing on the 3H/3He data. Fig. 5 shows that the deviation of the modeled curve from the 3H input curve is a function of the relative importance of dispersion versus advection expressed as the ratio of dispersivity and flow velocity (/v, given in years). A few samples are not very well represented by the dispersion model (samples 9, 10, 11, and 13). They may be influenced by mixing with water recharged from a small river (Mosoni Duna) south of the main river bed or with local precipitation.

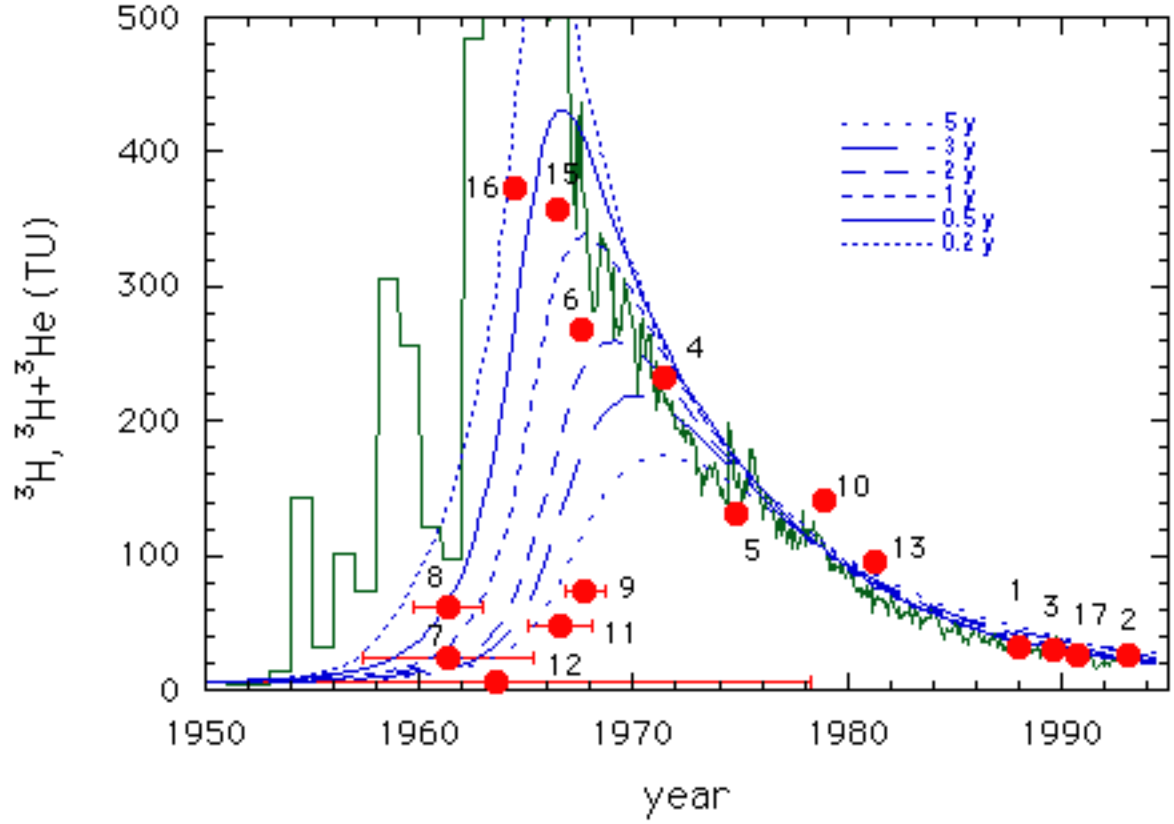

Fig. 5: Comparison of modeled and measured tritium data of the Danube river. The parameter is the ratio of dispersivity and flow velocity (/v, in years).

Conclusions

Our study is the first attempt to use the 3H/3He method to constrain flow and transport in a shallow aquifer recharged by bank infiltration. The agreement between the long time serie of Danube River tritium data and measured 3H/3He data confirms the reliability of the 3H/3He ages as a measure of the `true' age, i.e. the time elapsed since recharge from the Danube River. The distribution of 3H/3He ages may be used to verify a three-dimensional groundwater flow and transport model for the area and will provide a key element in understanding the dynamics of flow in this area.

References

Deàk, J., E. Deseö, J.K. Böhlke, and K. Rèvèsz (1995) Isotope hydrology studies in the Szigetkös region, north--west Hungary. In: Isotopes in Water Resources Management, IAEA-SM-336, Vienna, in press.

Poreda, R.J., T.E. Cerling, and D.K. Solomon (1988) Tritium and helium isotopes as hydrologic tracers in a shallow unconfined aquifer. J. Hydrol., 103, 1--9.

Rank, D, and W. Papesch (1992) Isotopenhydrologische Basisdaten (18O) der Donau und anderer Oberflächengewässer in Osterreich. Limnologische Berichte der 29. Arbeitstagung der Internationalen Arbeitsgemeinschaft Donauforschung, Kiew, 1991, Wissenschaftliche Kurzreferate, I, 234--238.

Rank, D. and W. Papesch (1993) written communication, Bundesversuchs-und Forschingsanstalt Arsenal, Vienna.

Schlosser, P., M. Stute, C. Sonntag, and K.O. Münnich (1989) Tritiogenic 3He in shallow groundwater. Earth Planet. Sci. Lett., 94, 245--256.

Tolstikhin, I.N. and I.L. Kamensky (1969) Determination of groundwater ages by the T-3He method. Geochem. Int., 6, 810--811.