

The hydrogeology of the Canadian Shield

with emphasis on the Saguenay-Lac-Saint-Jean area

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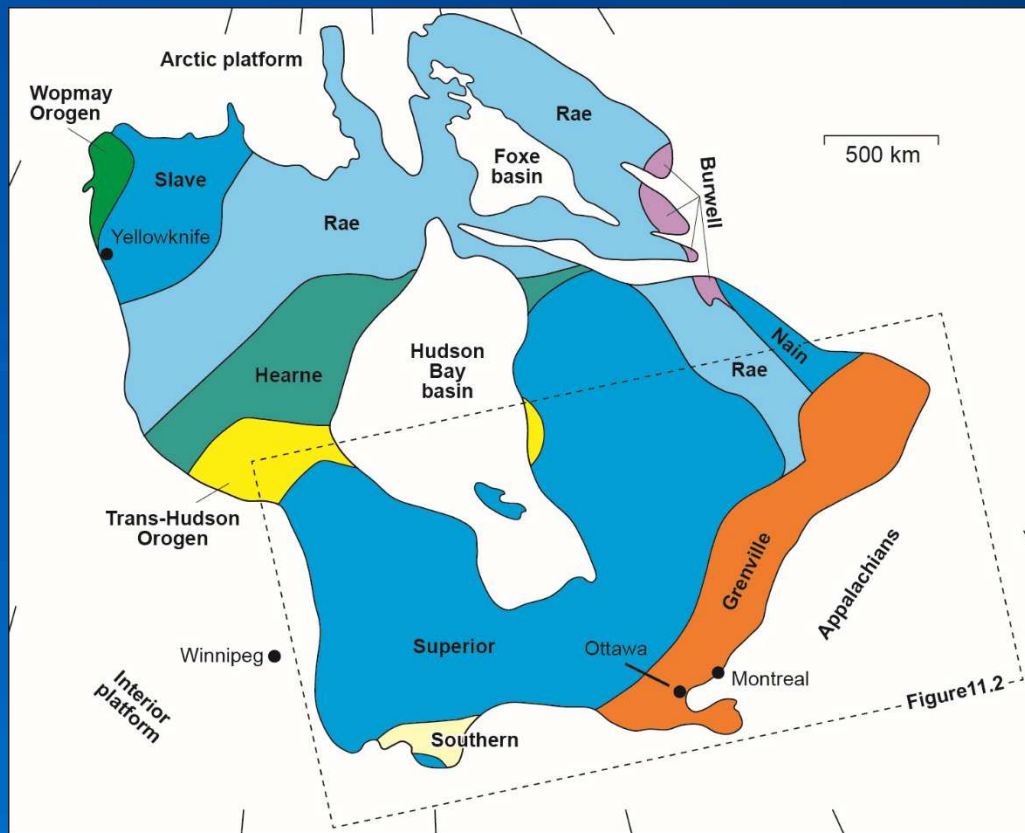
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Conférence internationale: «*Aquifères de socle:
le point sur les concepts et les applications opérationnelles*» - La Roche sur Yon - 2015

SUMMARY

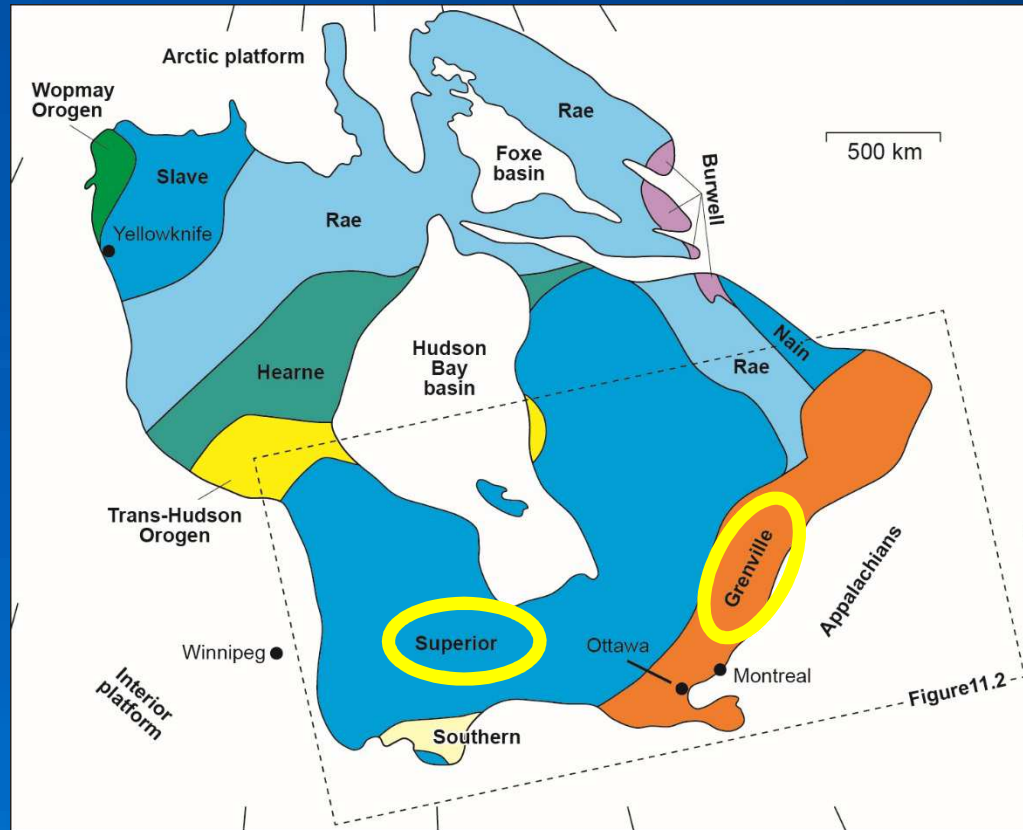
- 1. HYDROGEOLOGICAL CONTEXTS**
2. HYDROLOGY AND CLIMATE
3. HYDROGEOCHEMISTRY AND ISOTOPES
4. CONCLUSION

Geological Provinces of the Canadian Shield



Schematic pre-drift restoration (adapted from Hoffman, 1989)

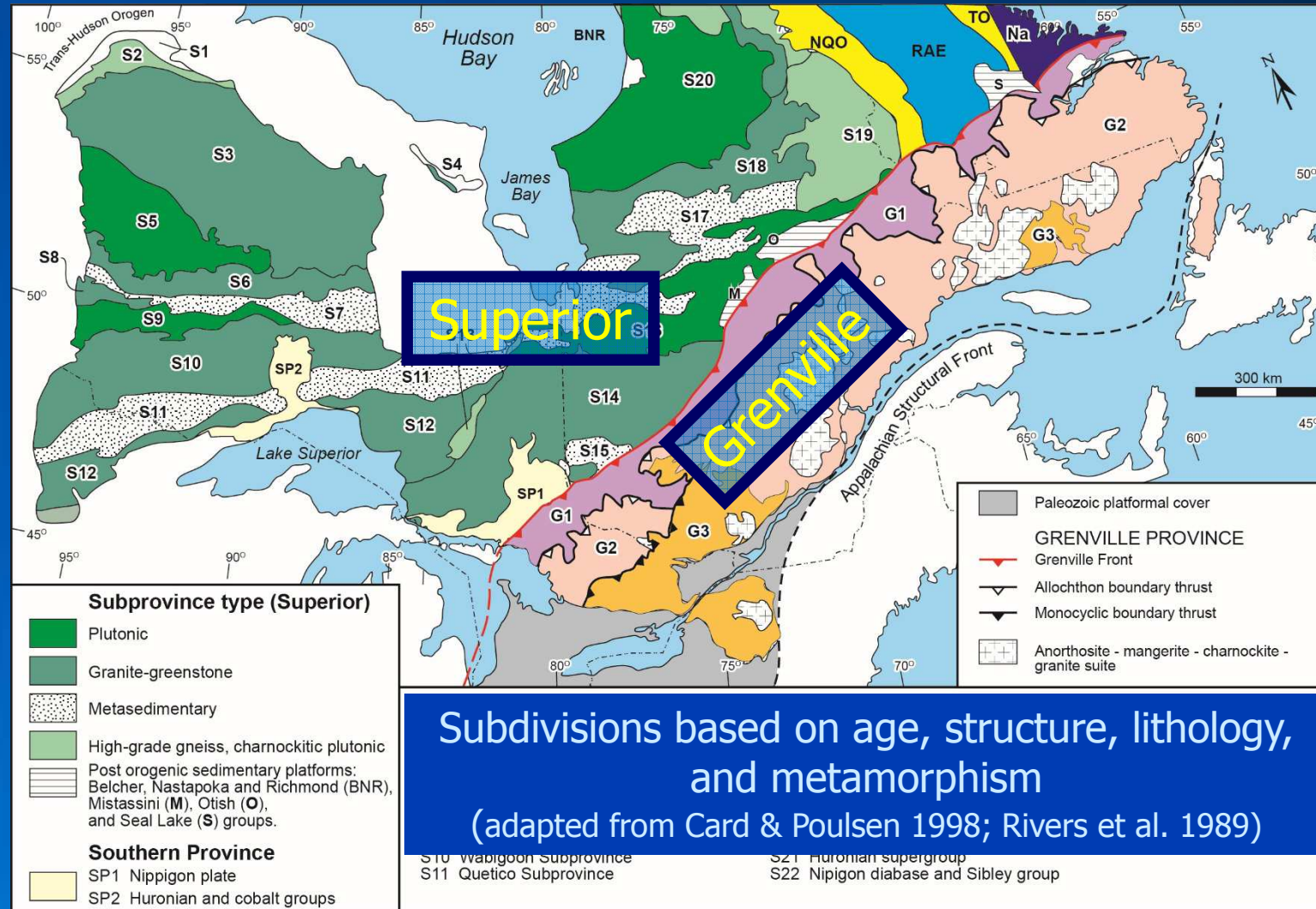
Geological Provinces of the Canadian Shield



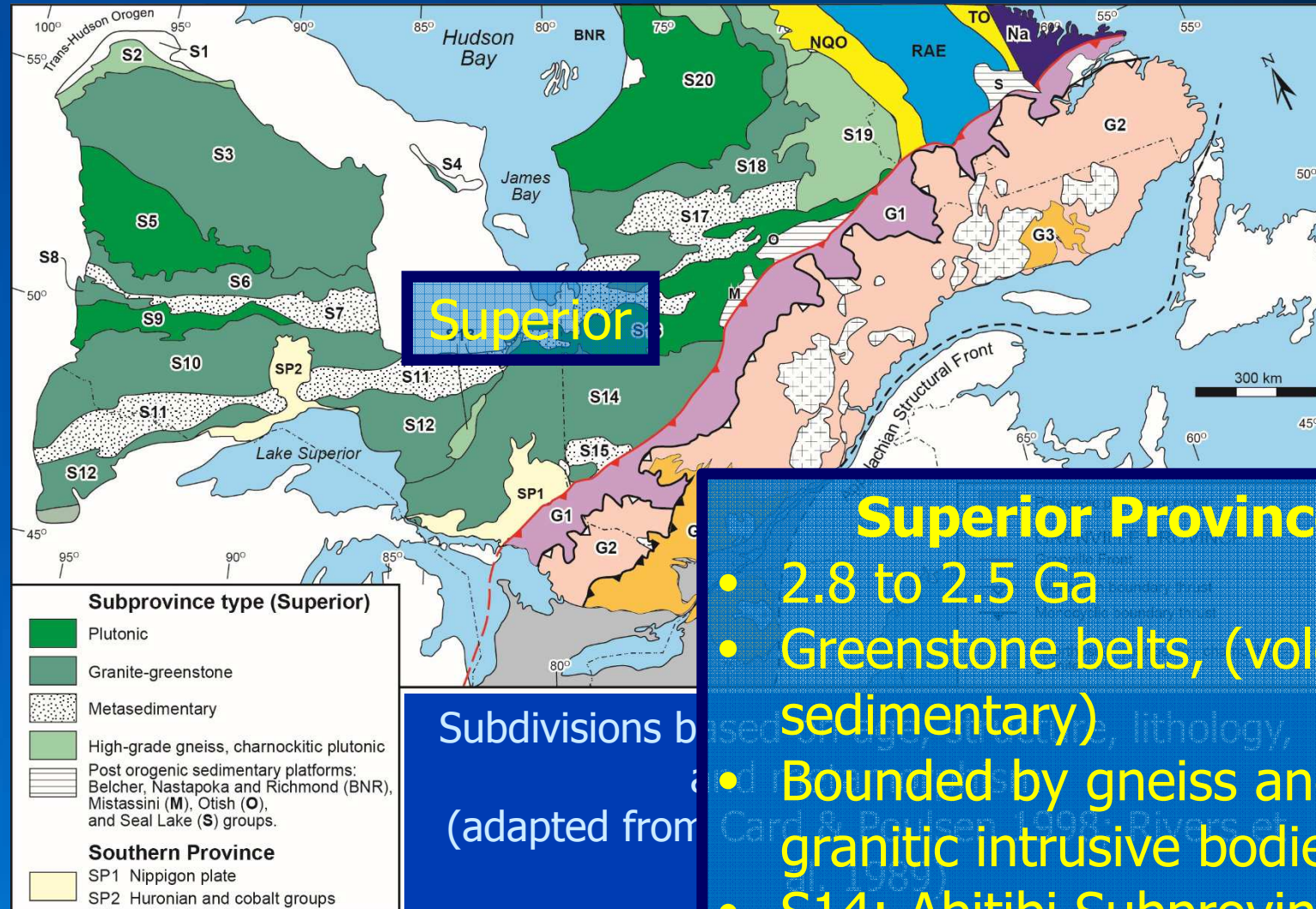
- Focus on Superior and Grenville Provinces
- South of continuous permafrost

Schematic pre-drift restoration (adapted from Hoffman, 1989)

Superior and Grenville Provinces

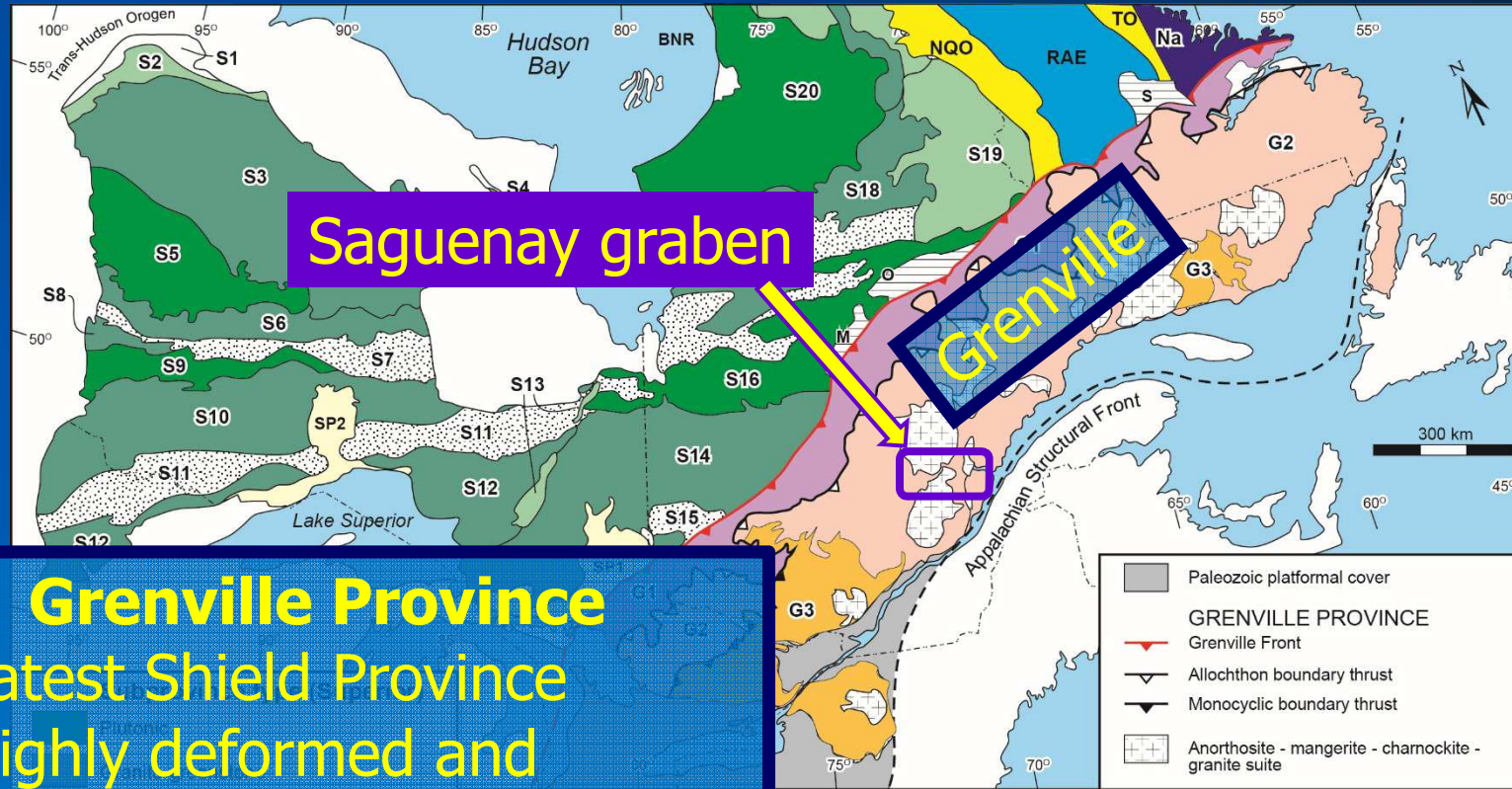


Superior and Grenville Provinces



- **Superior Province**
- 2.8 to 2.5 Ga
- Greenstone belts, (volcano-sedimentary)
- Bounded by gneiss and granitic intrusive bodies
- S14: Abitibi Subprovince - mining industry

Superior and Grenville Provinces



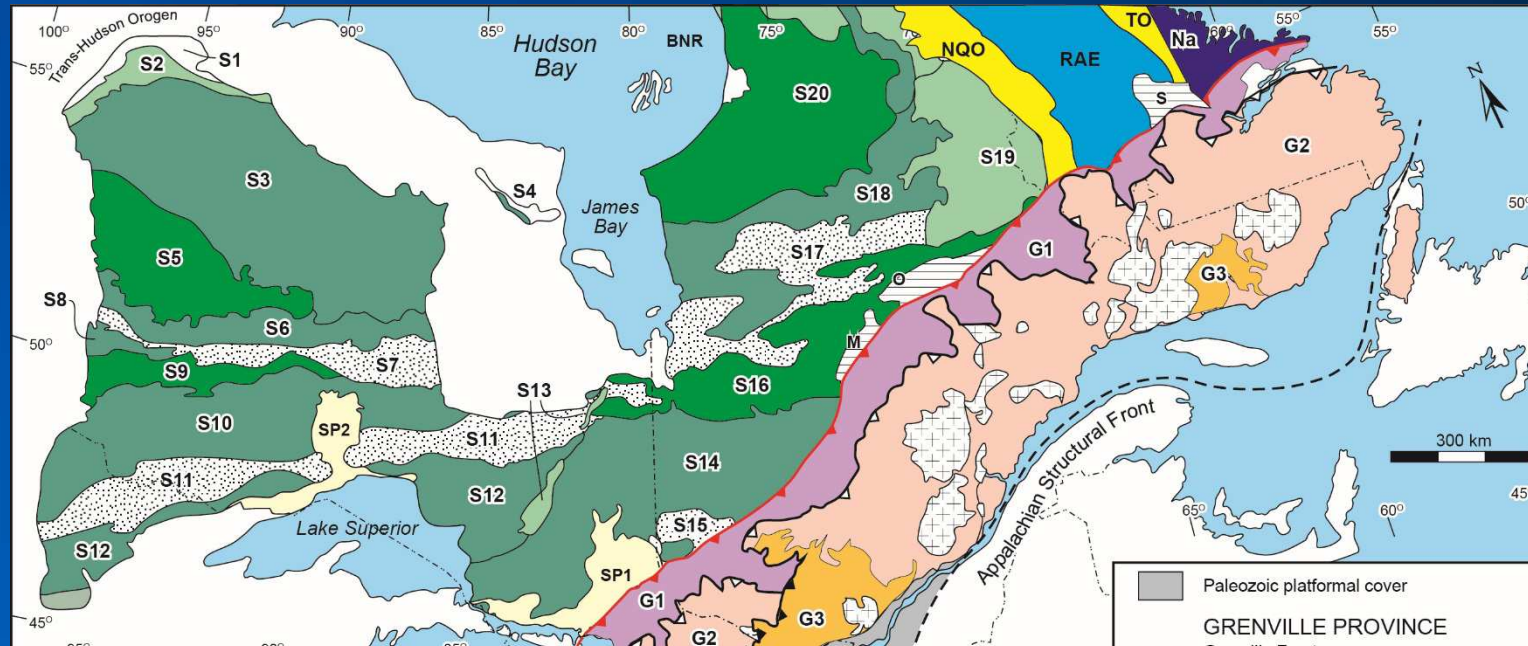
Grenville Province

- Latest Shield Province
- Highly deformed and metamorphosed rocks
- Large & high-temperature magmatic intrusions (e.g. anorthosite)
- Late granites

based on age, structure, lithology, and metamorphism

(adapted from Card & Poulsen 1998; Rivers et al. 1989)

Superior and Grenville Provinces



Local cover

- Subhorizontal sedimentary rock layers (Proteroz., Paleoz., Mesoz.)
- Quaternary deposits, including glaciofluvial (*e.g.* eskers) & deltaic in past glacial lakes and inland seas

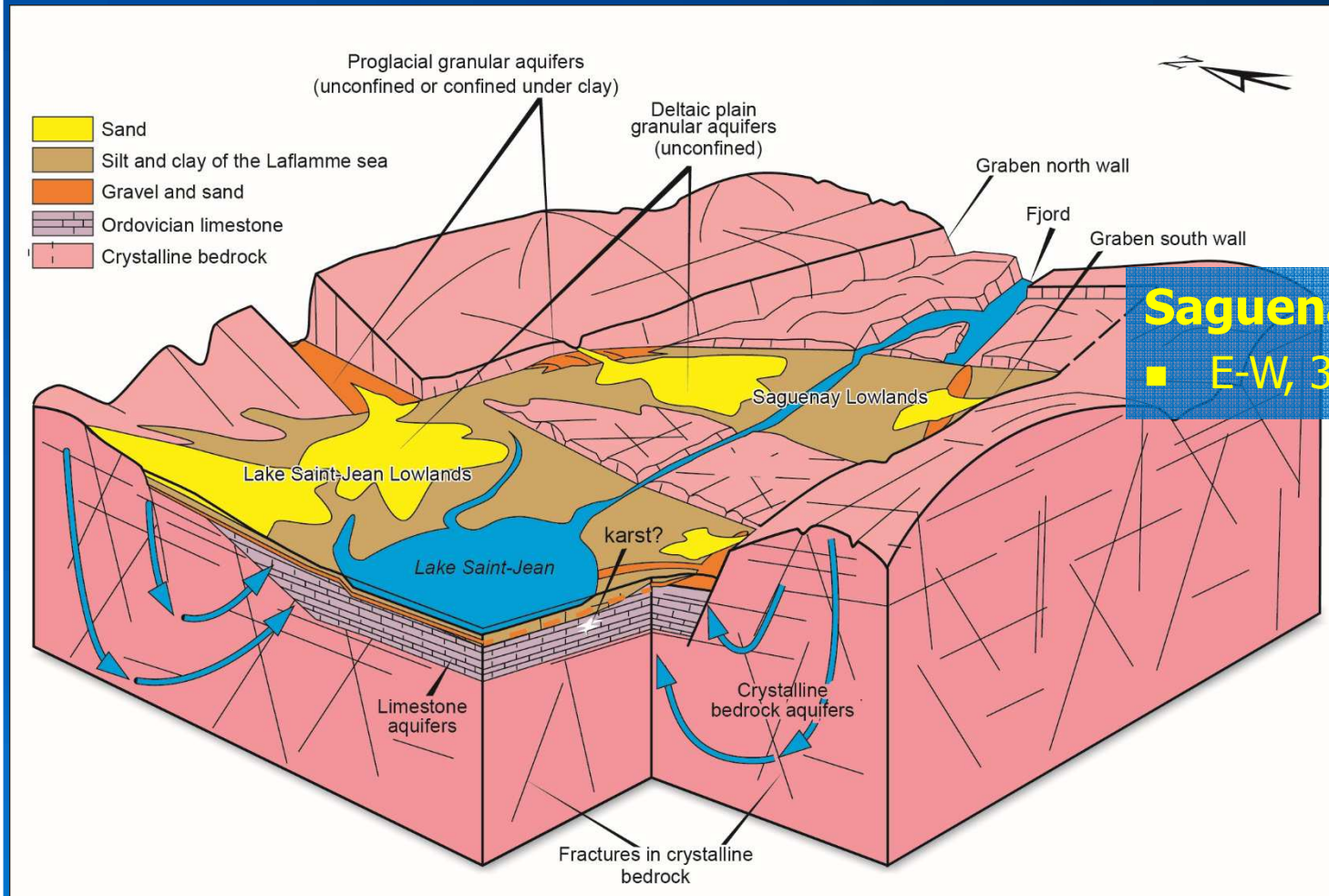
Superior and Grenville Provinces

Human population

- Low population density
- Industries
 - Forest and Mining
 - High energy users (hydro-electric); aluminium
- Surface water widely available
- Low use of groundwater
- GW data: mining sites, research sites for radioactive waste repository

Hydrogeological context

An example in the Grenville Province

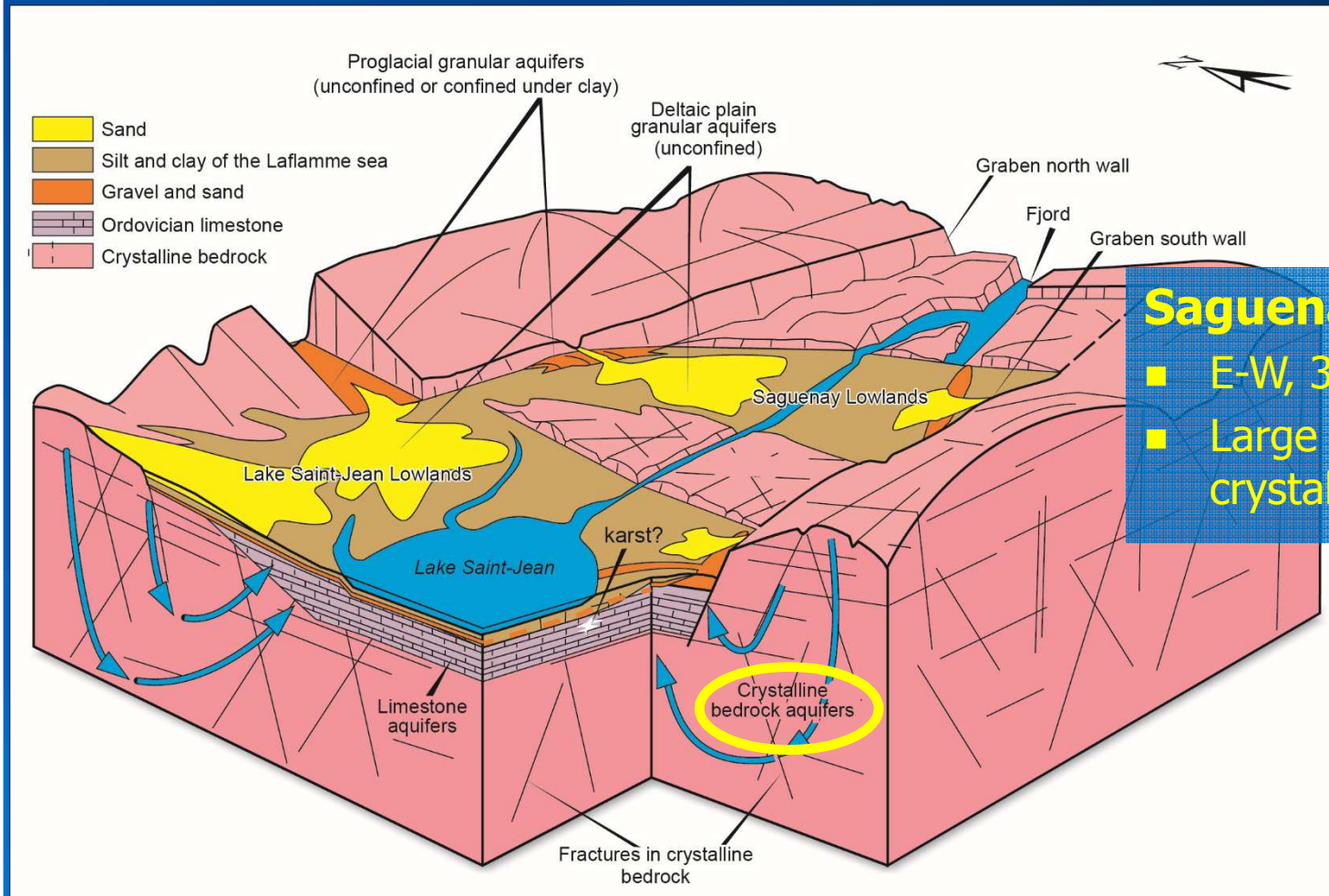


Saguenay graben
 ■ E-W, 30 km wide

(modified from Rouleau et al., 2011)

Hydrogeological context

An example in the Grenville Province



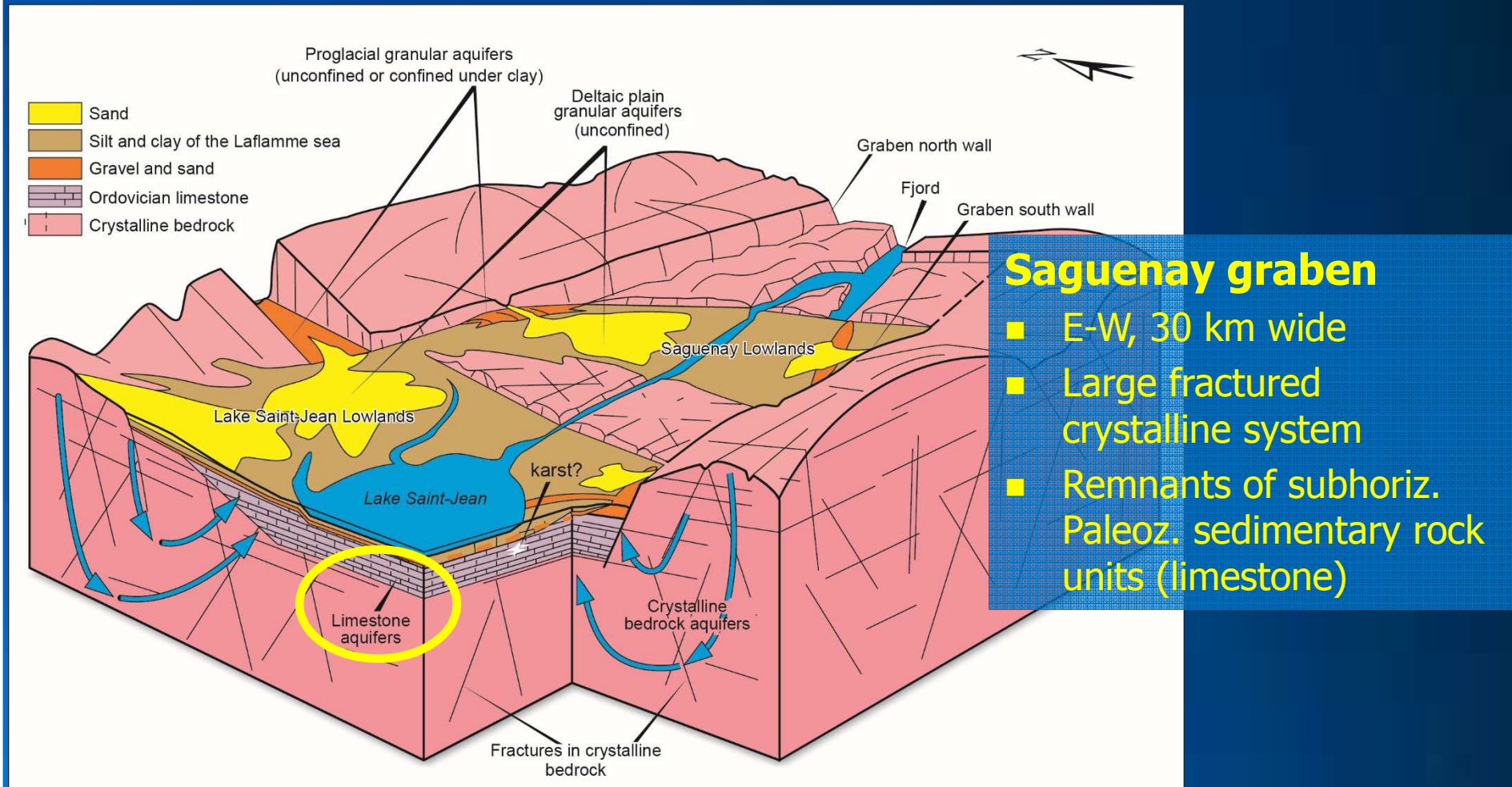
Saguenay graben

- E-W, 30 km wide
- Large fractured crystalline system

(modified from Rouleau et al., 2011)

Hydrogeological context

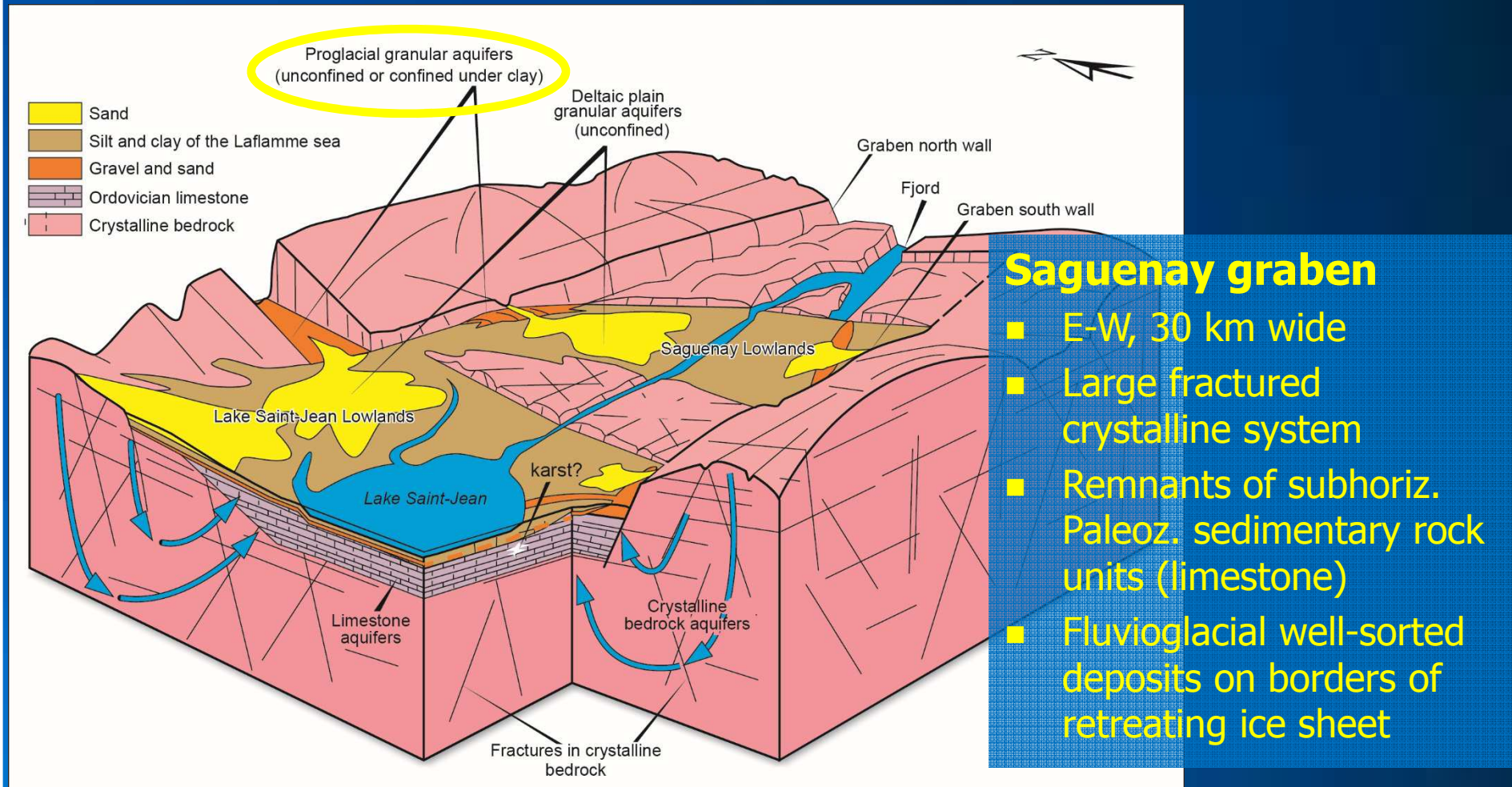
An example in the Grenville Province



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Hydrogeological context

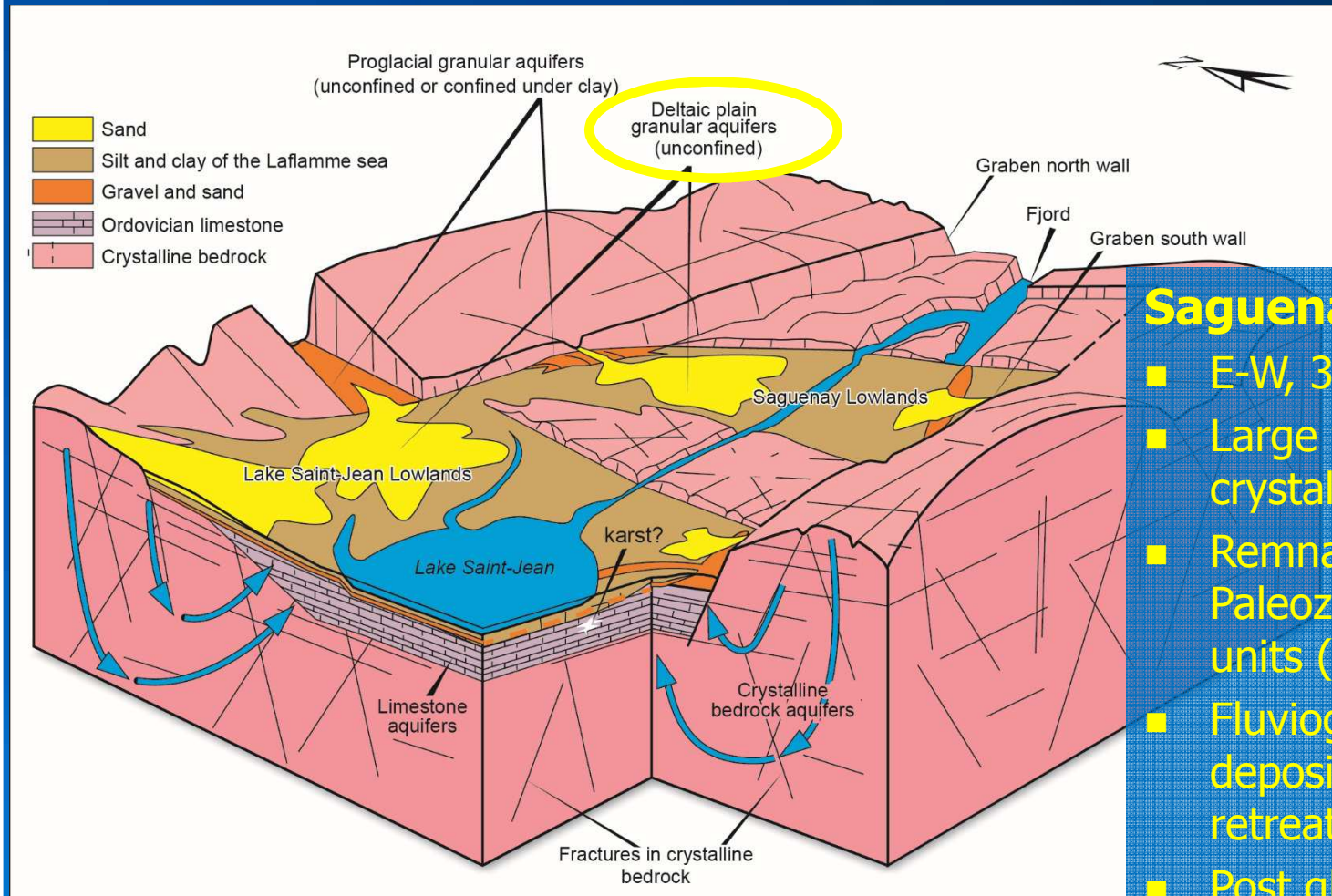
An example in the Grenville Province



(modified from Rouleau et al., 2011)

Hydrogeological context

An example in the Grenville Province



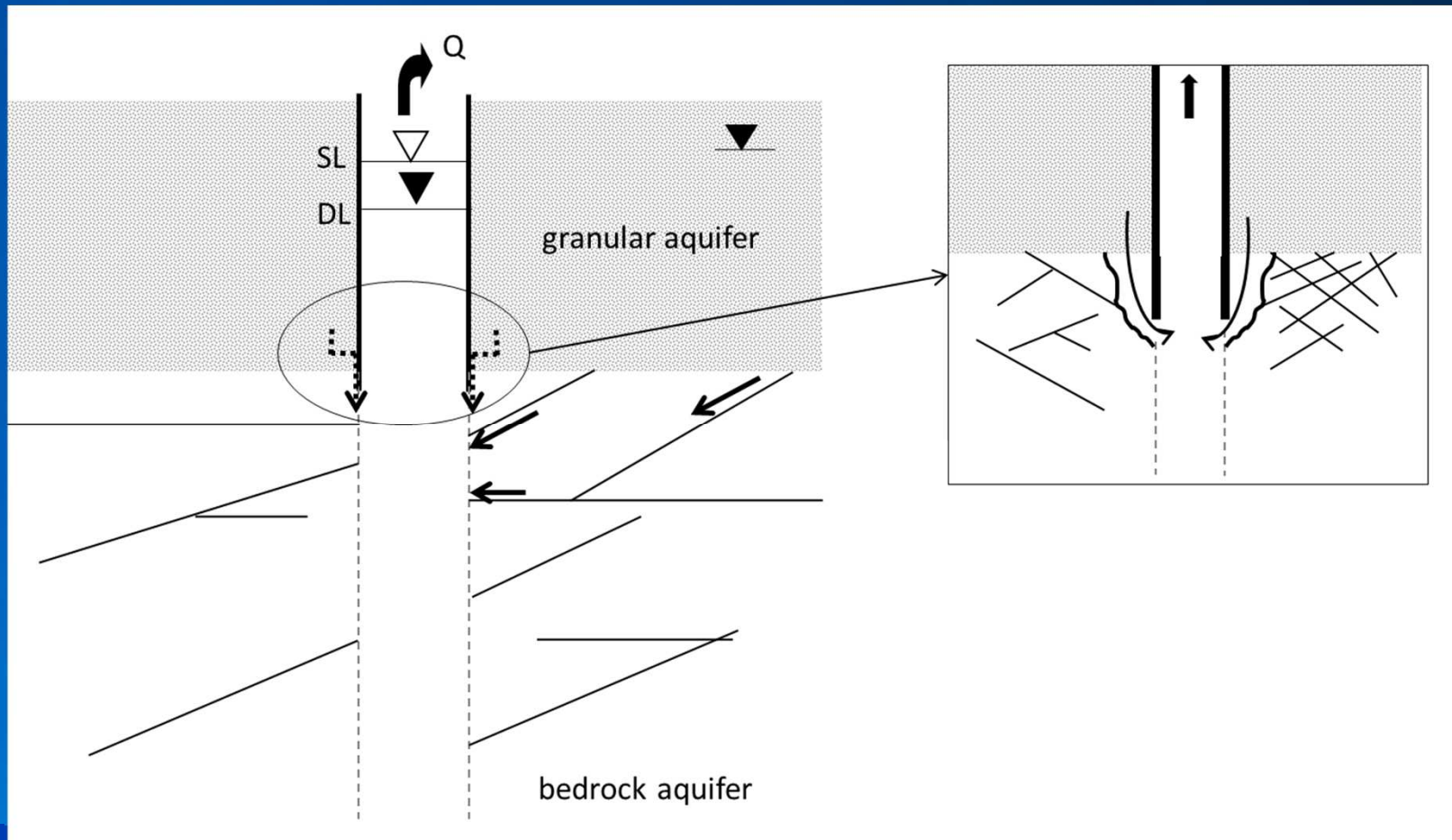
(modified from Rouleau et al., 2011)

Saguenay graben

- E-W, 30 km wide
- Large fractured crystalline system
- Remnants of subhoriz. Paleoz. sedimentary rock units (limestone)
- Fluvioglacial well-sorted deposits on borders of retreating ice sheet
- Post glacial deltaic plains, & silty clay, during invasion of Laflamme Sea

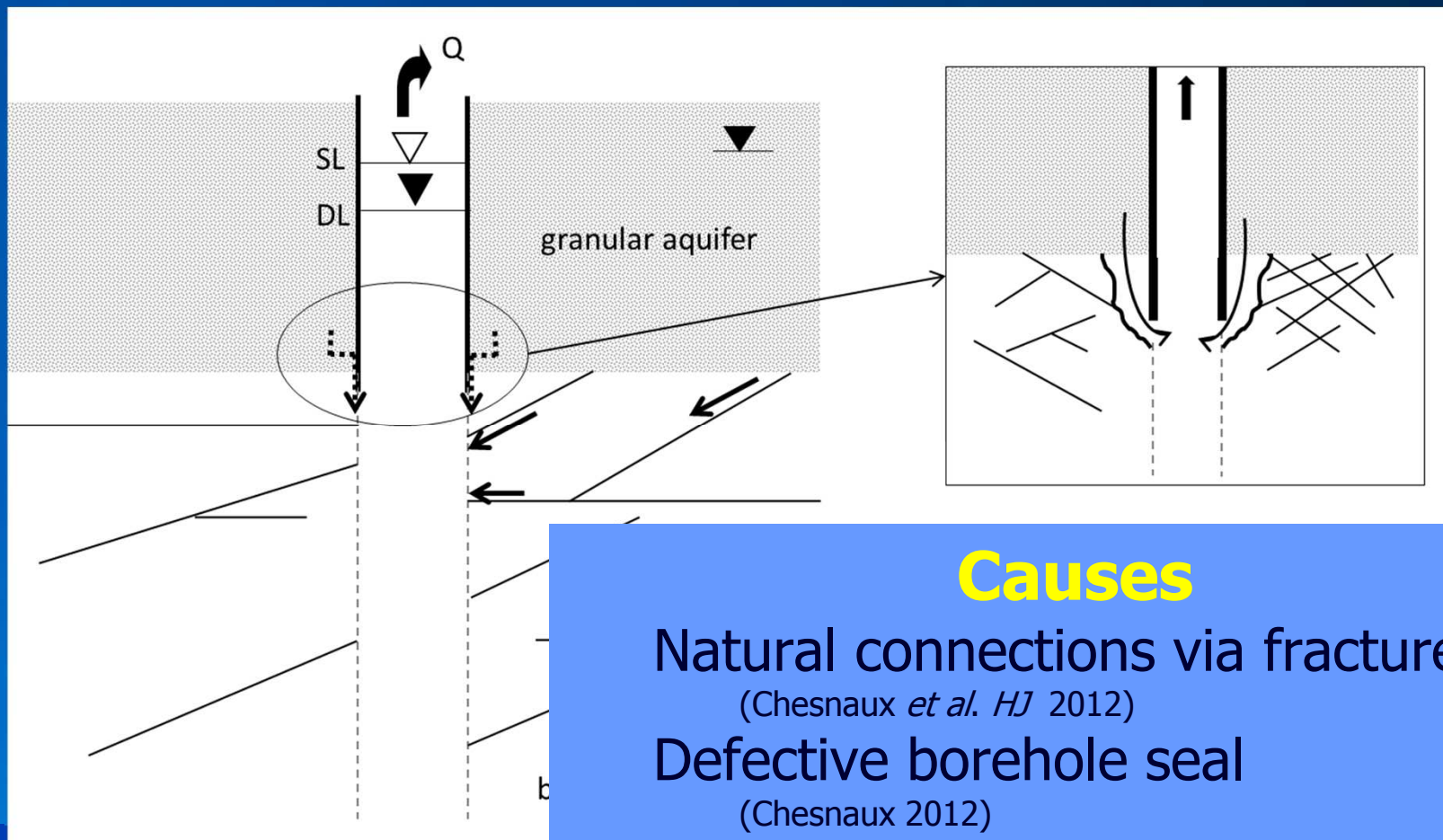
Hydraulic connections b/w bedrock & overlying granular aquifer

Poorly documented, but apparently prevalent



Hydraulic connections b/w bedrock & overlying granular aquifer

Poorly documented, but apparently prevalent



Causes

Natural connections via fractures

(Chesnaux *et al.* HJ 2012)

Defective borehole seal

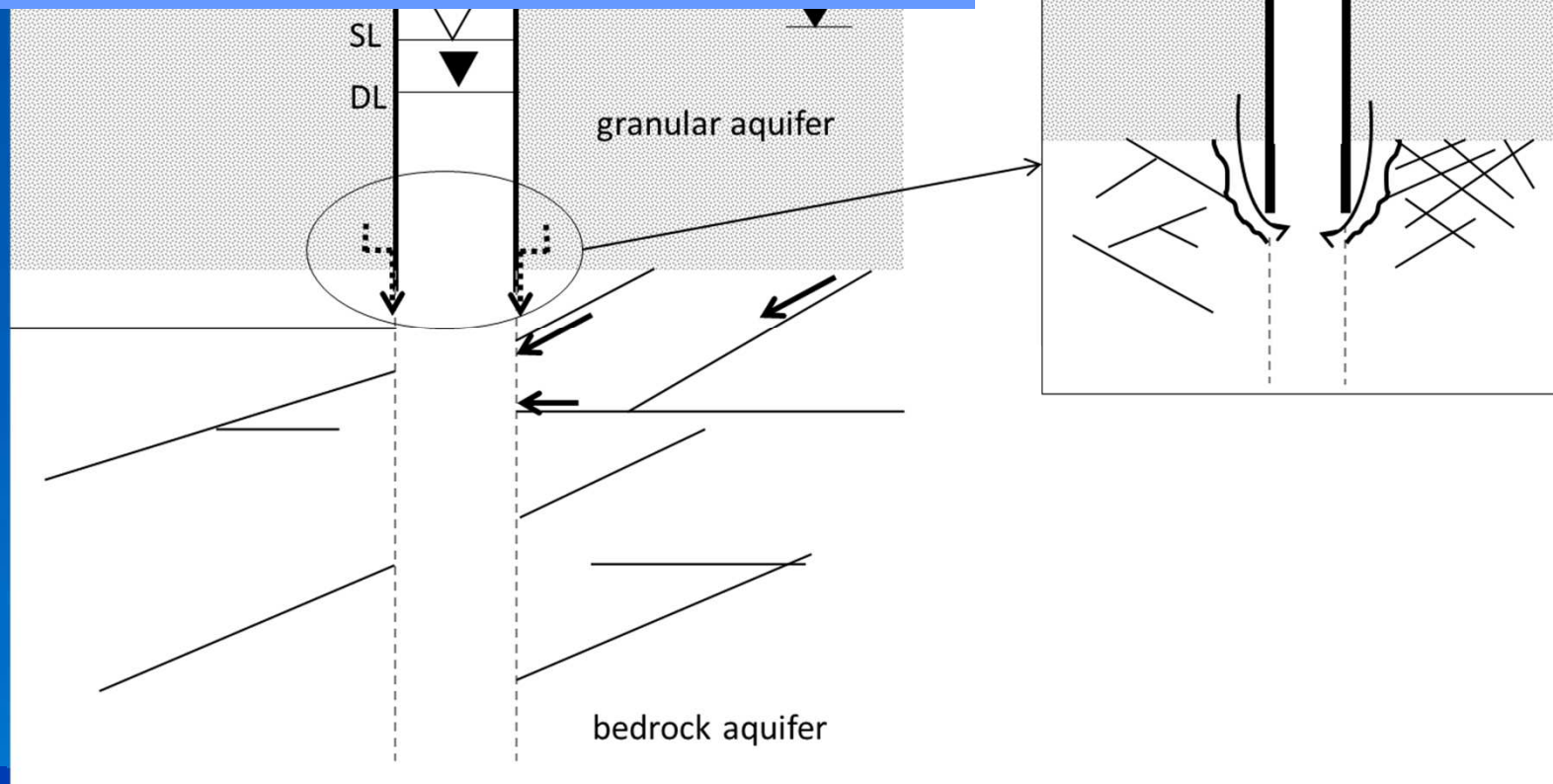
(Chesnaux 2012)

Hydraulic connections b/w bedrock & overlying granular aquifer

Impacts

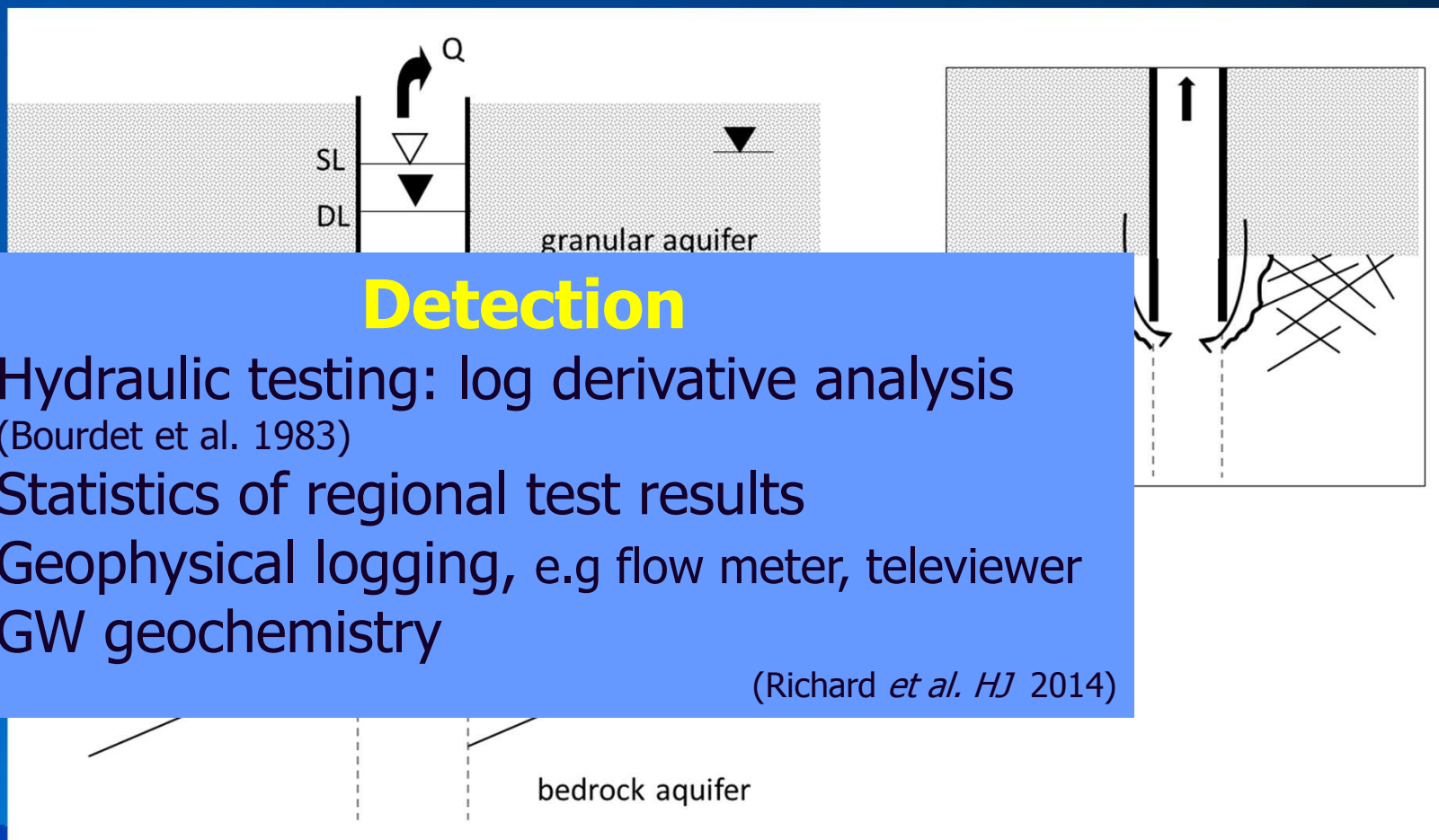
- Errors in parameter estimation
- Possible cross-contamination

apparently prevalent



Hydraulic connections b/w bedrock & overlying granular aquifer

Poorly documented, but apparently prevalent



Detection

- Hydraulic testing: log derivative analysis (Bourdet et al. 1983)
- Statistics of regional test results
- Geophysical logging, e.g flow meter, televiwer
- GW geochemistry

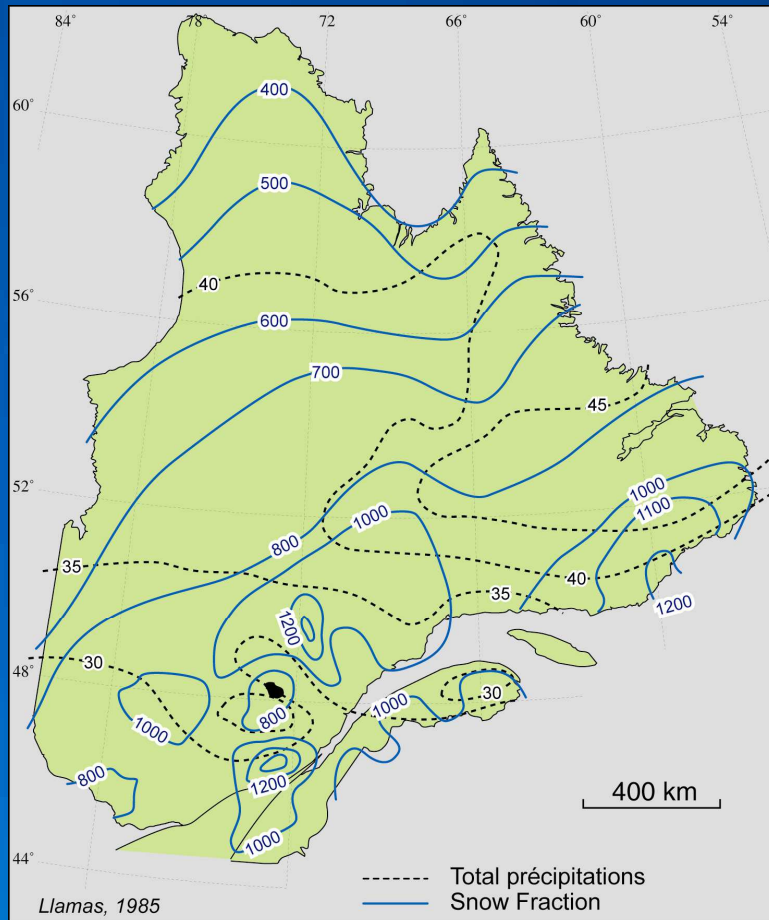
(Richard *et al.* HJ 2014)

SUMMARY

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Precipitation

Example:
Quebec & Labrador (NFLD)



North: ~ 400 mm/yr
South: up to 1 400 mm/yr

Snow fraction:
North: 50%
South: 25%

Permafrost and stream Flow

Permafrost to the North:

→ reduced recharge

Reduced evapotranspiration to the North

→ Runoff coefficient (runoff/precipitation; Q/P)

> 80 % (North) ~ 50% (South)

Stream baseflow ($\text{m}^3/\text{s}/\text{km}^2$)

5×10^{-4} (North)

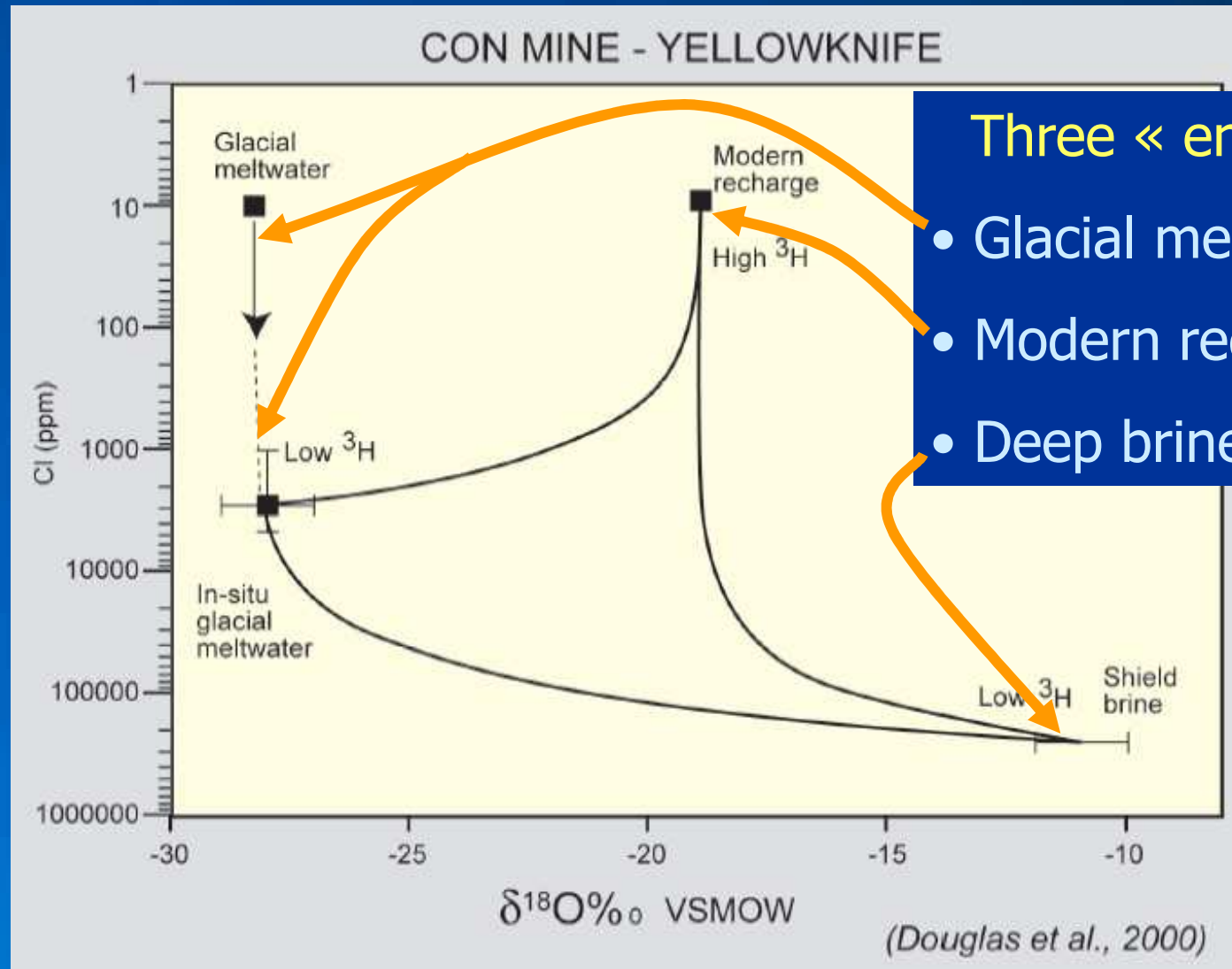
5×10^{-3} (South)

One of a few readily available GW data

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Isotopic zoning at a mine site



Three « end-members »

- Glacial melt water
- Modern recharge
- Deep brine

SELECTED CONCLUSIONS

- Low porosity, crystalline bedrock aquifers; decreasing K with depth
- GW flow along large discontinuities and connected fracture networks
- Prevalent hydraulic connections bedrock – granular aquifers
- Geochemistry: from fresh water to brines
- Isotopes content (O and H) : identification of old brines, glacial meltwater and modern recharge
- Mining sites: (underused) access to bedrock aquifers and gw sampling points

Thanks to:

- Geological Survey of Canada (Alfonso Rivera): initiative of book « *Canada's Groundwater Resources* » (2013)
- Alan Kohut, Richard Franklin, Claude Dallaire for drafting
- Numerous authors of previous works

Merci de votre attention
Thank you for your attention