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Outstanding Student Poster Contest

^{39}Ar groundwater dating of a coastal aquifer in the Nam Dinh Province, Vietnam

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Introduction

In the south of Nam Dinh Province, Red River Delta, Vietnam (fig. 1), fresh Pleistocene groundwater has been identified to exist next to brackish pore waters [1]. Extensive exploitation of the fresh water results in decreasing groundwater heads and migration of brackish water towards the freshwater [2].
Dating of the groundwater improves understanding of the dynamics and evolution of the aquifer and provides additional information on the origin of the salt (from paleowaters or recent intrusion).

Study Area

During the last glacial maximum, the Red River has carved out a valley, which has been filled with sediments during the Pleistocene/Holocene marine ingression [3]. To the west and north of the delta, Triassic bedrock is cropping out.
The Pleistocene/Holocene aquifers are mostly recharged from the triassic limestone hills in the west and by local infiltration of (river) water through rice paddies [1].

Figure 1: Location of the study area.

Methods

13 boreholes (using a submersible pump) and 4 pumping wells were sampled for several environmental tracers.
Samples for ^{3}He, ^{4}He and ^{20}Ne analysis were collected in copper tubes.
For ^{39}Ar analysis the gas from 2000-3000 liters of water was extracted in the field from which Ar was purified in the laboratories of University of Bern. ^{39}Ar activities were measured by gas proportional counting [4]. Before purification, the gas composition was measured by a quadrupol mass spectrometer to determine the amount of CH_4 in the gas.

Results

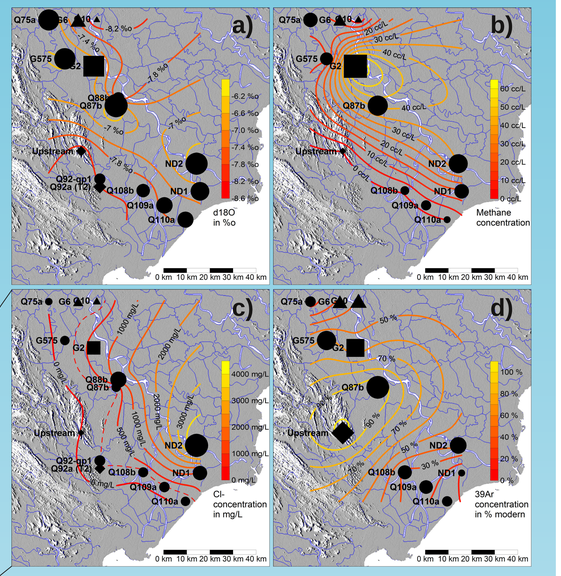


Figure 2: Spatial patterns of a) $\delta^{18}O$, b) methane concentration, c) Cl^- concentration and d) ^{39}Ar activity for the study area. The symbol refers to the geologic unit: ♦=Triassic, ▲=Neogene, ●=Pleistocene, ■=Holocene. The size of the symbol is scaled with the value measured. The isolines were created using standard kriging.

- The spatial pattern of $\delta^{18}O$ shows a clear distinction between wells in the north and east along the river and wells in the south and west, except for the deep Neogene wells
- A similar pattern is found in methane concentrations which are as high as 62 cm^3/L
- ^{39}Ar activity shows that the youngest water is present in the western triassic hills, from where it is flowing southwards and probably also northwards. Pistonflow ages vary from modern (upstream, Q87b) to 1200 years (ND1)
- The Cl^- concentration is higher along the river as well, but also shows a high local variability
- The stable isotopes of all samples are close to the local meteoric water line (not shown here)

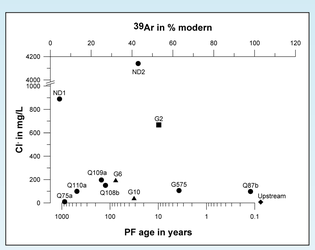


Figure 3: Cl^-concentrations as a function of ^{39}Ar, which is an indicator of water age. For comparison: ocean water has a Cl^-concentration of about 19'000 mg/L. The symbols refer to the same geologic units as in fig. 2.

Discussion

Origin of the salinity

Fig. 3 shows no obvious correlation between groundwater age and chloride. Old and young water both show high and low chloride concentrations. This is in line with previous findings [1] where recent and ancient Cl^- sources were identified in the area.

A closer look at the degassing process

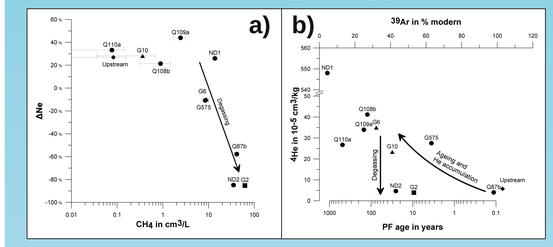
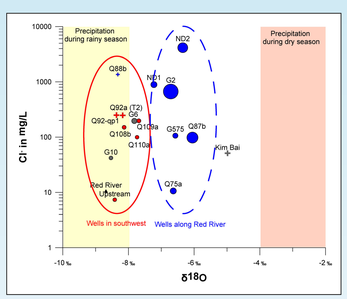


Figure 4: The two plots help to better understand the degassing process:
a) ΔNe as a function of the methane concentration.
b) ^{4}He against ^{39}Ar (i.e. decreasing age) showing the accumulation of ^{4}He over time. The most degassed samples show very low ^{4}He concentrations.

- Waters depleted in atmospheric neon (ΔNe<0%) show elevated CH_4 concentrations suggesting a link between the two (fig. 4 a))
- Degassing is diffusion dominated because degassed samples show the same ^{3}He/^{4}He ratio as samples with little CH_4 at a younger age (fig. 6)
  There are two possible processes:
  - Very fast degassing by methane bubbles forming in the well during sampling
  - Slow diffusion towards the water table driven by the CH4 concentration gradient
- The older degassed waters show ^{4}He concentrations as low as at infiltration (fig. 4 b))
- Stable isotopes show no signs of evaporation or mixing with ocean water for the wells along the river which are enriched in $\delta^{18}O$. The reason is more infiltration along the river during the dry season (fig. 5)

Figure 5:
Wells located in the vicinity of the Red River (blue) are enriched in $\delta^{18}O$ but not in Cl^- compared to wells in the southwest of Nam Dinh (red). Typical values for $\delta^{18}O$ in precipitation and the Red River are also shown. The size of the circles corresponds to the CH_4 concentration. A cross means CH_4 was not measured.



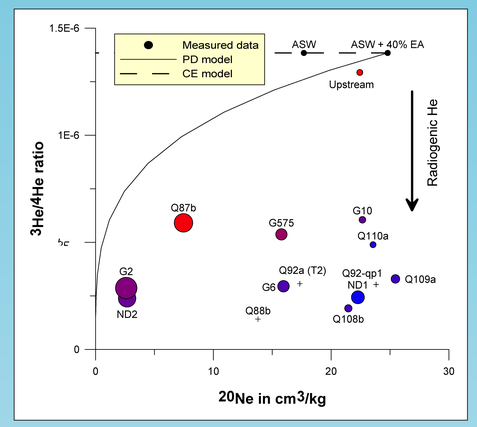


Figure 6: ^{20}Ne against ^{3}He/^{4}He with the size of the circles corresponding to the CH_4 concentration of the samples and the color representing the ^{39}Ar activity (blue = lowest, red = highest). A cross means CH_4 and ^{39}Ar was not measured. Shown is also air saturated water (ASW) and how groundwater will evolve starting from 40% excess air (EA) in case of solubility dominated degassing (CE model) and diffusion dominated degassing (PD model) [6].

Conclusions

- Groundwater residence times in the Nam Dinh province range from modern up to several hundreds and thousands of years
- Water in the southwest recharges in the triassic hills during the wet season
- Groundwater along the river probably has more local recharge during the dry season
- Local recharge or organic carbon in the sediments along the river are a source of CH_4
- CH_4 leads to diffusion dominated degassing at a late stage of groundwater evolution, the opposite of what was found at a coastal aquifer in Germany [5]
- The new data helps to better constrain groundwater models of Nam Dinh area and confirmed that the salt is derived from multiple sources

References

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