Regional Flow and Groundwater Residence Time Simulations in Chaudière-Appalaches, Québec, Canada- Implications for interpreting Regional Geochemistry

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PACES Chaudière-Appalaches | Projet d'acquisition de connaissances sur les EAUX SOUTERRAINES

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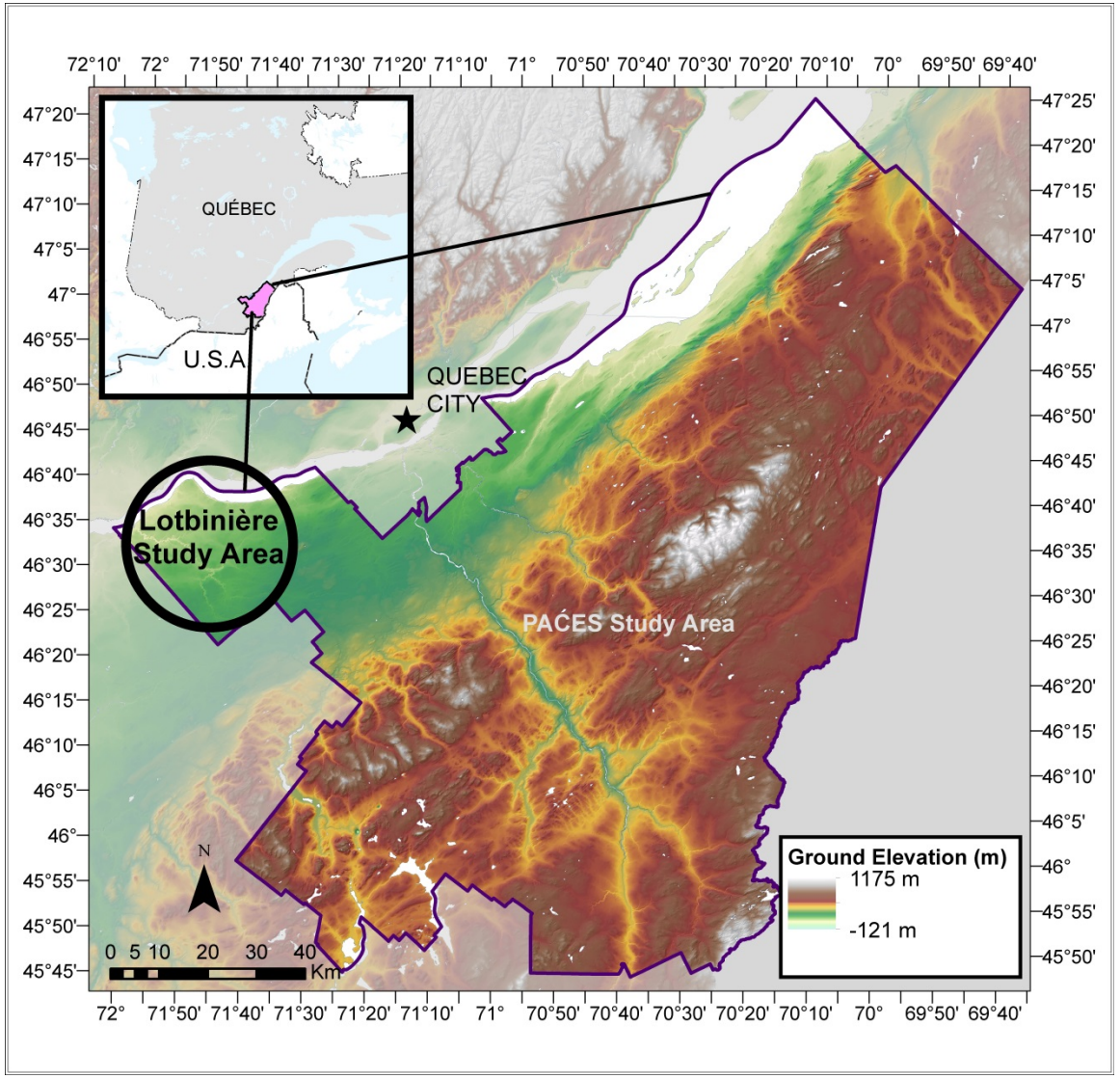
Outline:

1. Background
2. Goals and methods
3. Flow model
4. Age transport model
5. Sensitivity analysis for faults
6. Conclusions

1. Background

Geographic and Historic Contexts

- 134 municipalities over a 14 625 km^2 area
- Varied topography
- Lowlands flooded by Champlain Sea after last glaciation, ~ 10,000 years ago
- After withdrawal of the sea, the salt water left behind in the aquifers has slowly been leached by fresh recharge



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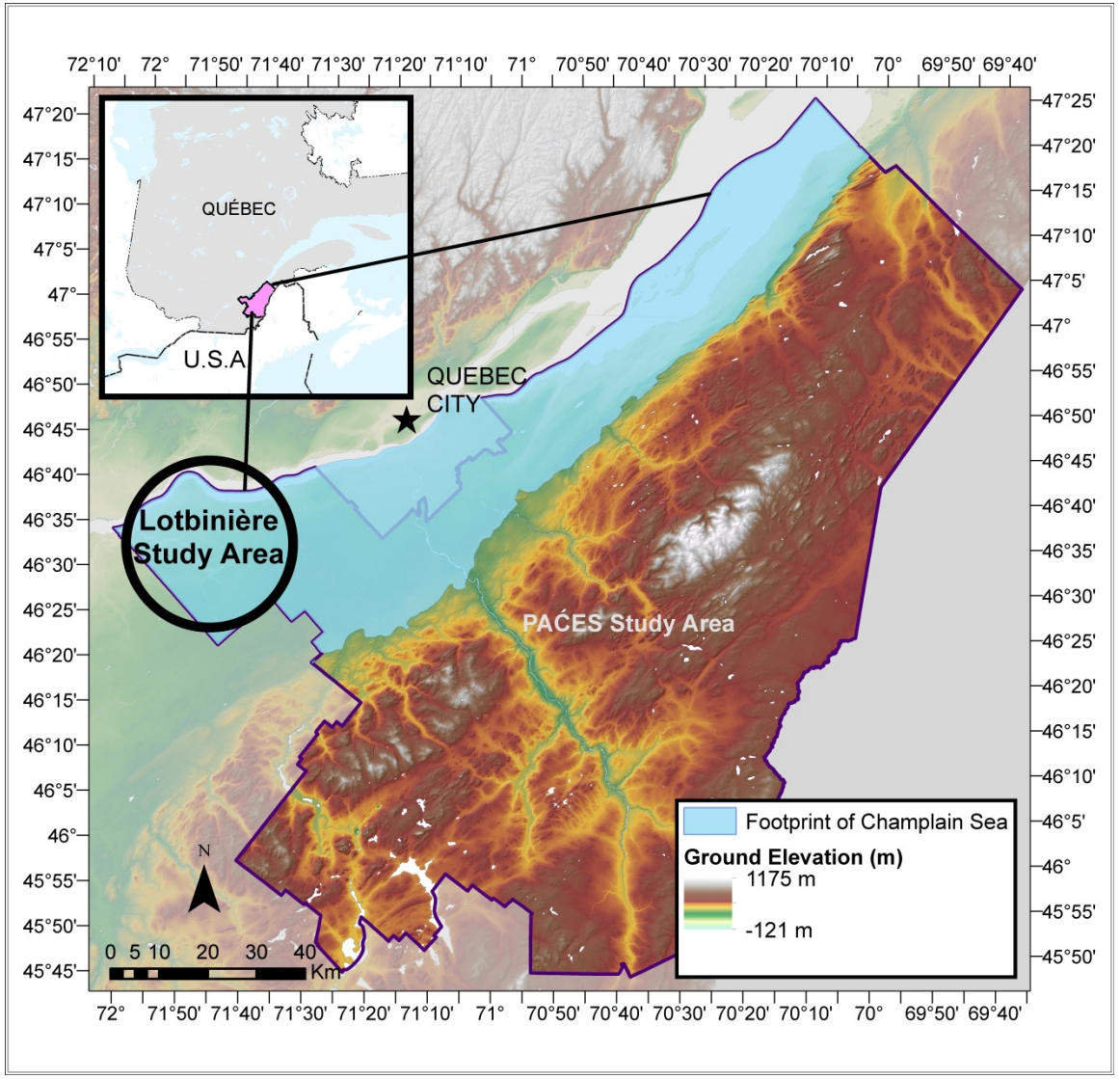


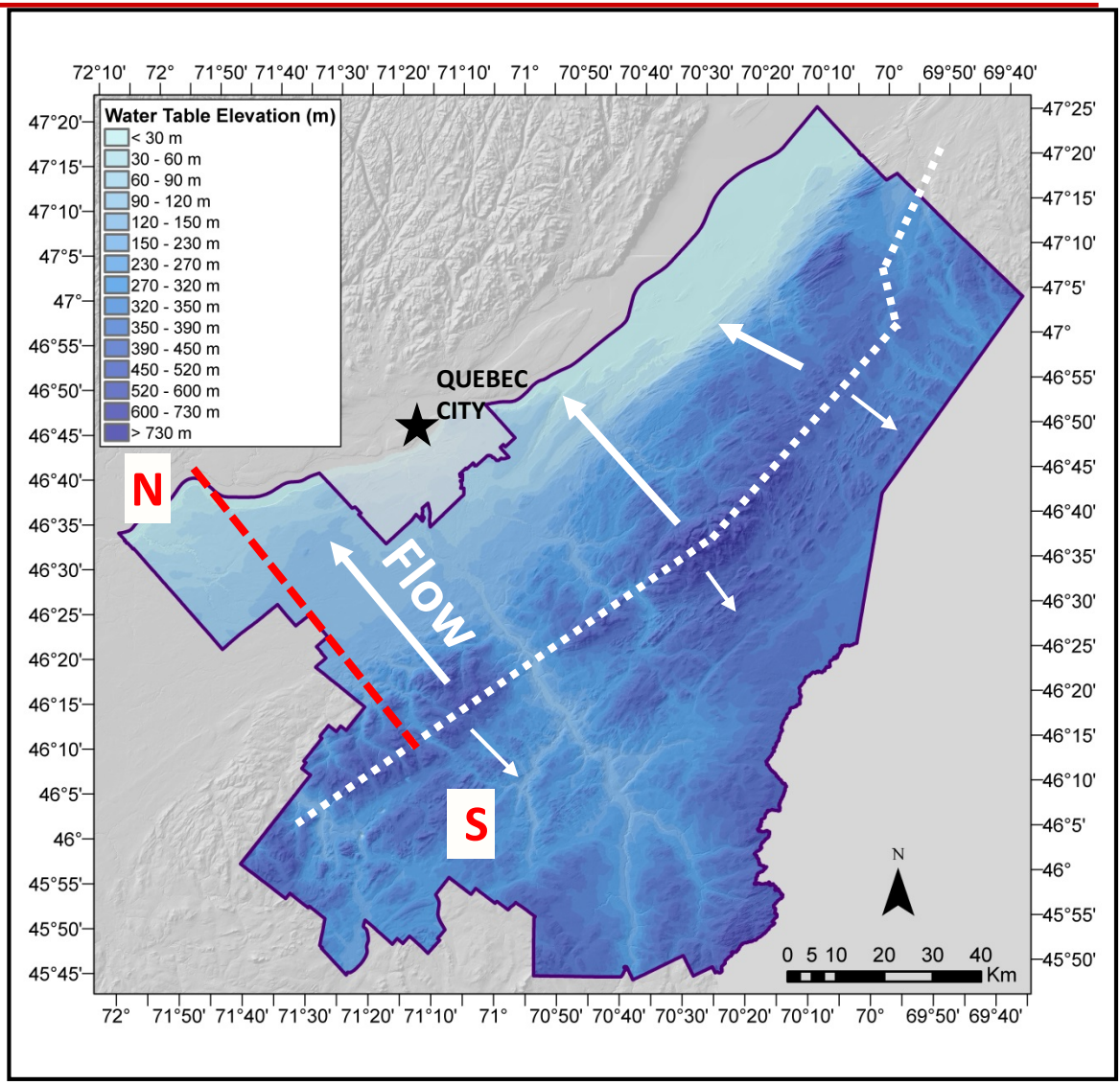
1. Background

Water Levels and Modelling Cross-Section

- Intermediate water divide extends in the SW-NE direction
- St. Lawrence River acts as the regional groundwater outlet
- Annual precipitation:

1150 mm/year,

- Recharge to fractured rock aquifer:166 mm/year

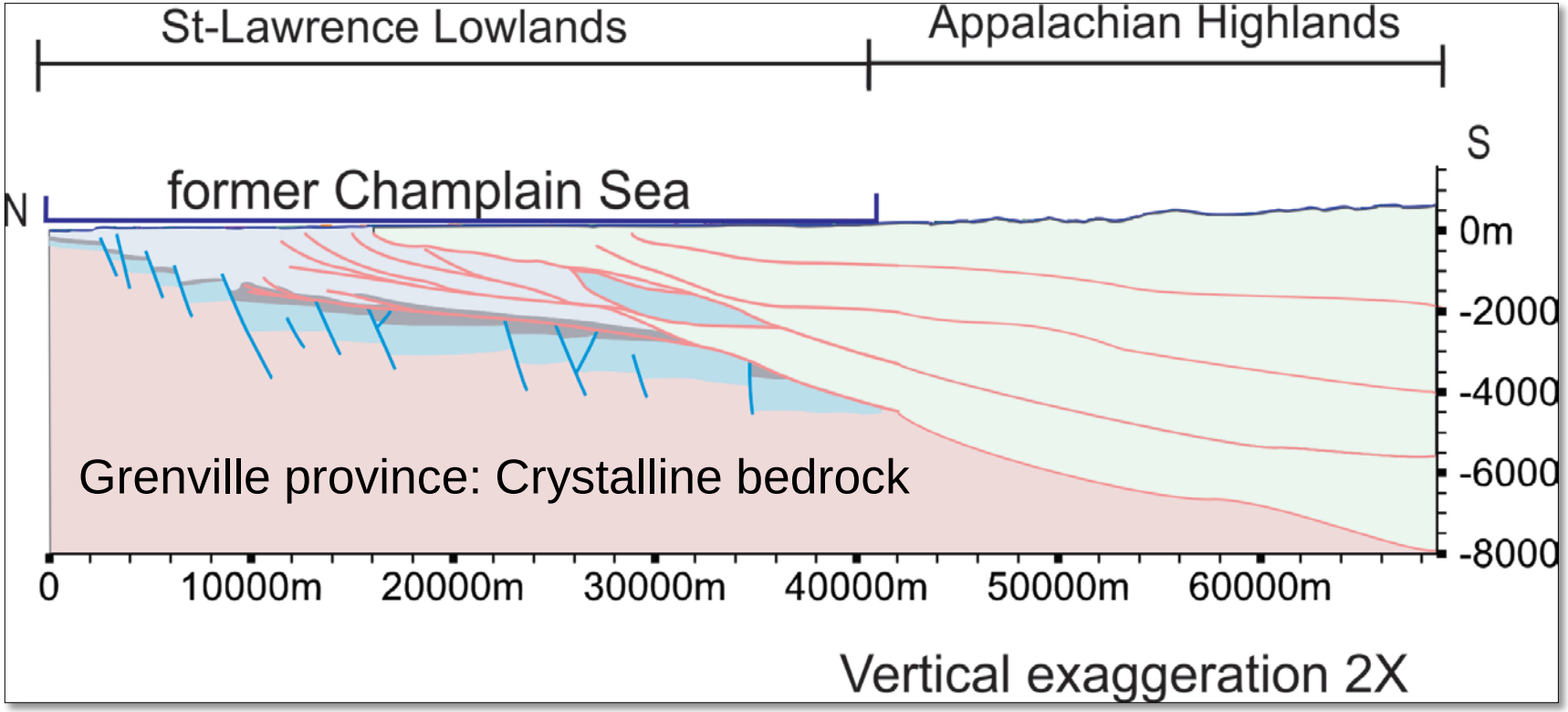


1. Background

Geology

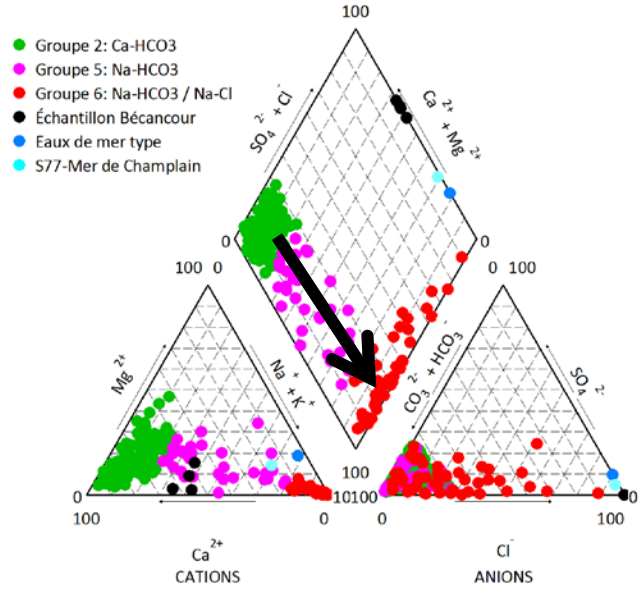
St. Lawrence Lowlands:
Normal faults mark the gradual lowering of the undeformed sedimentary sequence

Appalachians:
Highly deformed and metamorphosed sedimentary formations



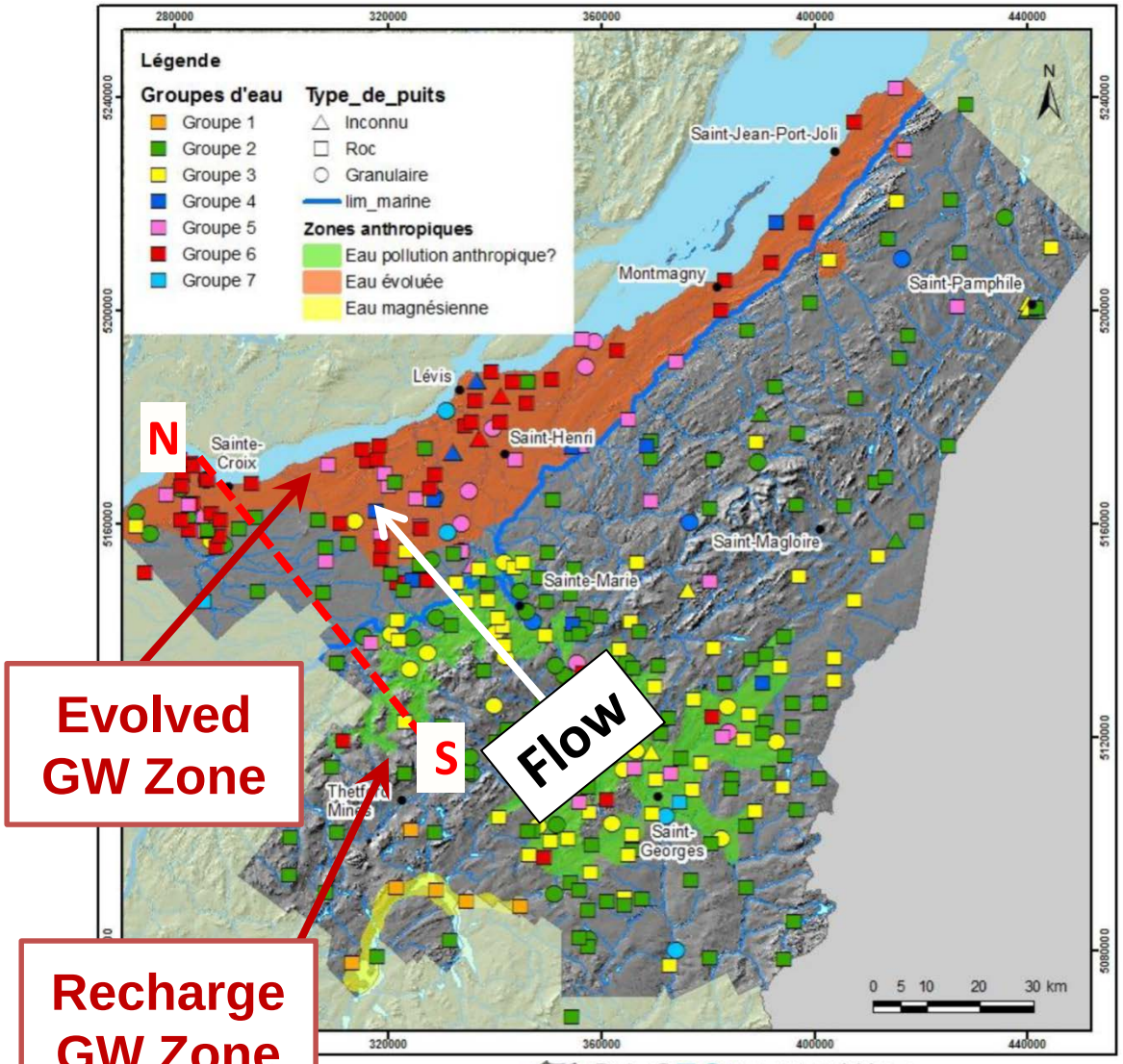
1. Background

Natural Water Types and Zones



Natural Water Types

- $Ca\text{-}HCO_3^-$: **Recharge waters**; dissolution of carbonates
- $Na\text{-}HCO_3^-$: **Evolved waters**; Ca^{2+}/Na^+ ion exchange
- **Na-Cl**: **Marine waters**; Traces of the former Champlain Sea and perhaps mixing with formation waters

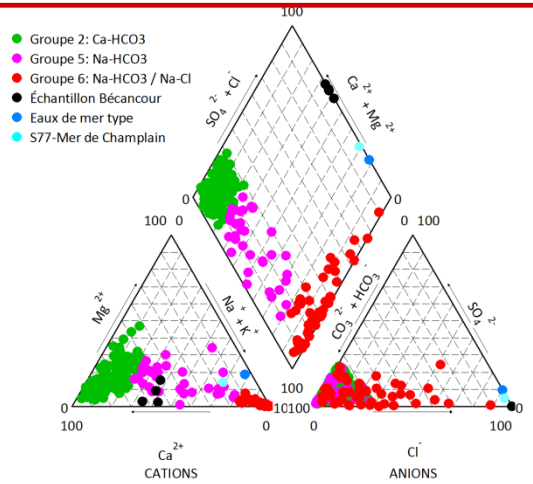


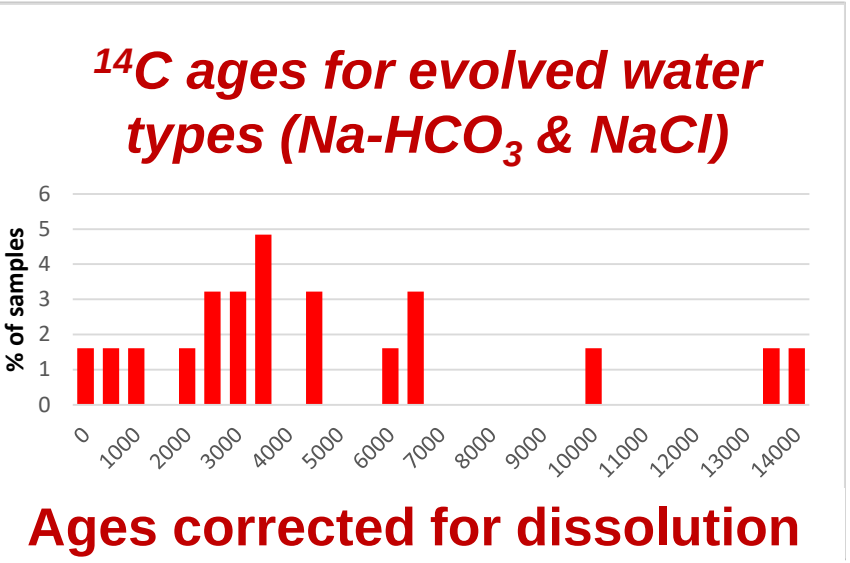
1. Background

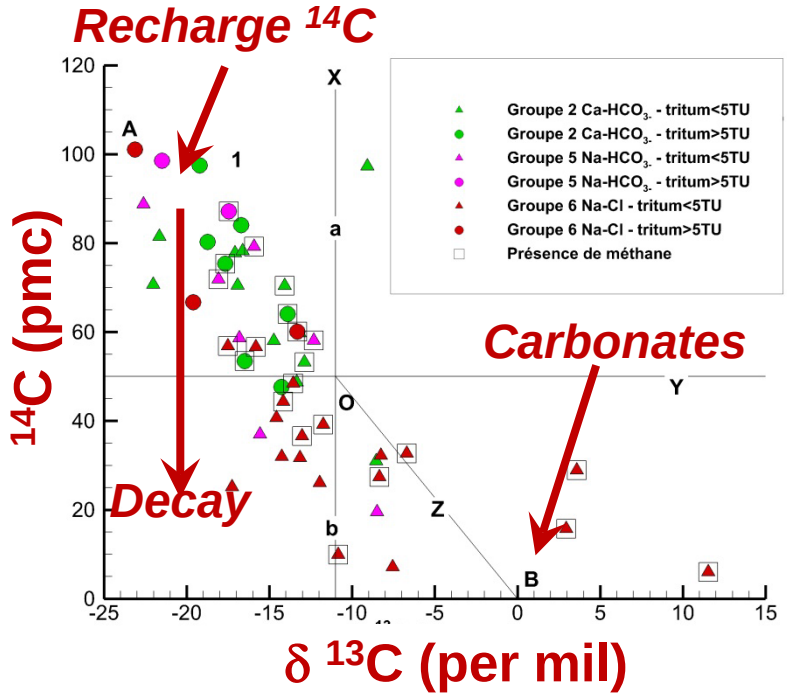
Processes affecting ^{14}C dating

Processes:

- Dissolution/precipitation of carbonate minerals
- Isotopic exchange between DIC, gases and C
- Methanogenesis :
  - with old organic matter → ^{14}C =0
  - with young organic matter → ^{14}C >0
- Mixing of different water types

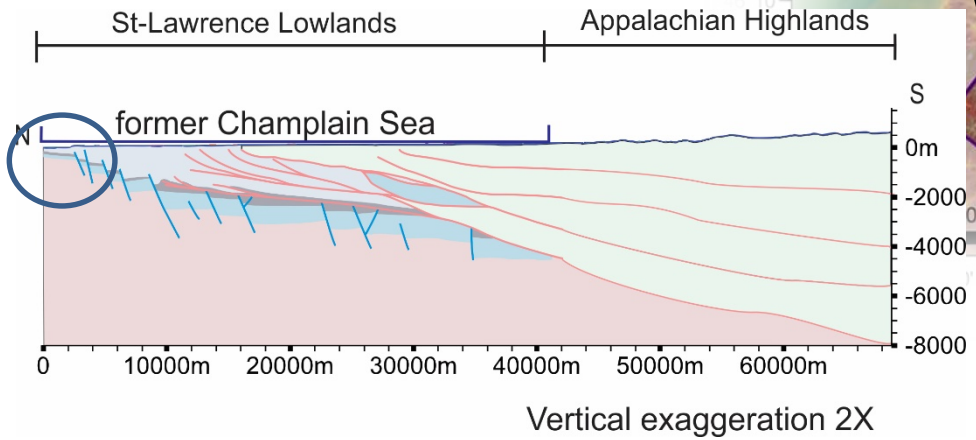






1. Background
Lotbinière Study

- Evidence of deep brine emergence near the Jacques-Cartier River Fault
  - ^{36}Cl ages between 1.75 and 1.95 million years
  - Upward flow of saline water



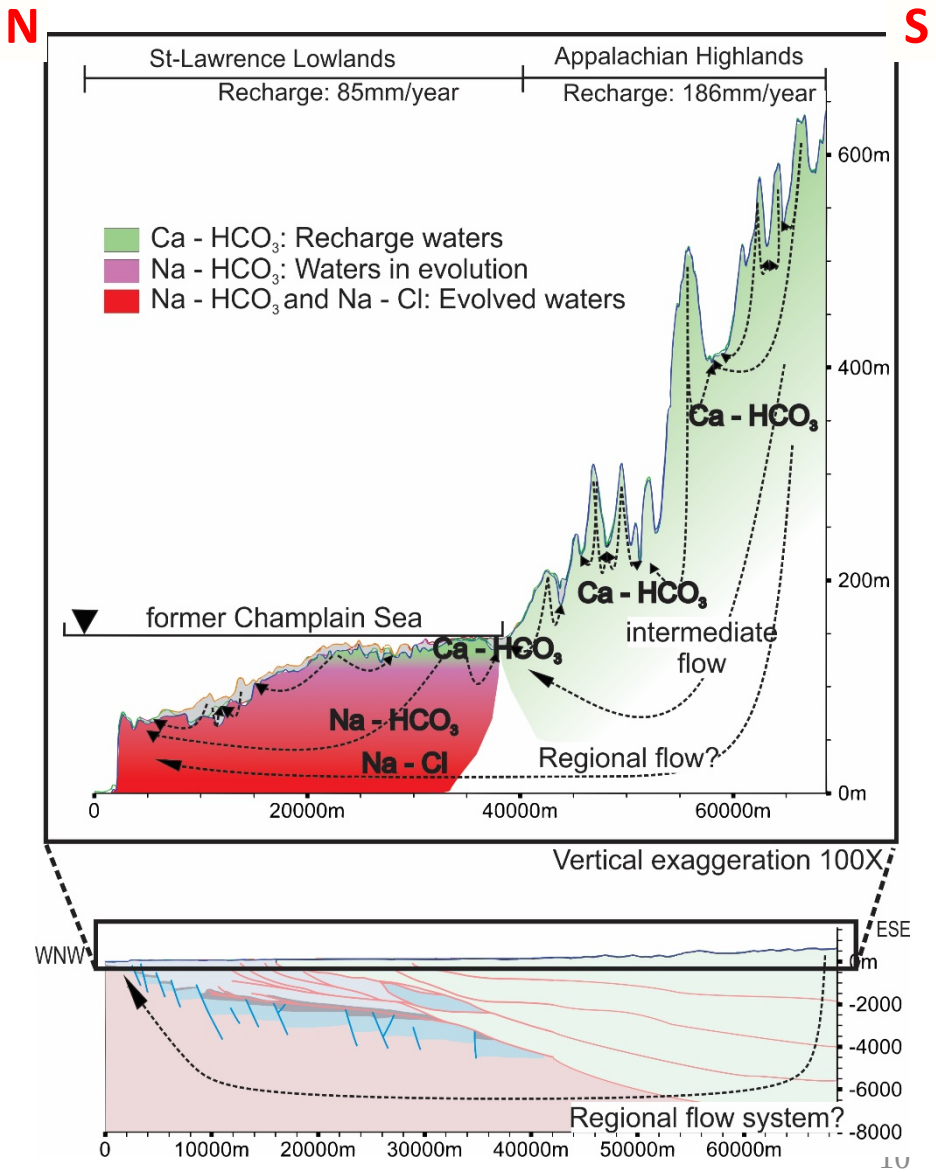
2. Goals and Methods

Aims

- Find maximum depth of active groundwater flow
- Quantify magnitude of regional flow
- Investigate distribution of groundwater residence times
- Investigate role of normal faults near the regional outlet

Method

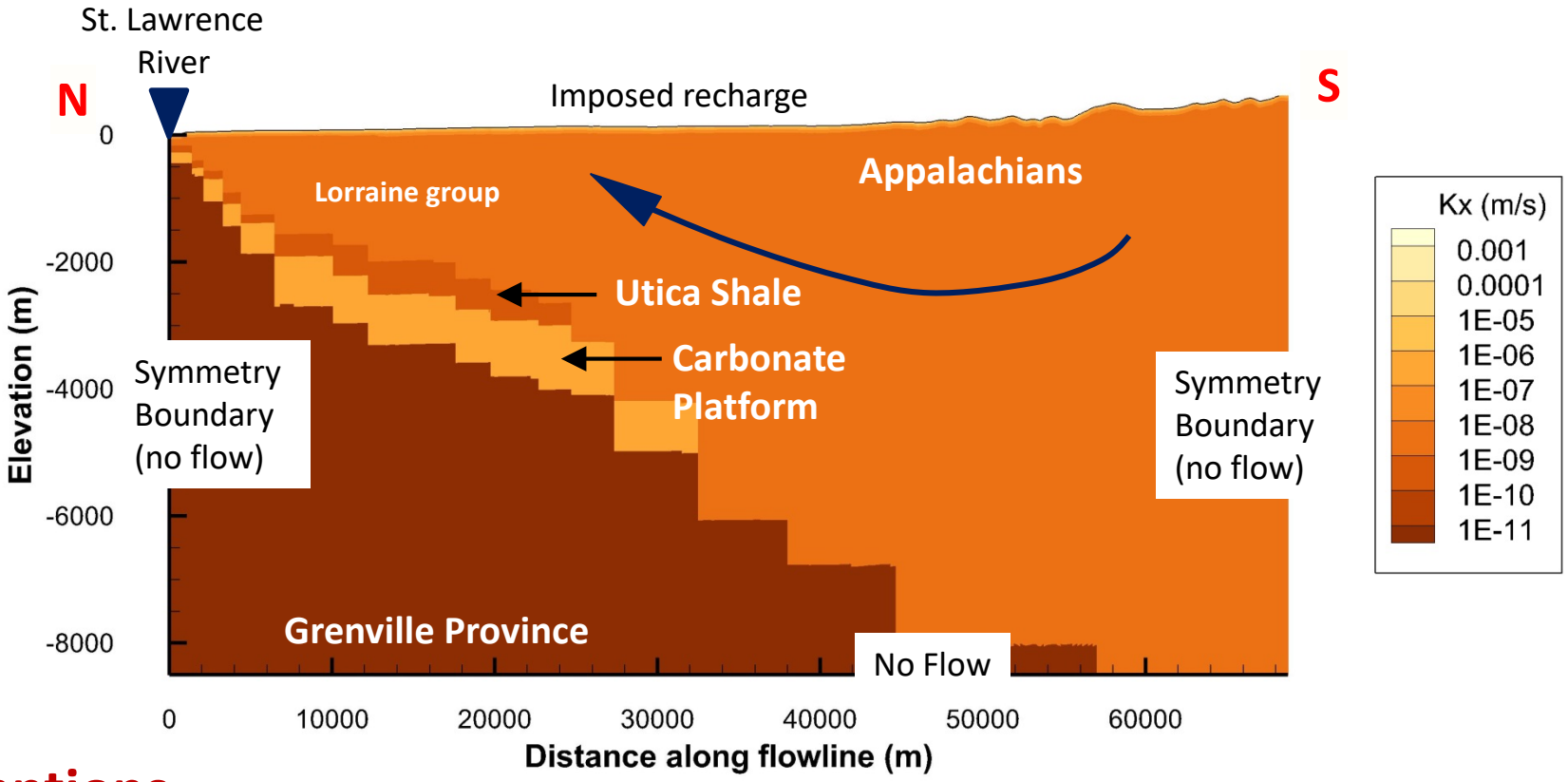
- 2D numerical modeling of regional flow and mean age transport
- Flownet, PEST, TR2
- Sensitivity analysis for different fault configurations



3. Flow Model

Conceptual Model and Boundaries

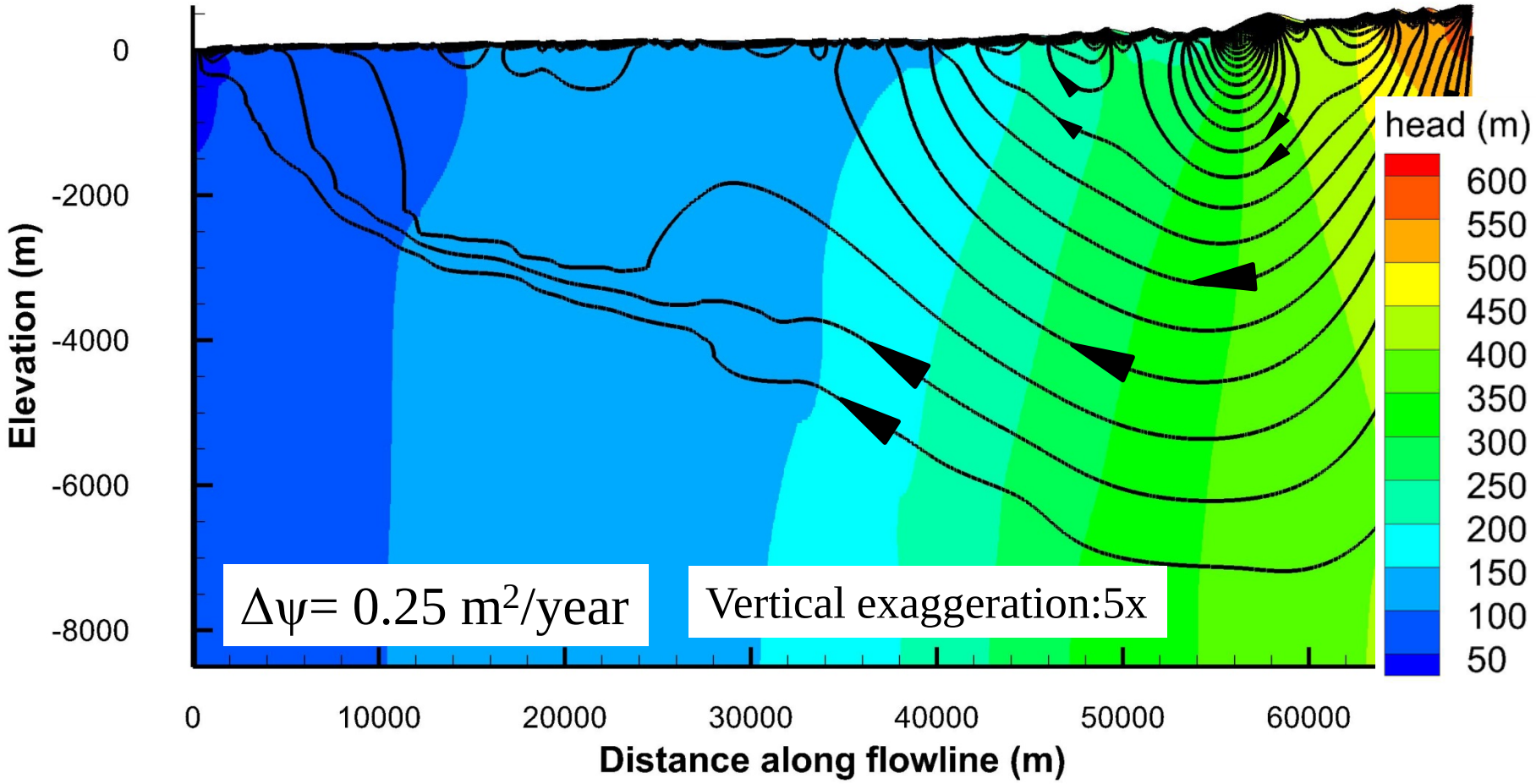
FLOWNET steady state flow model



Assumptions

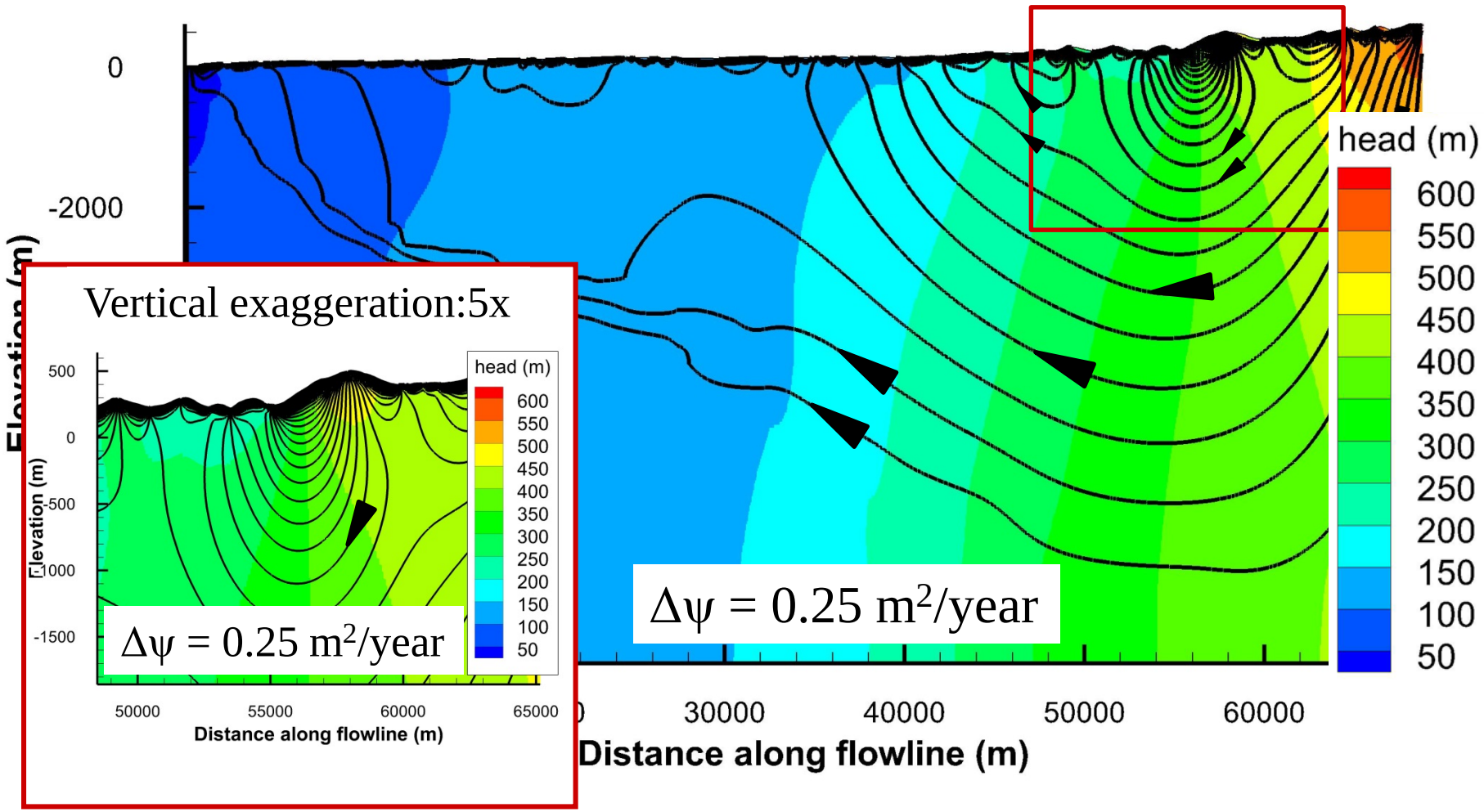
- Steady-state flow system
- Density, temperature and overpressure neglected
- Fractured rock as equivalent porous medium

3. Flow Model
Streamlines



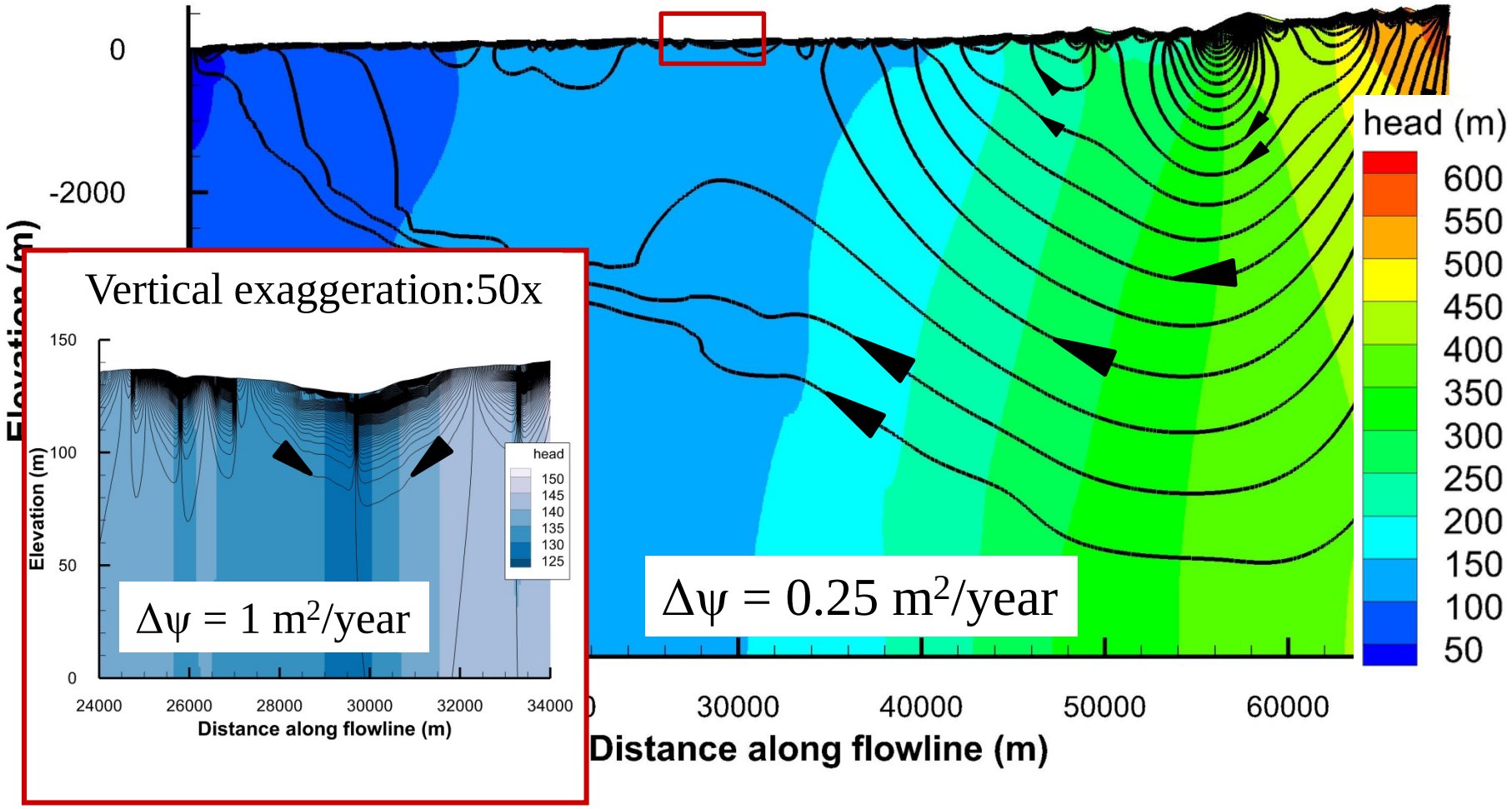
3. Flow Model

Streamlines – Details in Appalachians



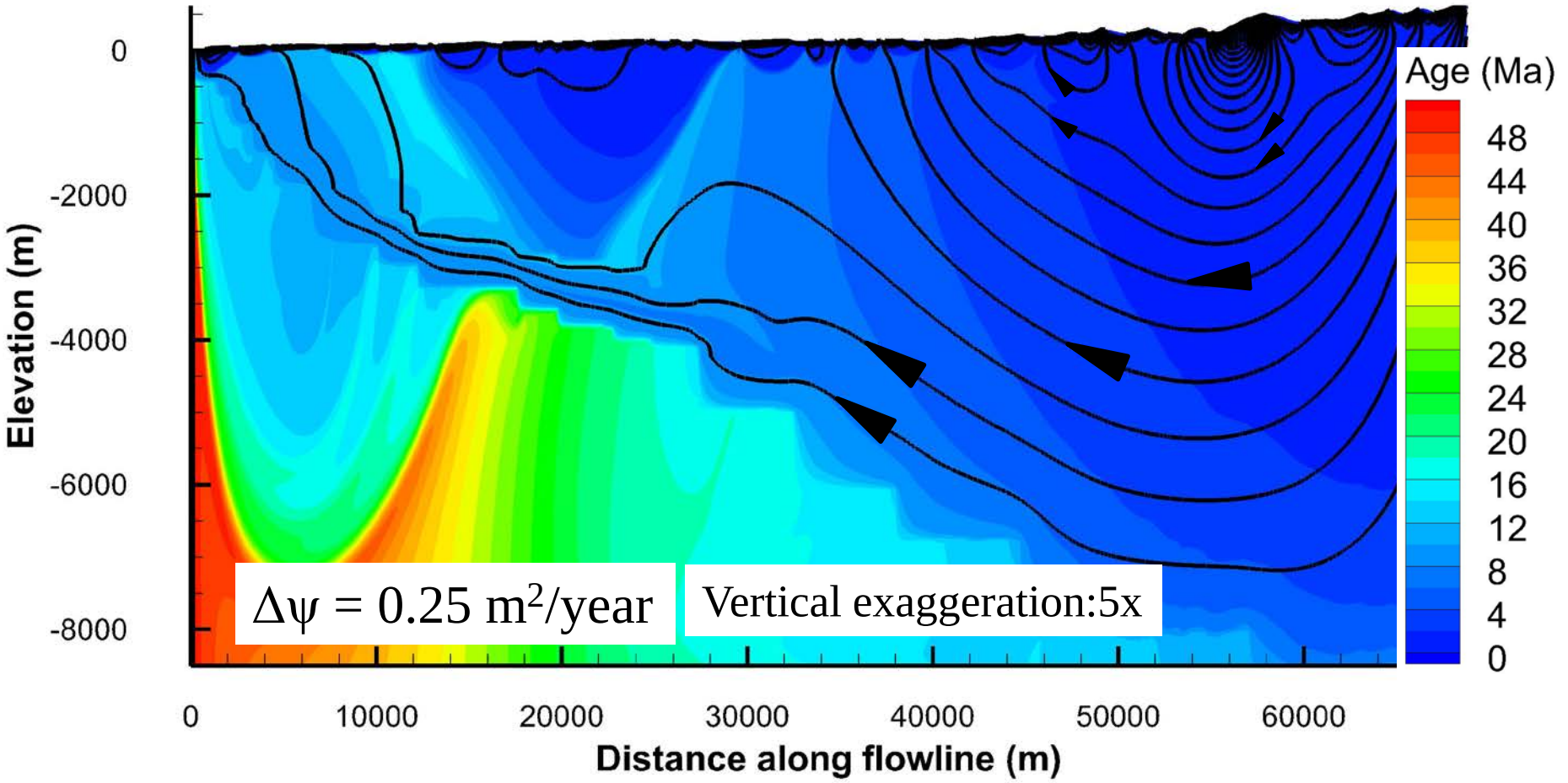
3. Flow Model

Streamlines – Details in Lowlands



4. Age Transport Model

Results



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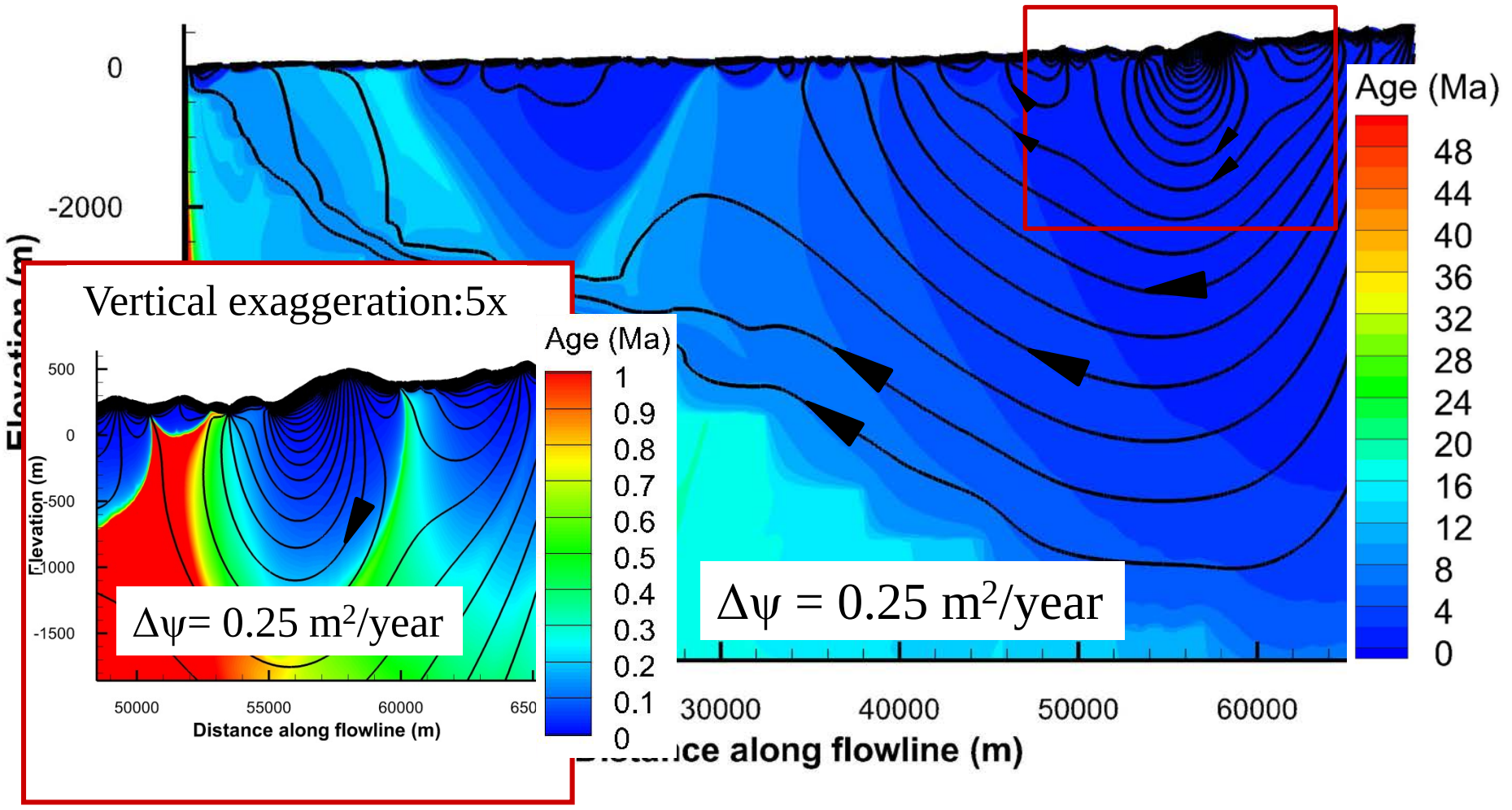

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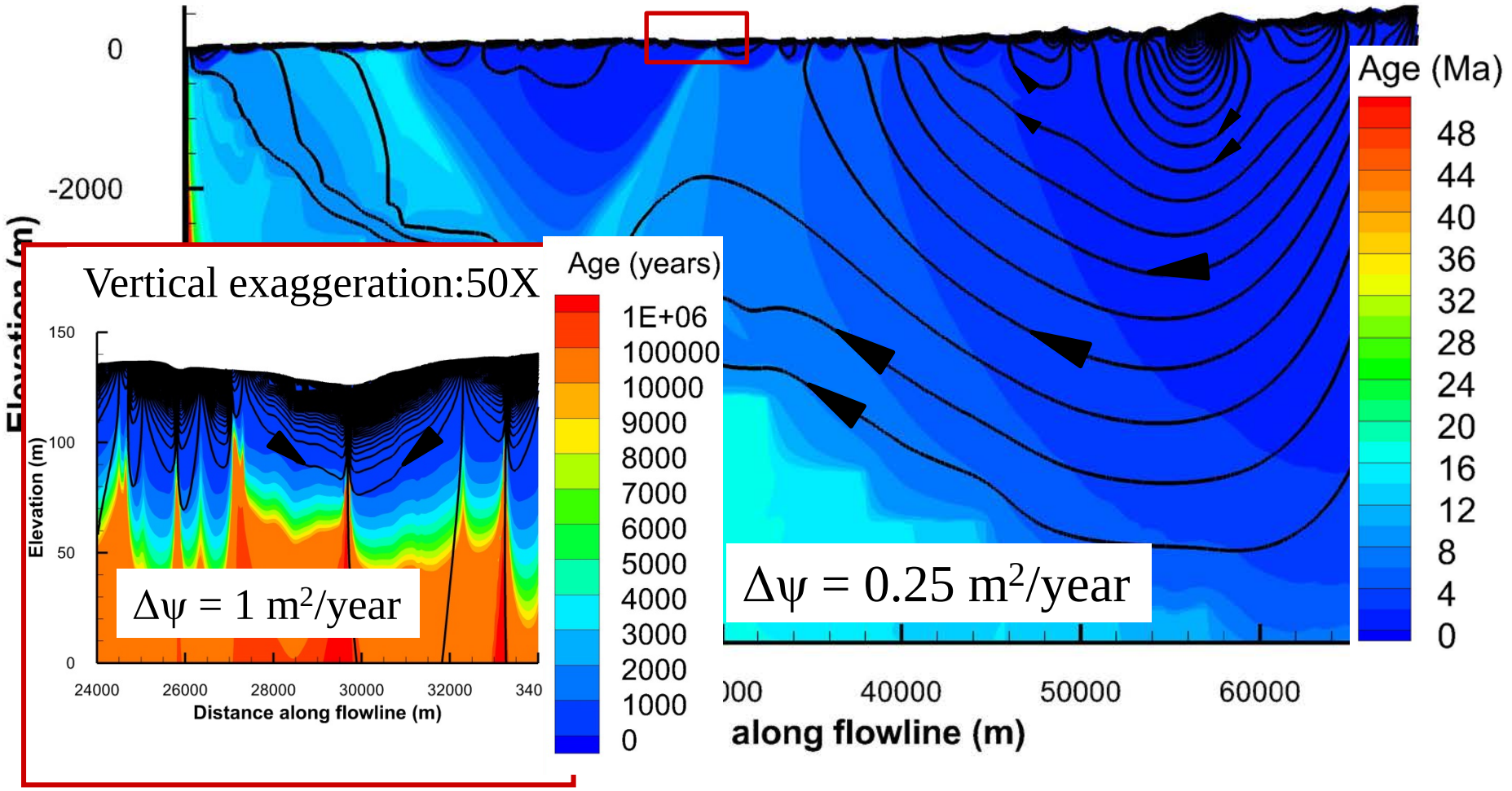


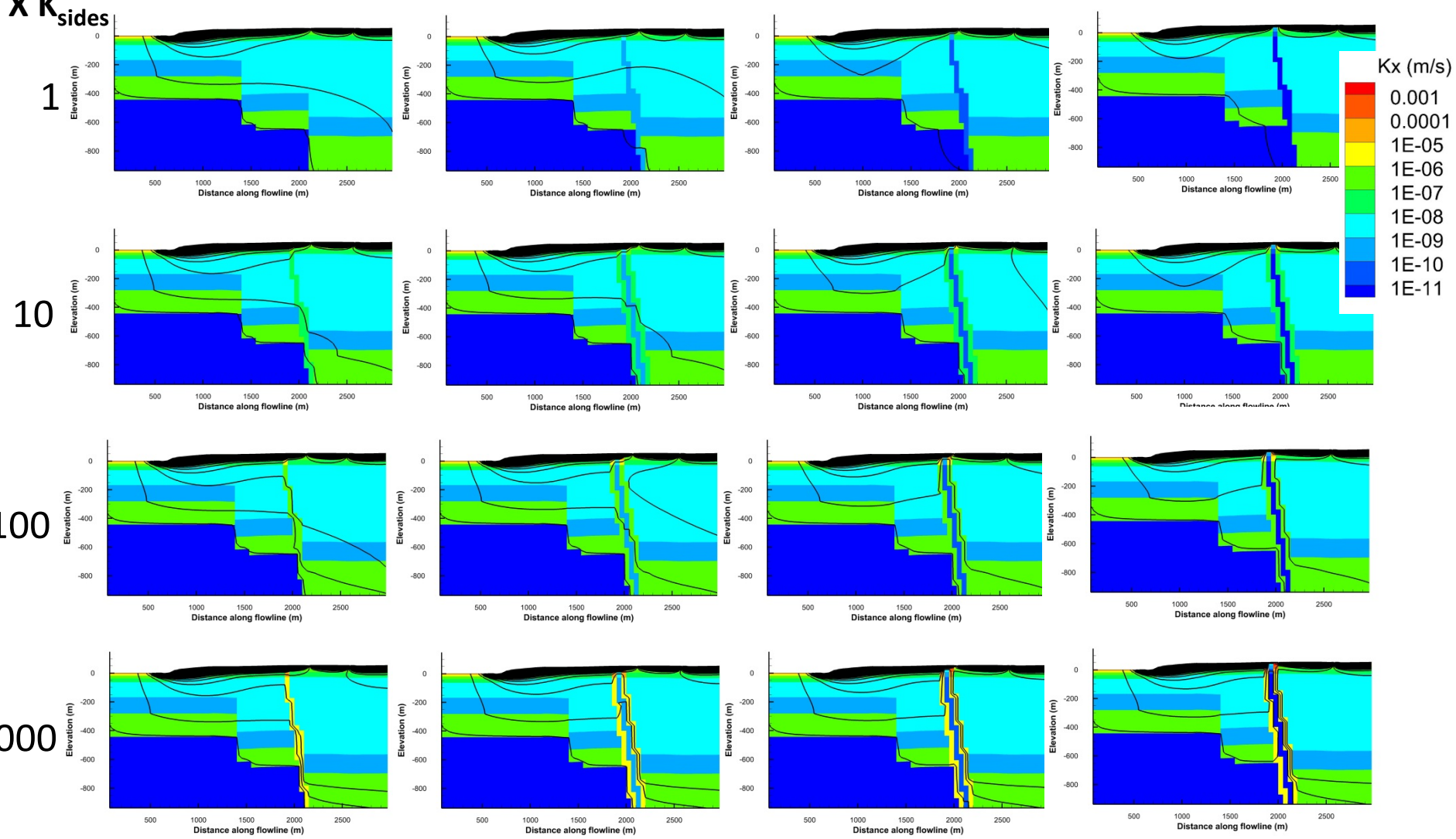
5. Fault Sensitivity Analysis

Fault scenarios : streamlines

$\Delta\psi$= **0.25 m²/year**

X K_{center}

X K_{sides}



5. Fault Sensitivity Analysis

Fault scenarios : Ages

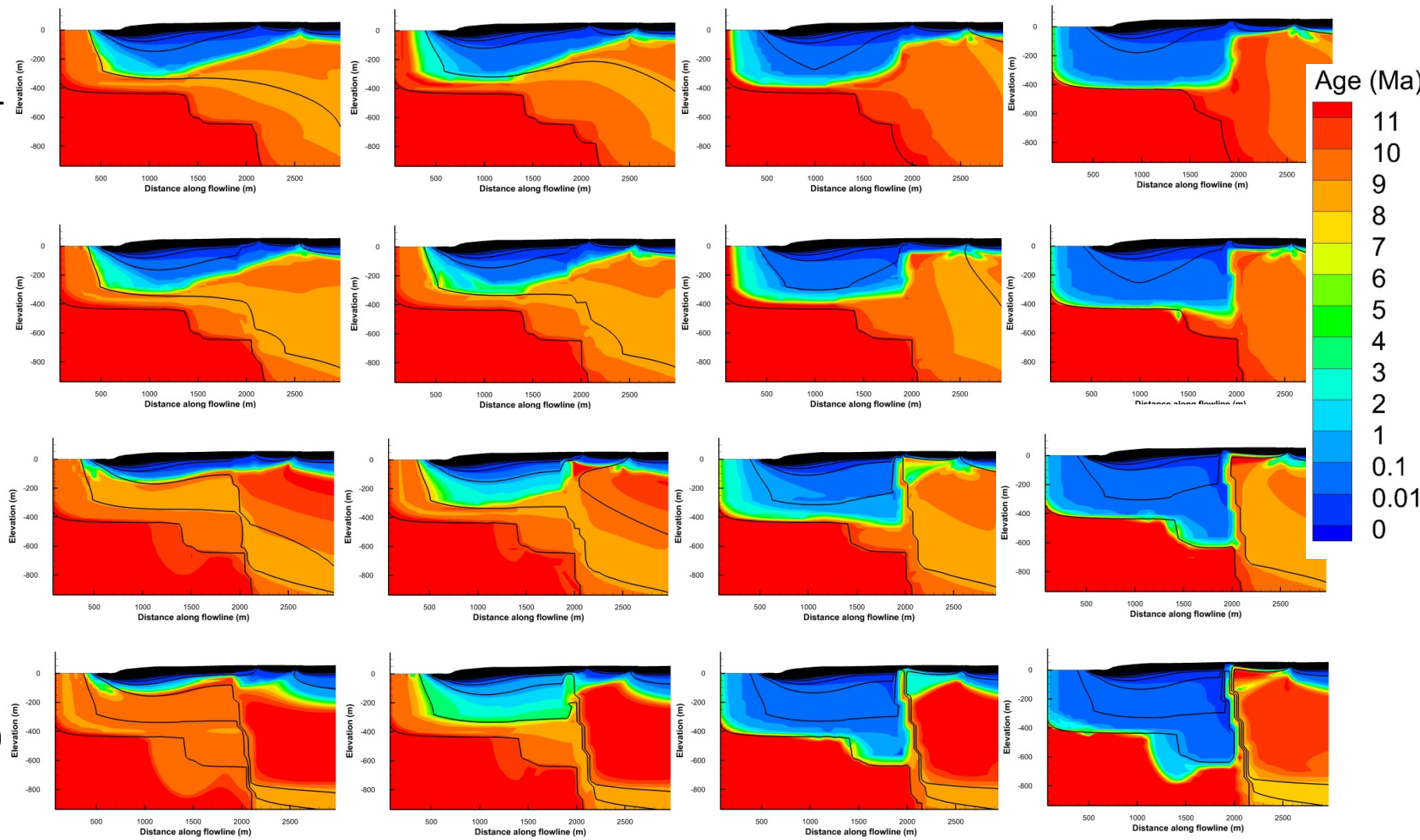
$\Delta\psi$= **0.25 m²/year**

Factor K_{center}

1 | 0.1 | 0.01 | 0.001

Factor K_{sides}

1 | 10 | 100 | 1000



7. Conclusions

- Maximum depth of active groundwater flow: ±50 m
- Intermediate flow system: ±2000 m in AHL
- Regional flow contribution:

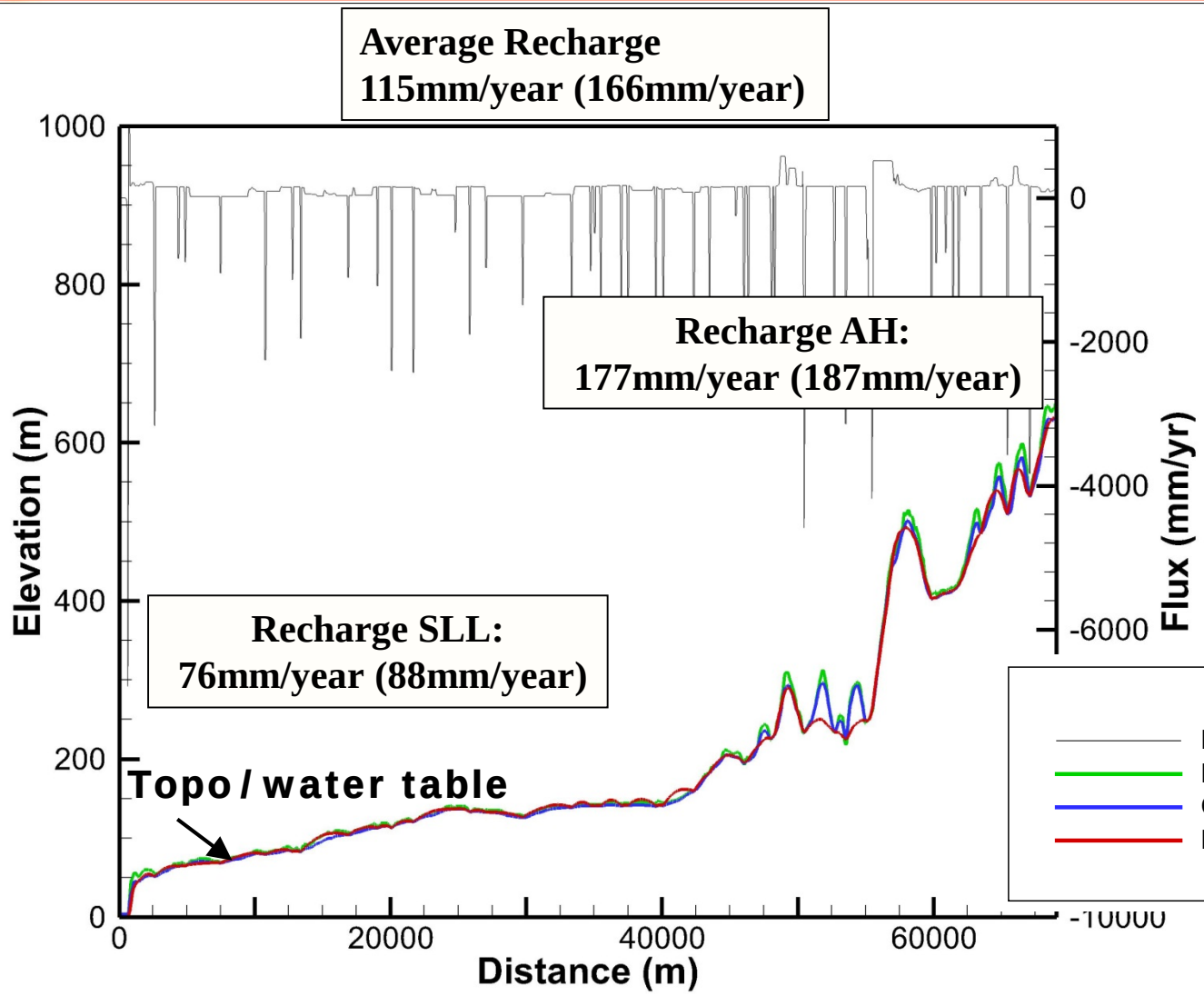
  ~ 0.2% of the total flow in the domain
- Regional flow may not be significant relative to near-surface flow, but it may still alter the geochemistry and mean age of groundwater near the surface
- Faults with an impermeable core near regional outlet :
  - Upstream: raises interface of active flow, increases age
  - Downstream: lowers interface active flow, decreases age

THANK YOU !

And a special thanks to:

Jean-Marc Ballard
Marc-André Carrier
Harold Vigneault
Annie Therrien
Xavier Malet
Châtelaine Beaudry
Christine Rivard
Geneviève Bordeleau
Marc Laurencelle

Calibration of Rock Aquifer Recharge



RMSE (m)	
BTSL	3.65
HTA	2.88
ALL	2.19