Montpellier, September 2016

The Impact of the Last Glaciation on Groundwater Flow in Estonia: A Numerical Study.

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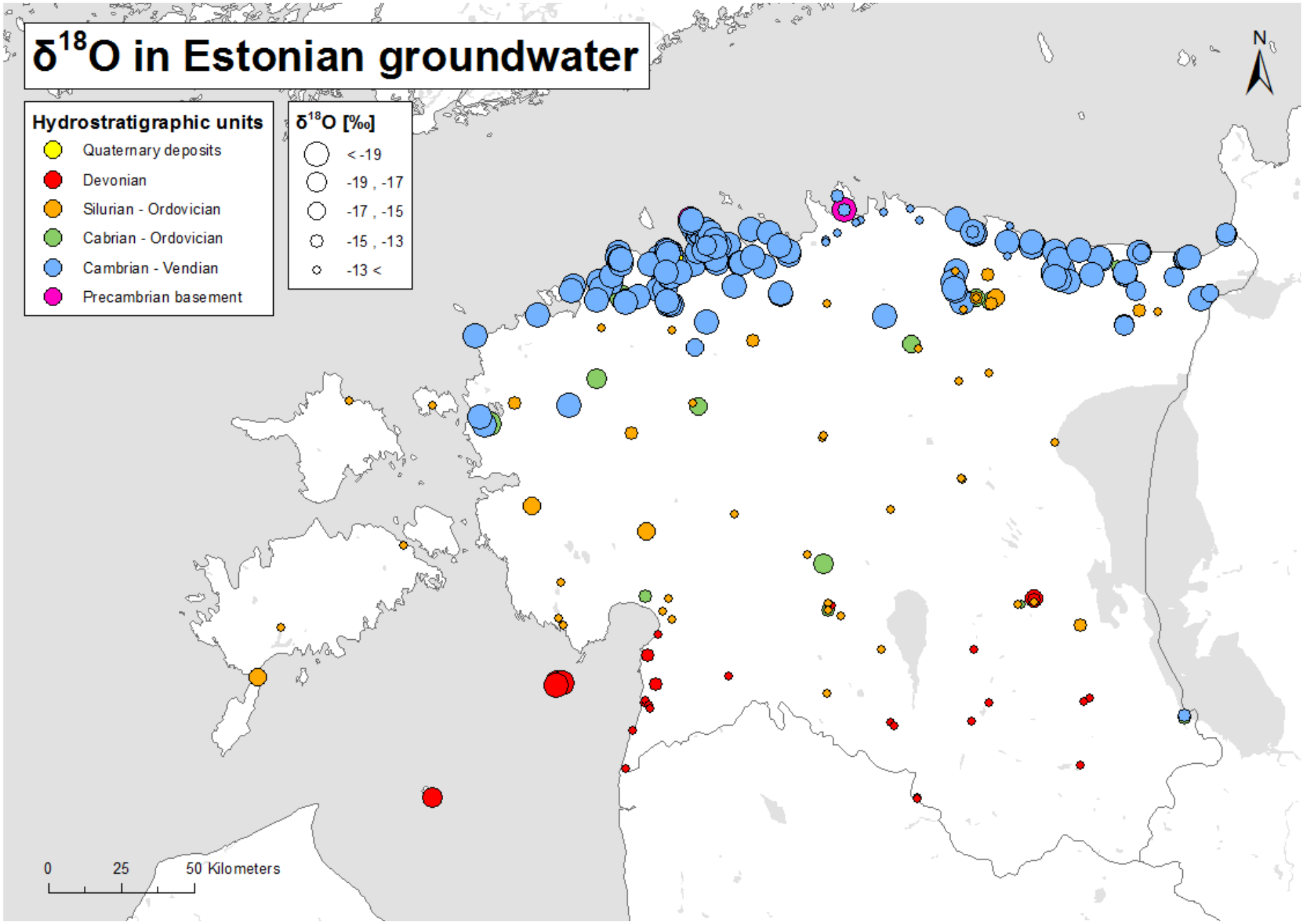
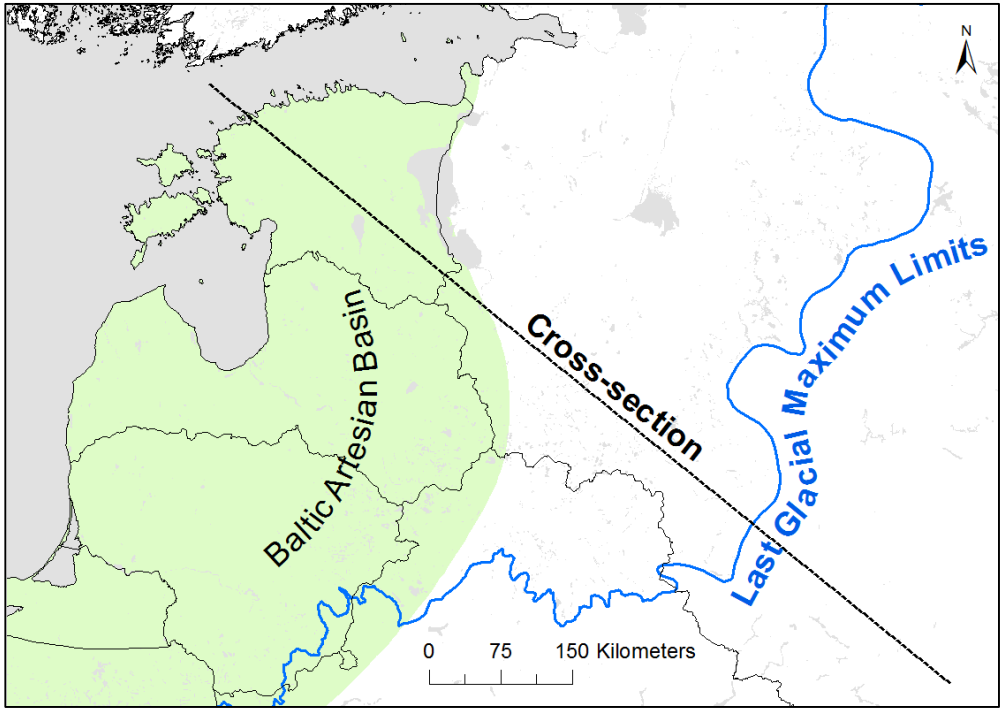
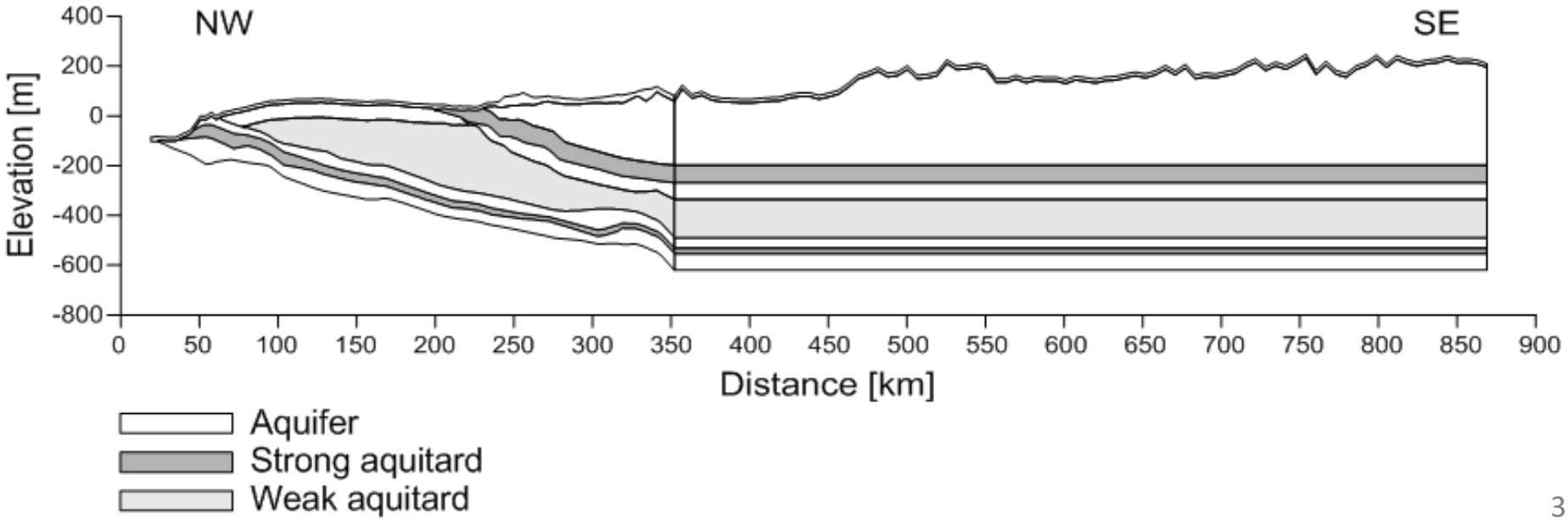


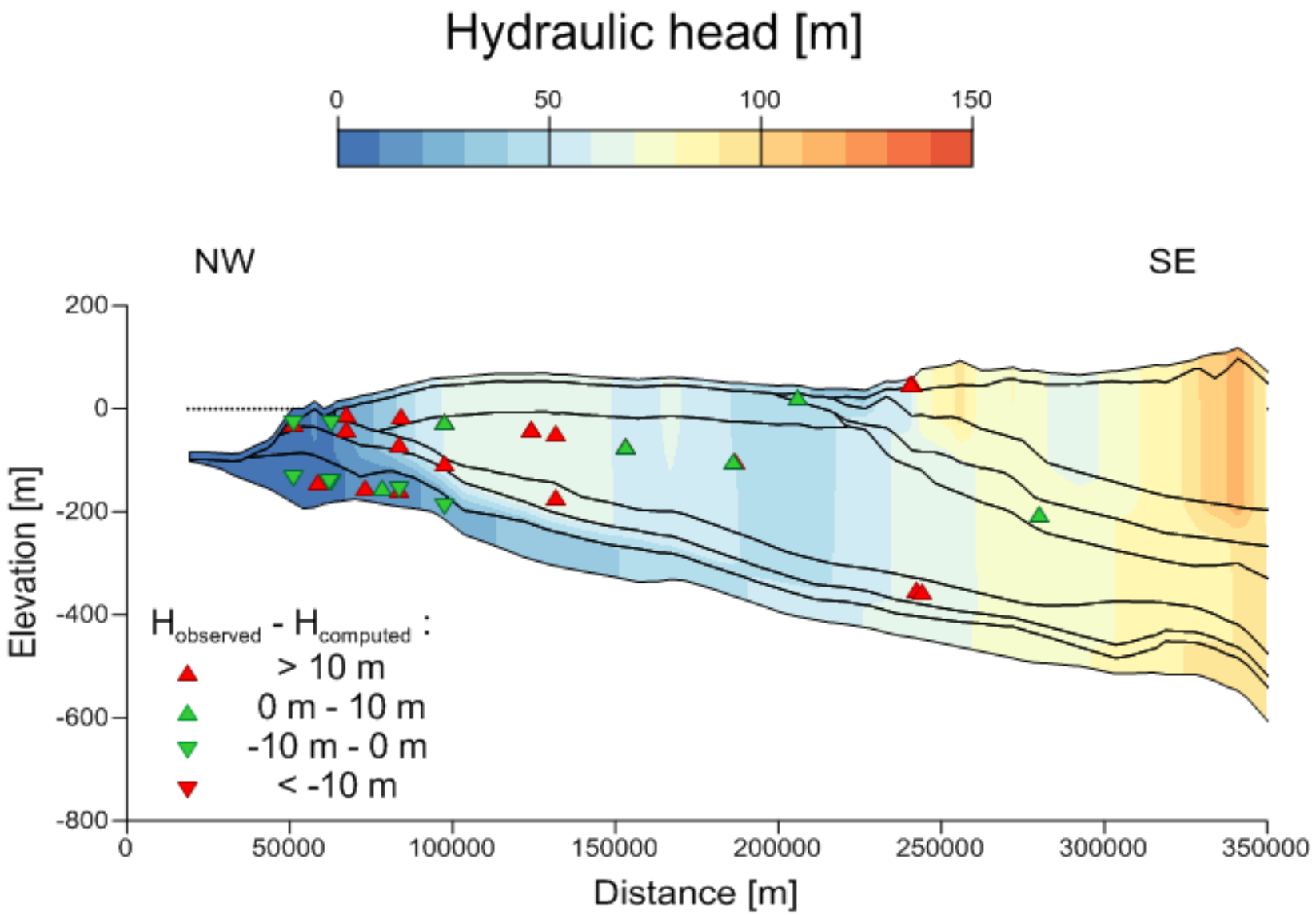
Source of $\delta^{18}O$ data: Technical University of Tallinn, Institute of Geology, 2014



- Baltic Artesian Basin hydrogeological model
  (Virbulis et al. 2013)

→ 42 layers in total

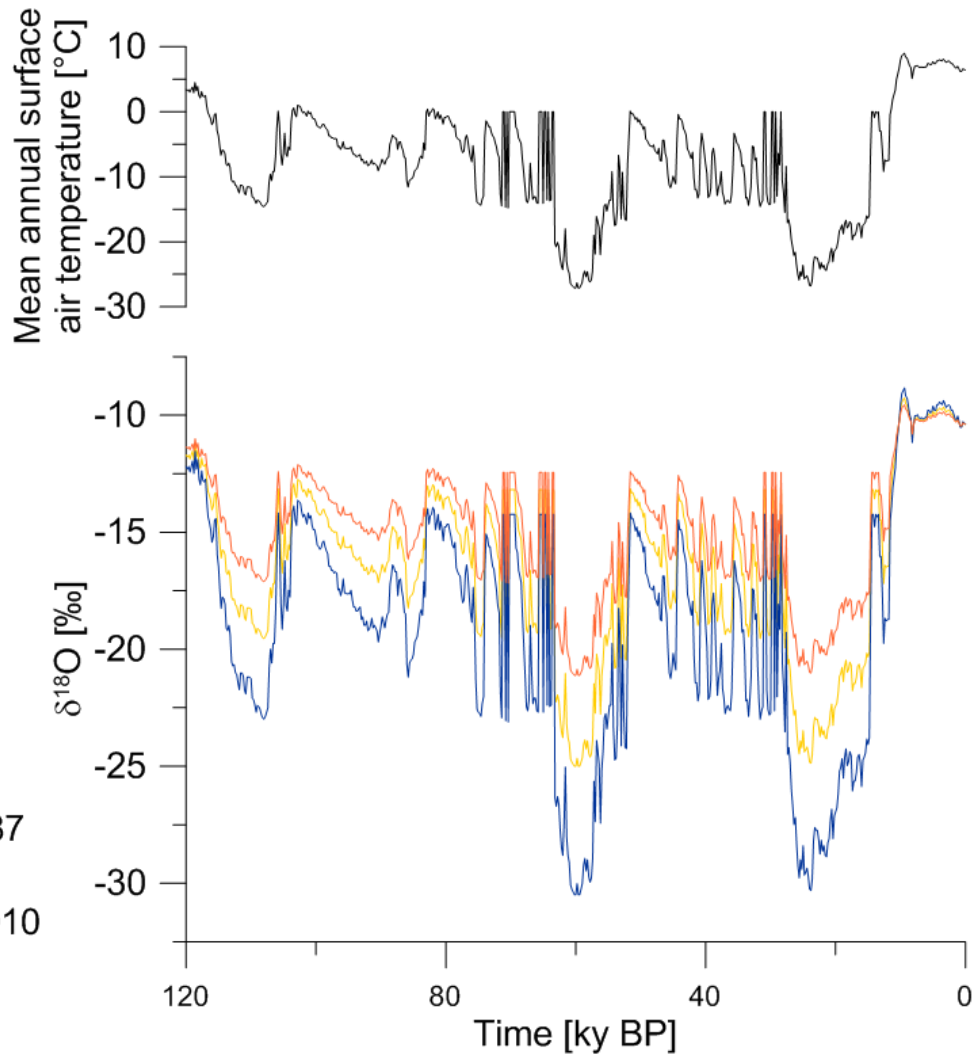


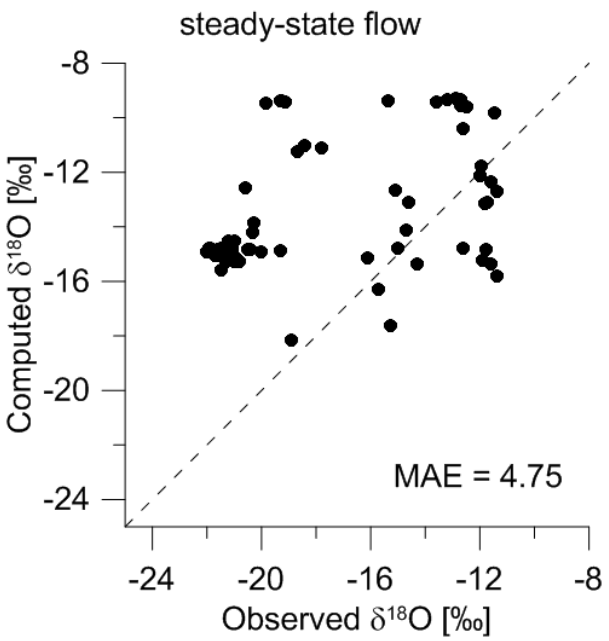

Hydraulic head [m]
0
50
100
150
NW
SE
200
0
-200
-400
-600
-800
Elevation [m]
$H_{observed}$ - $H_{computed}$:
> 10 m
0 m - 10 m
-10 m - 0 m
< -10 m
0
50000
100000
150000
200000
250000
300000
350000
Distance [m]

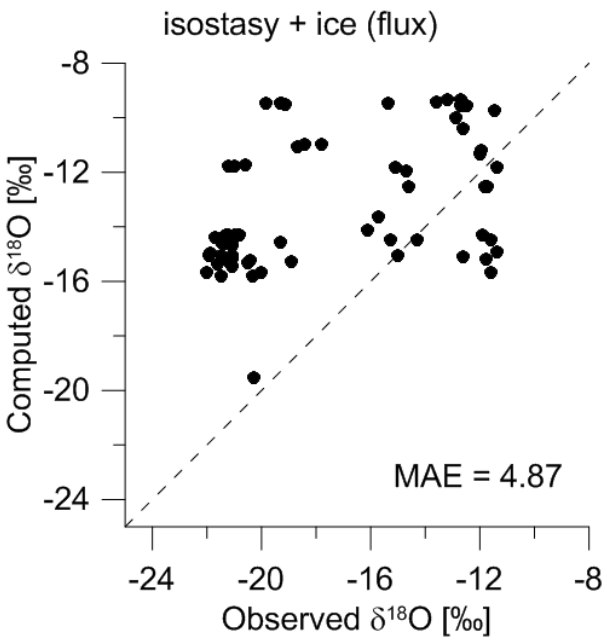
Glacial Systems Model of northern Europe *(Tarasov 2014)*

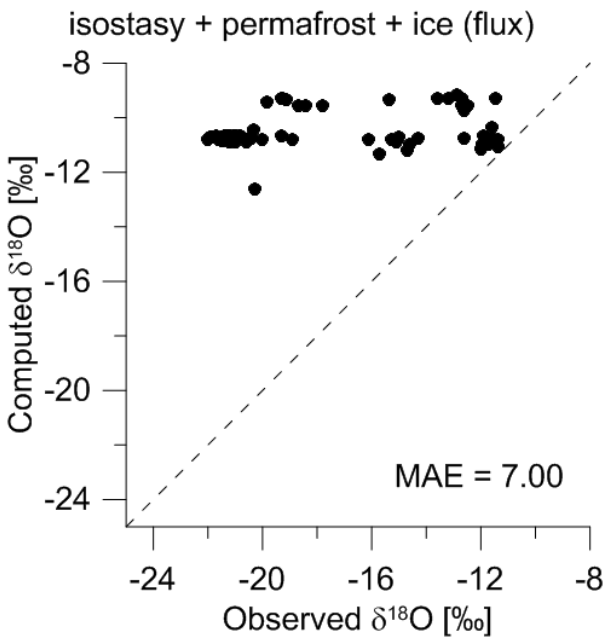
Long: 0.5° x Lat: 0.25° data over the last 120 ky:

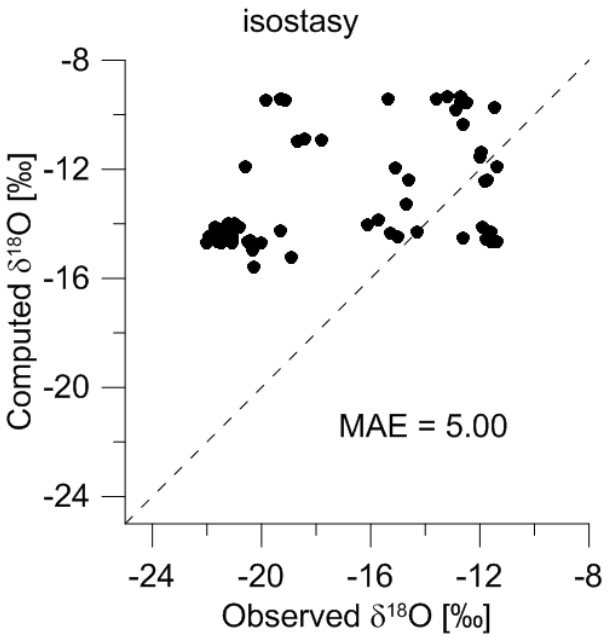
- Surface elevation
- Ice thickness
- Subglacial meltwater production
- Absolute sea level & lake water depth
- Permafrost thickness
- Mean annual surface air temperature

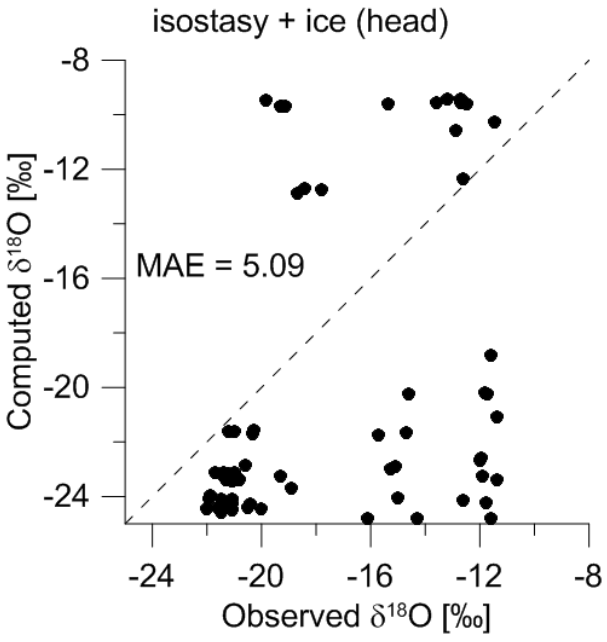


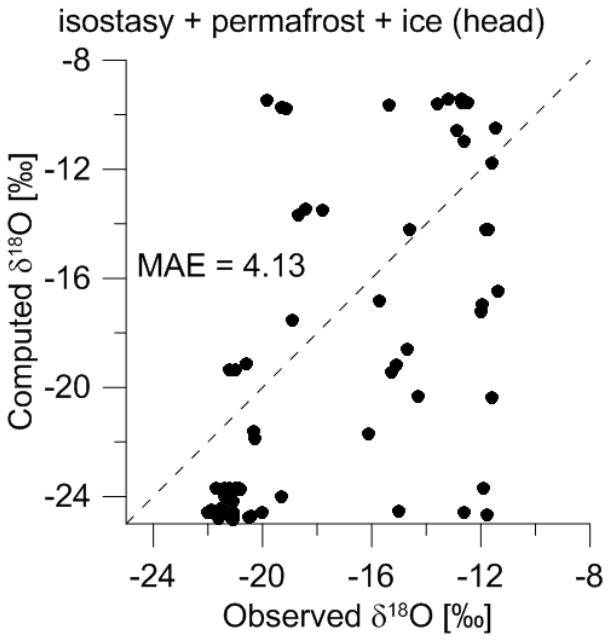

steady-state flow
Computed $\delta^{18}O$ [‰]
Observed $\delta^{18}O$ [‰]
MAE = 4.75


isostasy + ice (flux)
Computed $\delta^{18}O$ [‰]
Observed $\delta^{18}O$ [‰]
MAE = 4.87


isostasy + permafrost + ice (flux)
Computed $\delta^{18}O$ [‰]
Observed $\delta^{18}O$ [‰]
MAE = 7.00


isostasy
Computed $\delta^{18}O$ [‰]
Observed $\delta^{18}O$ [‰]
MAE = 5.00


isostasy + ice (head)
Computed $\delta^{18}O$ [‰]
Observed $\delta^{18}O$ [‰]
MAE = 5.09


isostasy + permafrost + ice (head)
Computed $\delta^{18}O$ [‰]
Observed $\delta^{18}O$ [‰]
MAE = 4.13

Batch analysis, testing several scenarios

One single glacial event, 3 variables:

- Ice-sheet thickness = [1, 1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75, 3] km
- Start of the Last Glacial Maximum = [25, 24, 23, 22, 21, 20, 19] ky BP
- $\delta^{18}O$ of meltwater = [-32.5, -30, -27.5, -25, -22.5] ‰

→ 315 simulations

→ “best fit” simulation: MAE = 2.58

2.5 km / 19 ky BP / -32.5 ‰

What’s next?

- Compare with the situation in Latvia
- Make some predictive scenarios of the fate of glacial water in Estonia

Lahemaa National Park (northern Estonia)

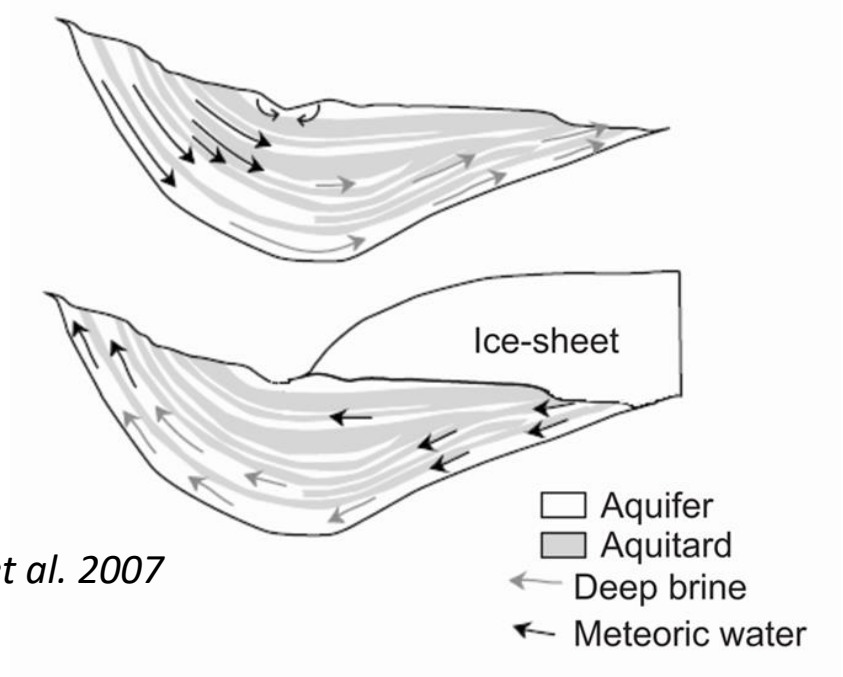
Thank you for your attention !

- Highly depleted in heavy isotopes (^{18}O and ^{2}H)
- Recharge temperature inferred from noble gases around 3,5 °C

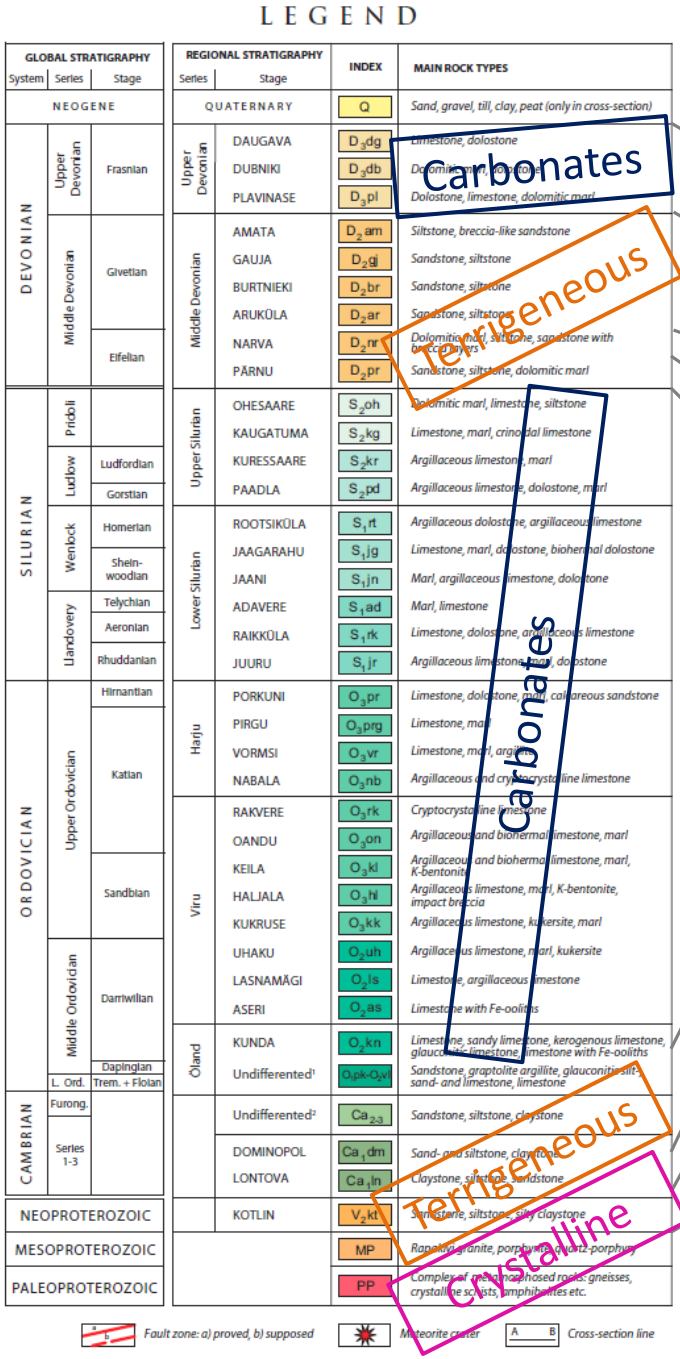
➔ *Recharge in a cooler climate*

- ^{14}C ages vary from 30 to 19 ky BP (Raidla et al., 2012)
- Low salinity (< 1 g/L)

➔ *Recharge near the end of the Last Glaciation*



Modified after Person et al. 2007

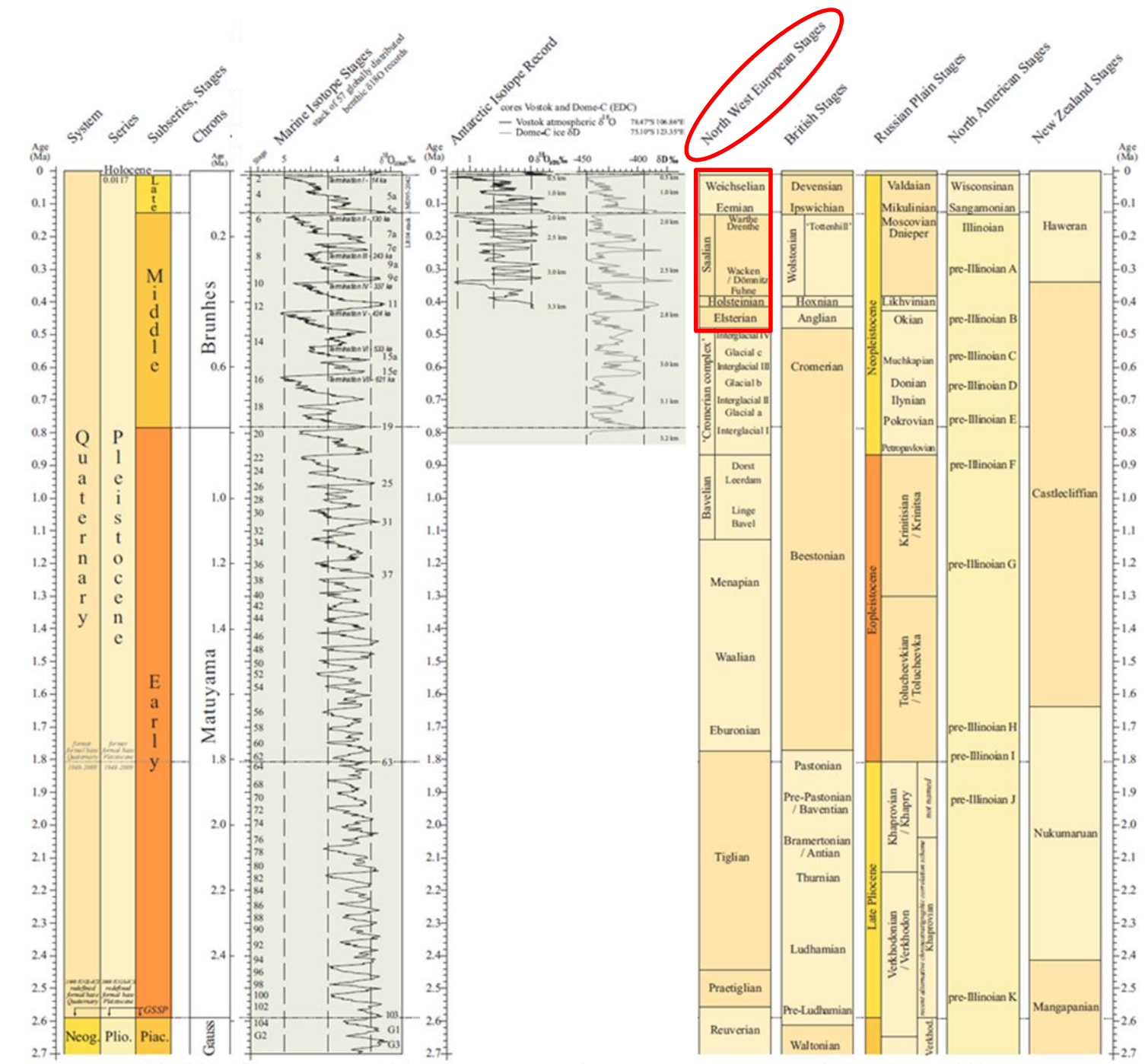


Hydrostratigraphy

Q	Quaternary deposits
D3	Upper Devonian aquifer
D2	Middle Devonian aquifer
	Narva aquitard
D2-1	Middle-Lower Devonian aquifer
S-O	Ordovician-Silurian aquifer
	Ordovician-Silurian aquitard
Cm-O	Cambrian-Ordovician aquifer
	Lükati-Lontova aquitard
Cm-V	Voronka aquifer
	Kotlin aquitard
	Gdov aquifer
PR	Crystalline basement

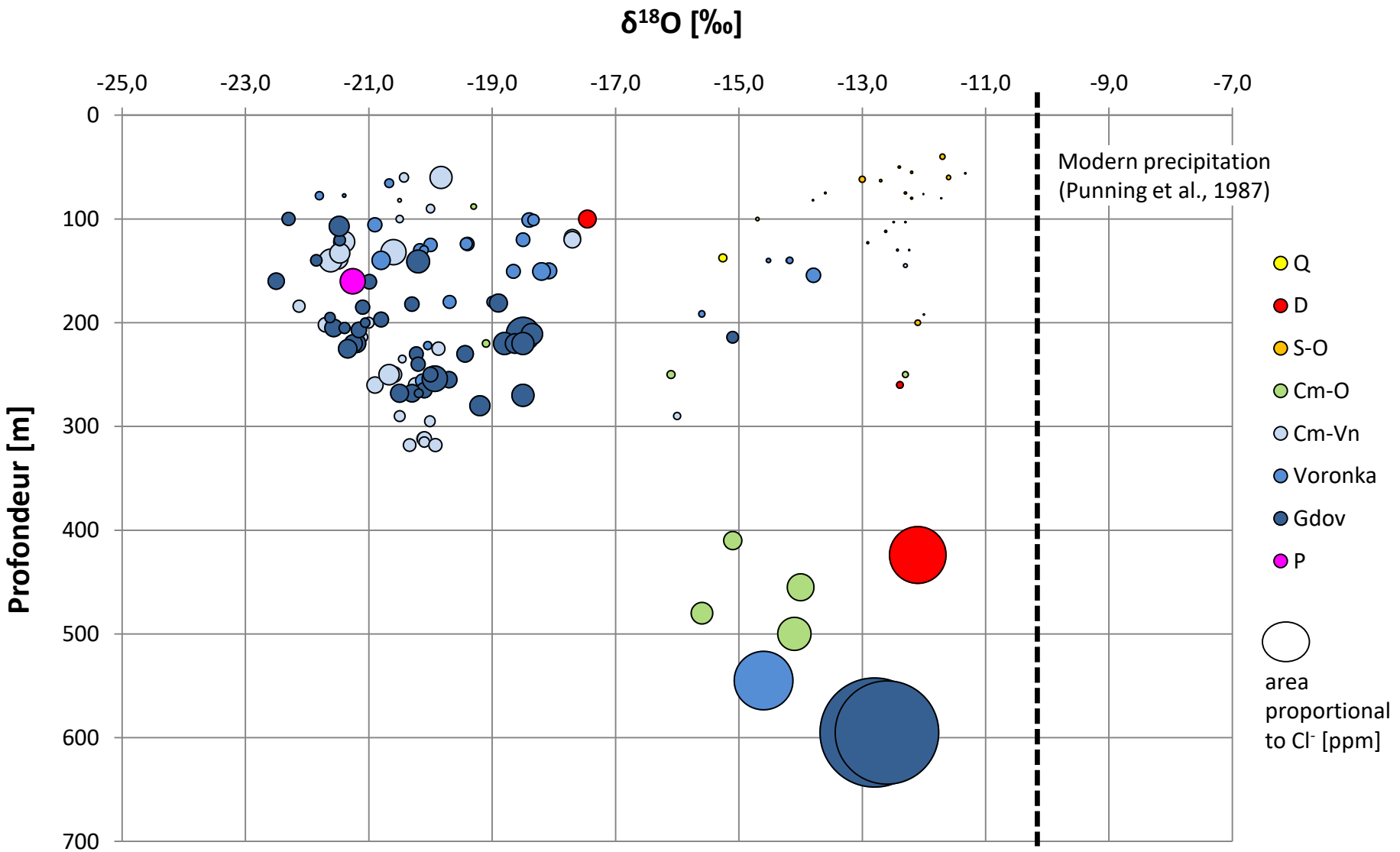
Aquifer

Aquitard

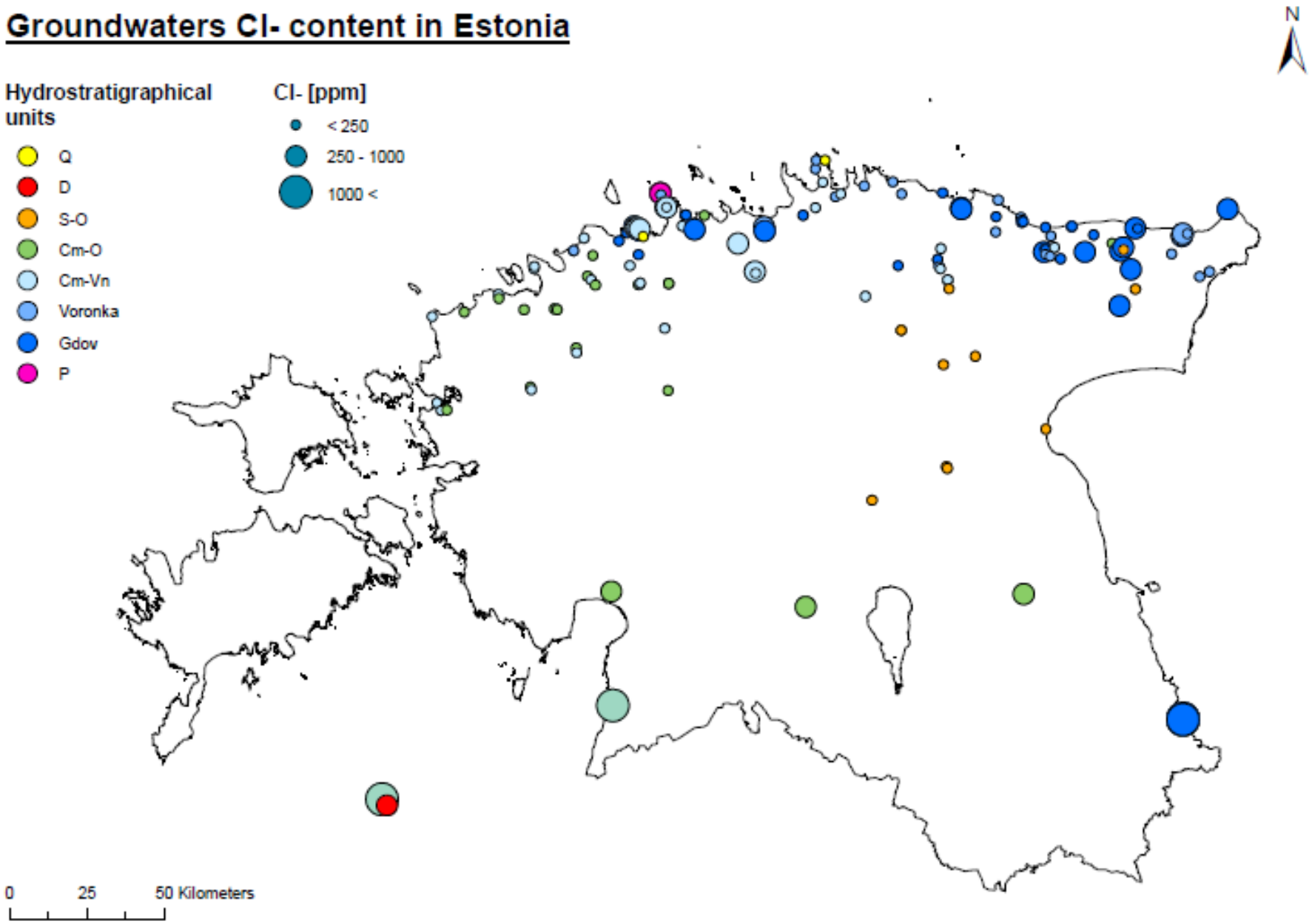


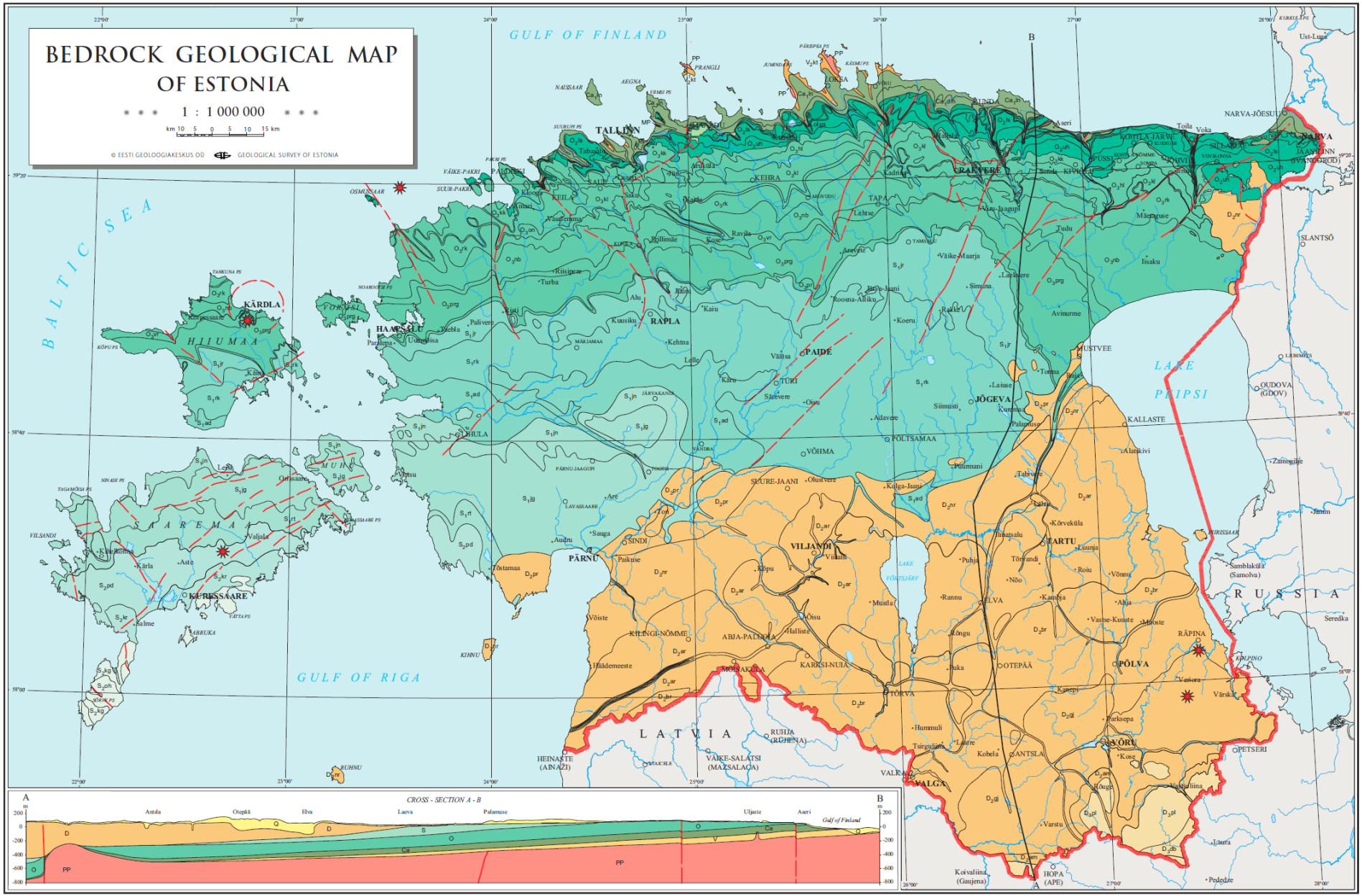
Modifié d'après Cohen & Gibbard, 2011

Géochimie et isotopes



Groundwaters Cl- content in Estonia




BEDROCK GEOLOGICAL MAP
OF ESTONIA
1 : 1 000 000
© EESTI GEOLOOGIAKESKUS OÜ
GEOLOGICAL SURVEY OF ESTONIA
GULF OF FINLAND
BALTIC SEA
GULF OF RIGA
LAKE PEIPSI
LAKE VÕRTSJÄRV
TALLINN
HAAPSALU
KÄRDLA
HIIUMAA
RAPLA
PÄRNU
PAIDE
TÜRI
JÕGEVA
VILJANDI
TARTU
PÕLTSAMAA
MUSTVEE
KALLASTE
KURESSAARE
SAAREMAA
MUHU
LATVIA
RUSSIA
NARVA
NARVA-JÕESUU
SLANTSÖ
RÄPINA
PÕLVA
VALGA
VÕRU
PETSERI
KILINGI-NÕMME
ABJA-PALUOJA
KARKSI-NUIA
MÕISAKÜLA
TÕRVA
HEINASTE (AINAŽI)
VÄIKE-SALATSI (MAZSALACA)
RUHJA (RŪJIENA)
VALKA
Koivalina (Gaujena)
HOPA (APE)
CROSS - SECTION A - B
A
B
Antsla
Otepää
Elva
Laeva
Palamuse
Uljaste
Aseri
Gulf of Finland


Map of Estonia
Elevation
60 m
120 m
180 m
240 m
Finland
Helsinki
Saint-Petersburg
Gulf of Finland
Tallinn
Kohtla-Jarve
Narva
Baltic Sea
Pandivere Heights
Lake Peipus
Hiiumaa
Saaremaa
Lake Vortsjarv
Tartu
Russia
Parnu
Kihnu
Ruhnu
Gulf of Riga
Latvia
N
0
30
60 Kilometers
Riga