ESTIMATION OF GROUNDWATER AGE IN THE CENTRAL PART OF THE BALTIC ARTESIAN BASIN BASED ON NEW ISOTOPE DATA FROM LATVIA

Alise Babre[1], **Andis Kalvans**[2], **Konrads Popovs**[1], **Inga Retike**[1], and **Aija Delina**[1]

[1]Faculty of Geography and Earth Sciences, Centre of Geological Processes Research and Modelling, University of Latvia, Riga, Latvia (e-mail: alise.babre@lu.lv)

[2]Faculty of Science and Technology, Institute of Ecology and Earth sciences, University of Tartu, Tartu, Estonia

1. INTRODUCTION

A new data set of δD, $\delta^{18}O$, $\delta^{13}C$ DIC and ^{14}C in the groundwater from the central part of the Baltic Artesian Basin where existing data was sparse is presented. In 2010 to 2012 an extensive field campaign was undertaken, collecting noticeable quantity of groundwater samples for deuterium and stable oxygen analysis, 30 samples for stable carbon and for radiocarbon analysis 10 samples, mostly from the central part (Latvia) of the BAB covering all the major aquifer systems.

A specific motivation for the research was to identify relict glacial meltwater in the groundwater system. The broader aim was to estimate the isotopic composition of groundwater in the regionwithin each groundwater exchange zone.

2. GEOLOGY AND HYDROGEOLOGY

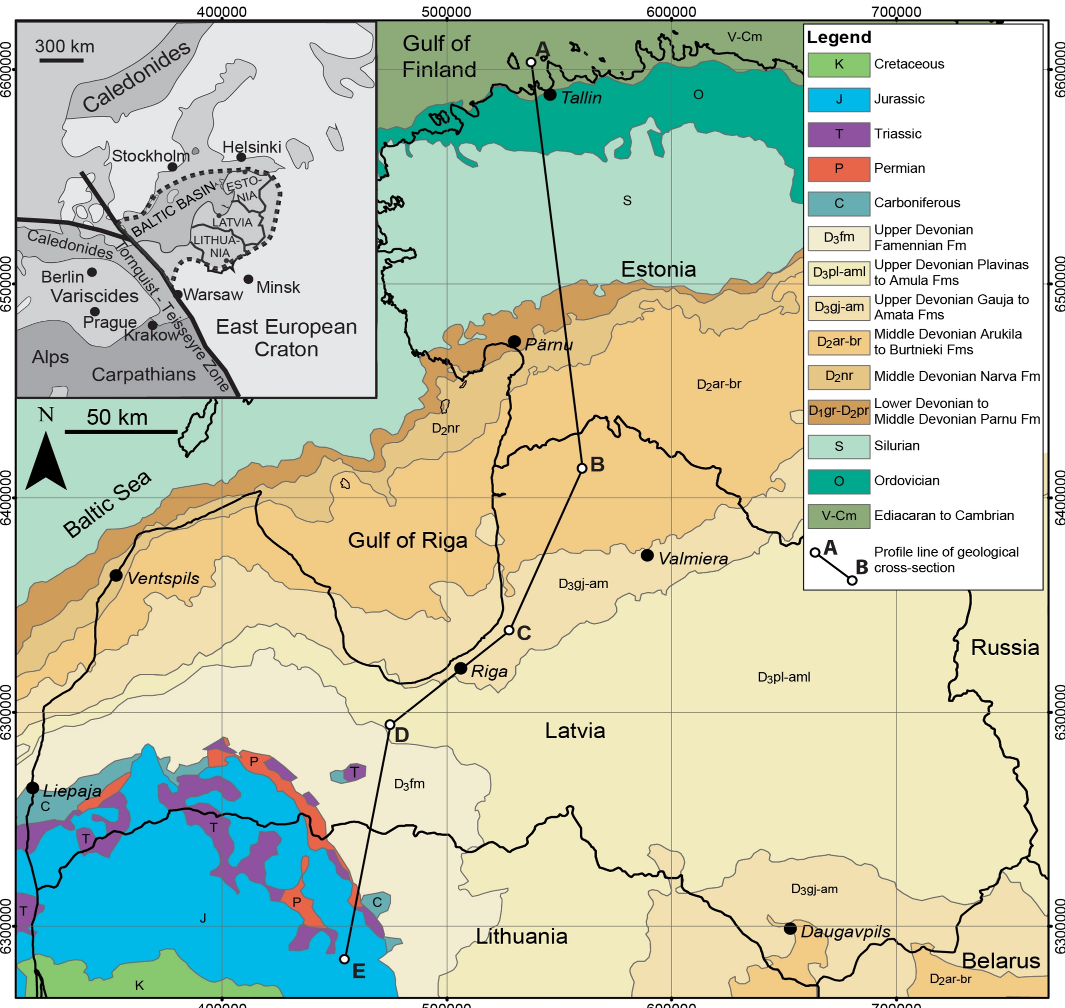

Fig. 1. Geological map and geological cross section of the study region, generated from the geological-hydrogeological model of the Baltic Artesian Basin. Coordinates given in TM Baltic 93 coordinate system (Compiled after Popovs et al. (in press) and Virbulis et al. (2013)).

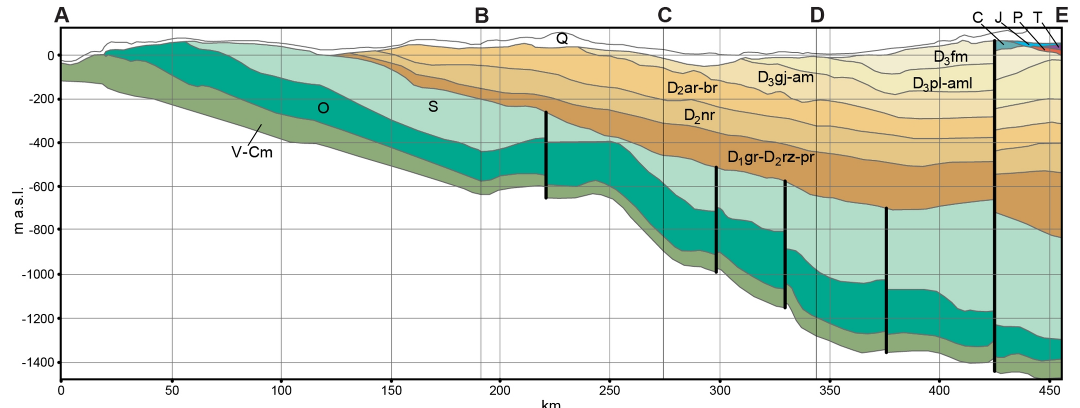

Fig. 2. Geological cross section of the study region, generated from the geological-hydrogeological model of the Baltic Artesian Basin (Compiled after Popovs et al. (in press) and Virbulis et al. (2013)). See the cross-section line in Fig. 1.

The study area is a part of the East European platform and covers the central part of the BAB.

Considering the depth, complexity of sedimentary cover and significant thicknesses of strata with low permeability groundwater system must be examined within lesser categories. Therefore for the Latvian part of the BAB, three distinct water circulation and chemical composition zones are traditionally identified:

- Stagnation zone: Ediacaran – Cambrian complex.
- passive (brackish) water exchange zone: lower and middle Devonian complex;
- active water exchange zone: above Narva regional aquiclude.

3. SAMPLE DISTRIBUTION

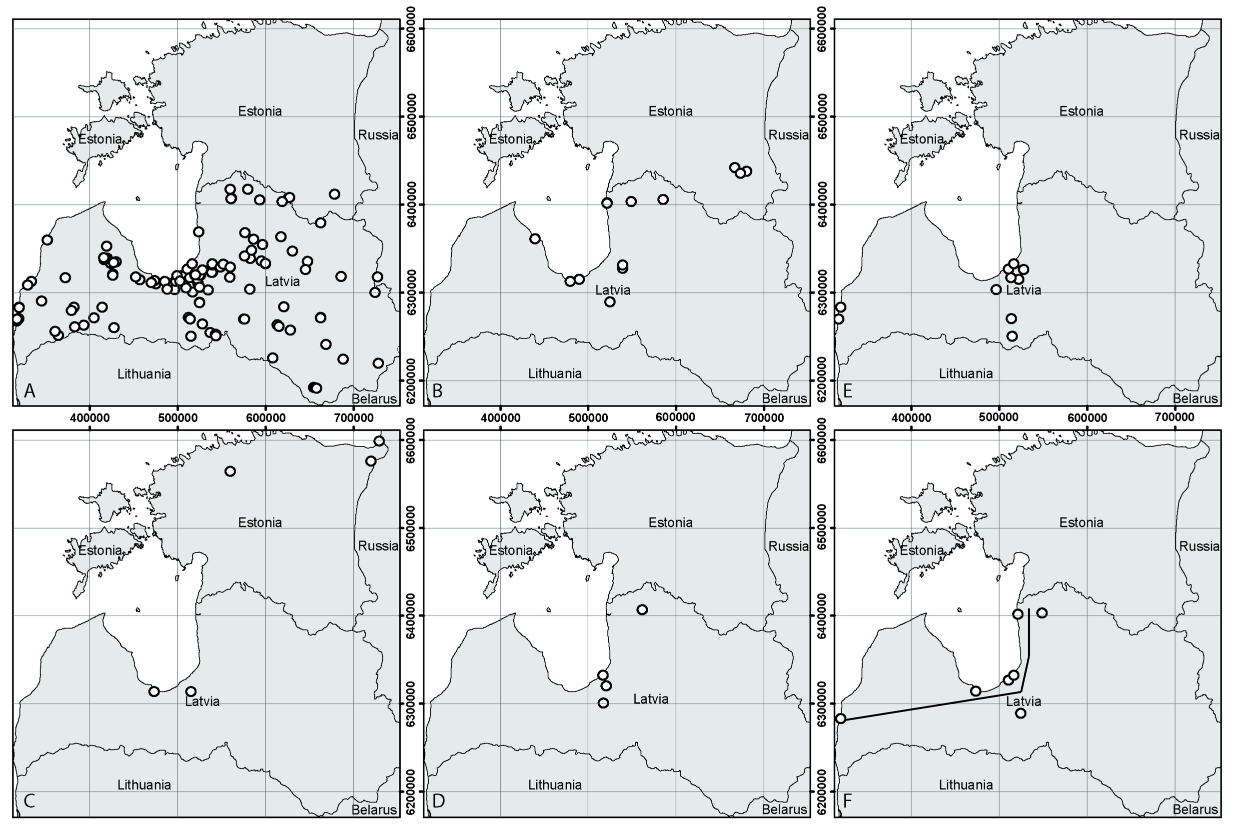

*Fig. 3. Location of sampling points: **a** - $\delta^{18}O$ and δD of active water exchange zone; **b** – $\delta^{18}O$ and δD of slow water exchange zone; **c** – $\delta^{18}O$ and δD of stagnant water exchange zone; **d** – $\delta^{18}O$ and δD of surface waters; **e** – $\delta^{13}C$; **f** – C^{14}.*

Fieldwork took place during years 2010-2012. Priority was given to the monitoring wells. Where no suitable monitoring wells were identified, groundwater extraction wells, geological mapping wells or springs were sampled.

In total 227 samples for $\delta^{18}O$ and δD and were taken, 27 samples collected for δ13C DIC and nine samples for radiocarbon analysis. Samples for $\delta^{18}O$ and δD were evenly collected covering all aquifers in the area, however $\delta^{13}C$ DIC samples represent only lower aquifers of active zone. ^{14}C samples are situated mainly in the slow and stagnant groundwater exchange zones.

4. METHODOLOGY

All measurements performed at the Tallinn University of Technology. Radiocarbon activities measured with scintillation spectrometer. The ^{14}C results are reported as percentage of the modern standard (pMC) and as Apparent Radiocarbon age (BP). The stable isotope ratio of oxygen and carbon were measured on a IRMS and CRDS. The results are expressed in ‰ deviation relative to VSMOW for Deuterium and oxygen isotopes and VPDB for stable carbon isotopes in DIC.

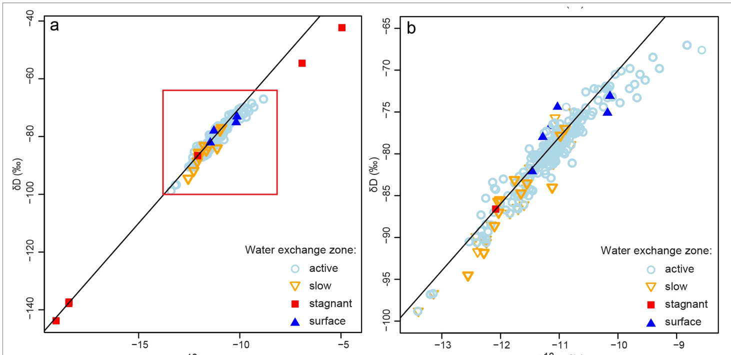

*Fig. 4. The measured δD and $\delta^{18}O$ values of the groundwater and surface water samples compared to global meteoric water line: **a** full range of obtained values; **b** zoom-in of the point cloud in the center of **b**.*

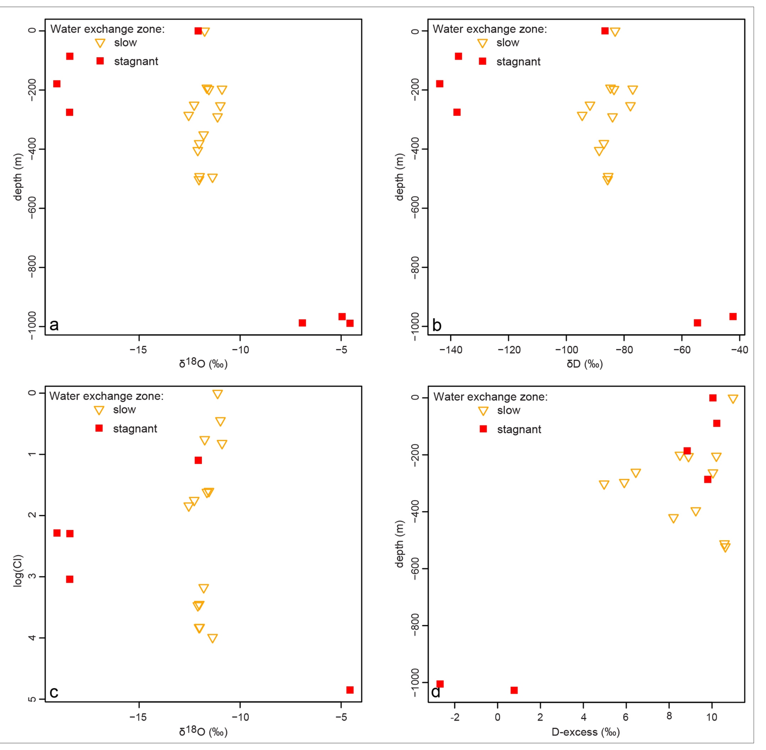

*Fig. 5. Relation of the isotopic composition, sampling depth and Cl⁻ concentration: **a** $\delta^{18}O$ versus sampling depth, **b** δD versus sampling depth, **c** $\delta^{18}O$ versus log(Cl⁻) and **d** D-excess versus sampling depth.*

5. RESULTS

Table 1. Summary of isotopic composition of groundwater in the three water exchange zones.

Water exchange zone	$\delta^{18}O$, ‰	δD, ‰	$\delta^{13}C$, ‰	^{14}C, pMC
Stagnant Range	-8,83 ...-13,4	-67,02...-98,8	-	12,4±0,4
Slow (passive) Range	-10,89...-12,65	-77...-94,5	-	4,42±0,09 ... 21,4±0,5
Active Range	-4,95...-19,08	-42,3...-143,8	-11,3...-18,4	2,59±0,08 ... 4,18±0,08
Precipitation water (IAEA/WMO, 2006) weighted mean	-9,74	-72,6	-	-

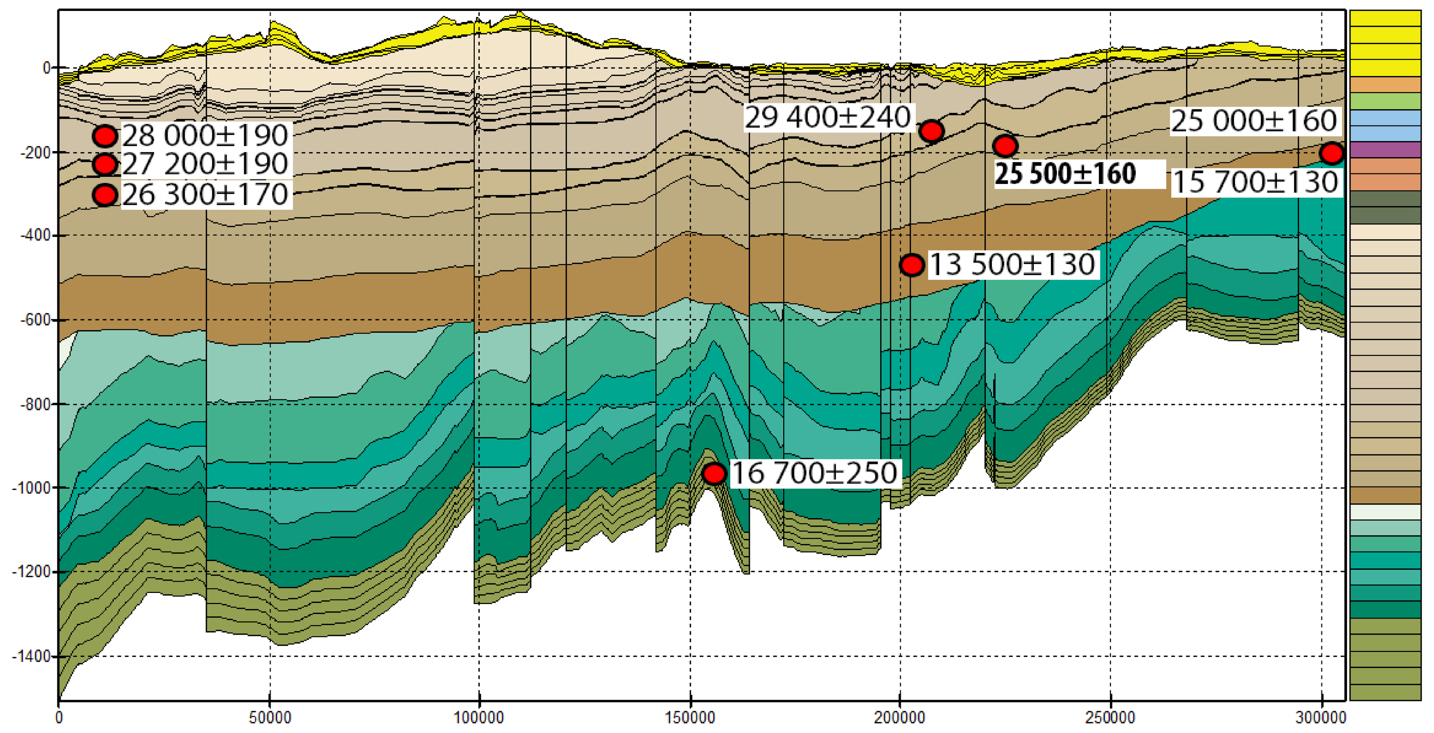

Fig. 6. Apparent ^{14}C age (BP) calculated fromDIC. Location of cross section in Fig 3-f.

Groundwater in the upper aquifers represents stable isotope values characteristic of precipitation in today's climate, large variability most likely is controlled by season of recharge and location of the recharge area, such as altitude and continentality of the recharge area, as well as links to the surface water bodies. The groundwater in the slow exchange zone is more depleted in $\delta^{18}O$ and δD than the groundwater in the active and slow exchange zone. Deepest - stagnation zone is strongly enriched in $\delta^{18}O$ and δD.

The brine in stagnant zone has particularly low D-excess, deviating noticeably from the global meteoric water line (Fig. 4).The D-excess value has a tendency to increases with depth (Fig. 5d).

Groundwater occurring in the Middle and Upper Devonian, i.e., lowest part of active exchange zone have $\delta^{18}O$ values are in the range of -13.4 to -9.6 ‰ with more depleted values observed near discharge areas of particular aquifers, however less depleted values are situated in the southern part and closer to the recharge areas of these aquifers. Some radiocarbon samples taken in these aquifers show low radiocarbon activity within the range of 2.5 - 4.18 thus apparent age is 25 - 30 k yr BP. This presents a characteristic downwards C shaped trend.The C-shaped trend can be explained by mixing of three components: brine, glacial meltwater and modern infiltration water.

In the groundwater ^{14}C activity of DIC ranged from 2.59 to 21.4 (Table 1) with smallest activity in the bottom of the active groundwater zone.

According to apparent radiocarbon age, the oldest groundwater is situated in the Middle Devonian aquifer and much younger groundwater can be found under it (Fig.6). However further analysis need to be carried out to crystallize such conclusions.

CONCLUSIONS

- The $\delta^{18}O$ values in the Cambrian brine are above -5 ‰ and δD values are approaching -40‰.
- The slow exchange zone is characterized by $\delta^{18}O$ values around -11.7 ‰ and δD values around -85.3 ‰ (standard deviation 0.5 ‰ and 5.0 ‰).
- Mean $\delta^{18}O$ and δD value of the groundwater in the active water exchange zone is -11.1 ‰ and -79.9 ‰ (standard deviation 0.7 ‰ and 5.1 ‰).
- A gentle heavy isotope depletion trend with increasing depth is observed in the slow water exchange zone;
- The range of $\delta^{13}C$ of DIC in the samples is quite narrow, i.e., from -11.3 to 18.3 $\delta^{13}C$ VPDB. There was no correlation nor with aquifer, chemical properties or other stable isotopes. Differences can't be observed even spatially.
- Even though $\delta^{18}O$ and δD values did not show any signs of the glacial meltwater relict in the aquifers, radiocarbon results suggest that groundwater in the slow, stagnant and even in the lower part part of active zone recharged during the maximum extend and during the retreat of the ice sheet of the last glaciation, i.e., at the end of Pleistocene.

ERAF EIROPAS REĢIONĀLĀS ATTĪSTĪBAS FONDS
EIROPAS SAVIENĪBA
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