Revised potential of the Upper Muschelkalk Formation (Central Swiss Plateau) for CO_2 storage and geothermal electricity

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In cooperation with the CTI

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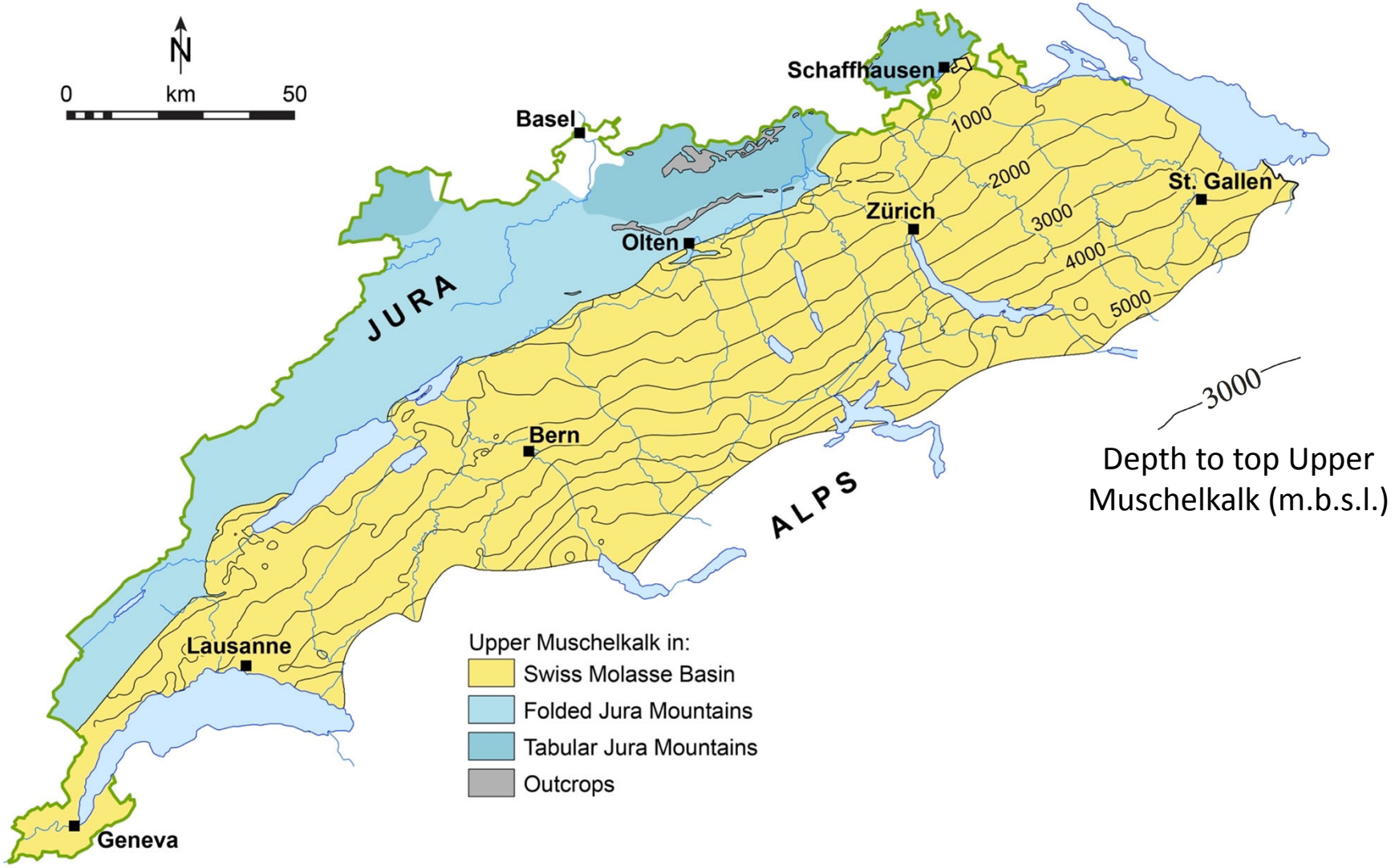
Switzerland's largest deep saline aquifer

Upper Muschelkalk dolomite sealed by impermeable evaporite caprock

Underlies entire Swiss Plateau (Molasse Basin)



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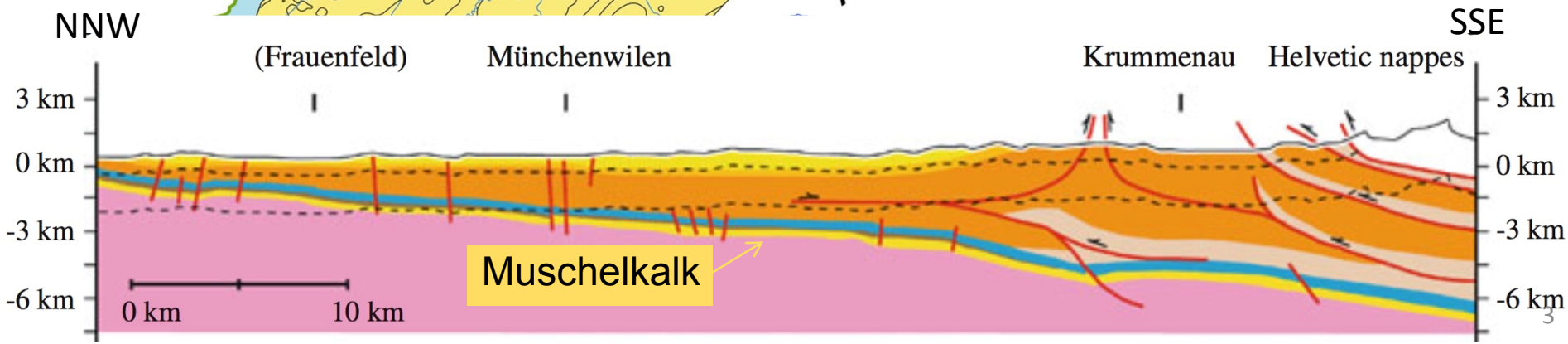
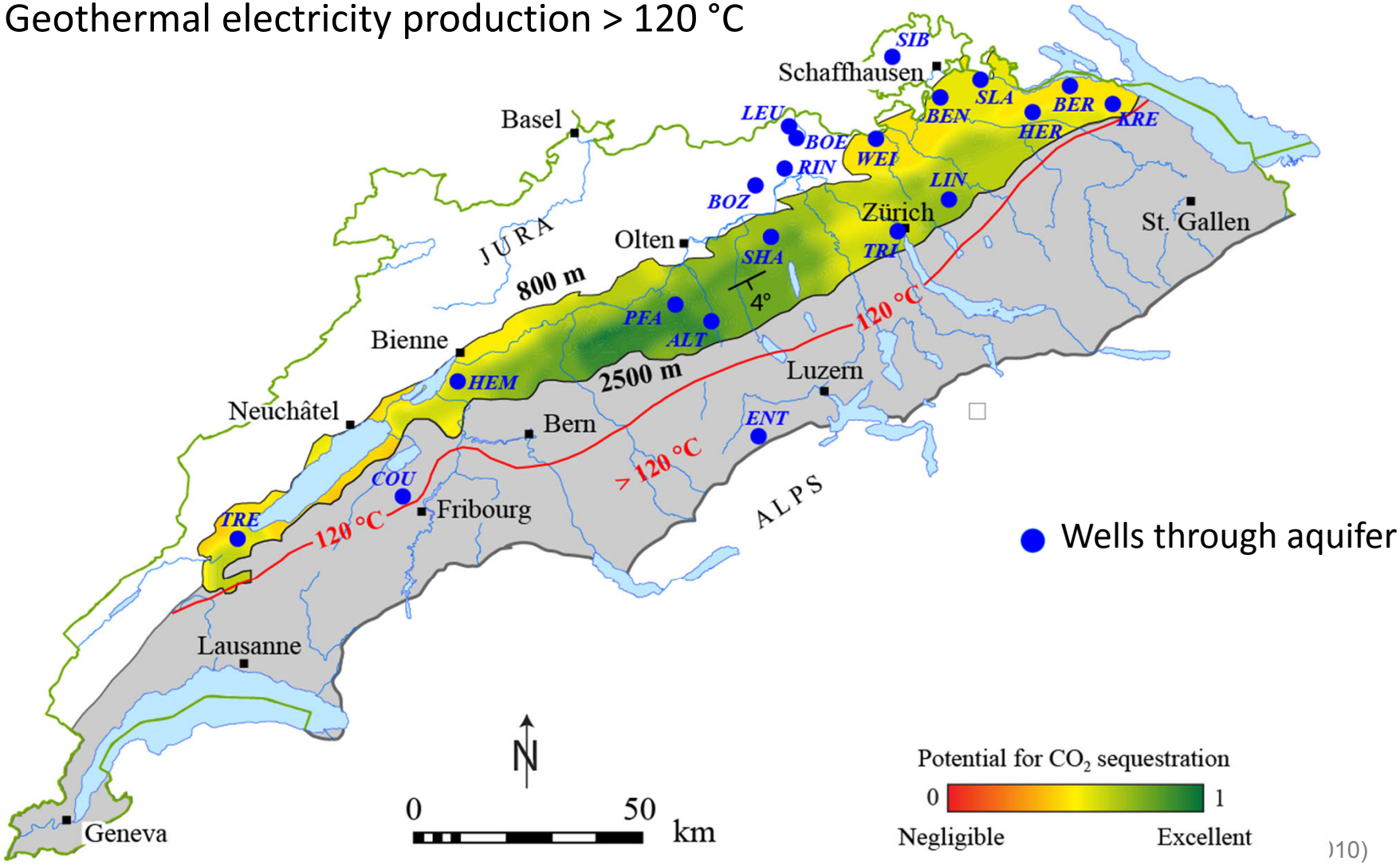


Preliminary appraisal of geoenergy potential

Literature study by Chevalier et al. (2010)

CO_2 storage at 800–2500 m depth (high capacity indicated)

Geothermal electricity production > 120 °C



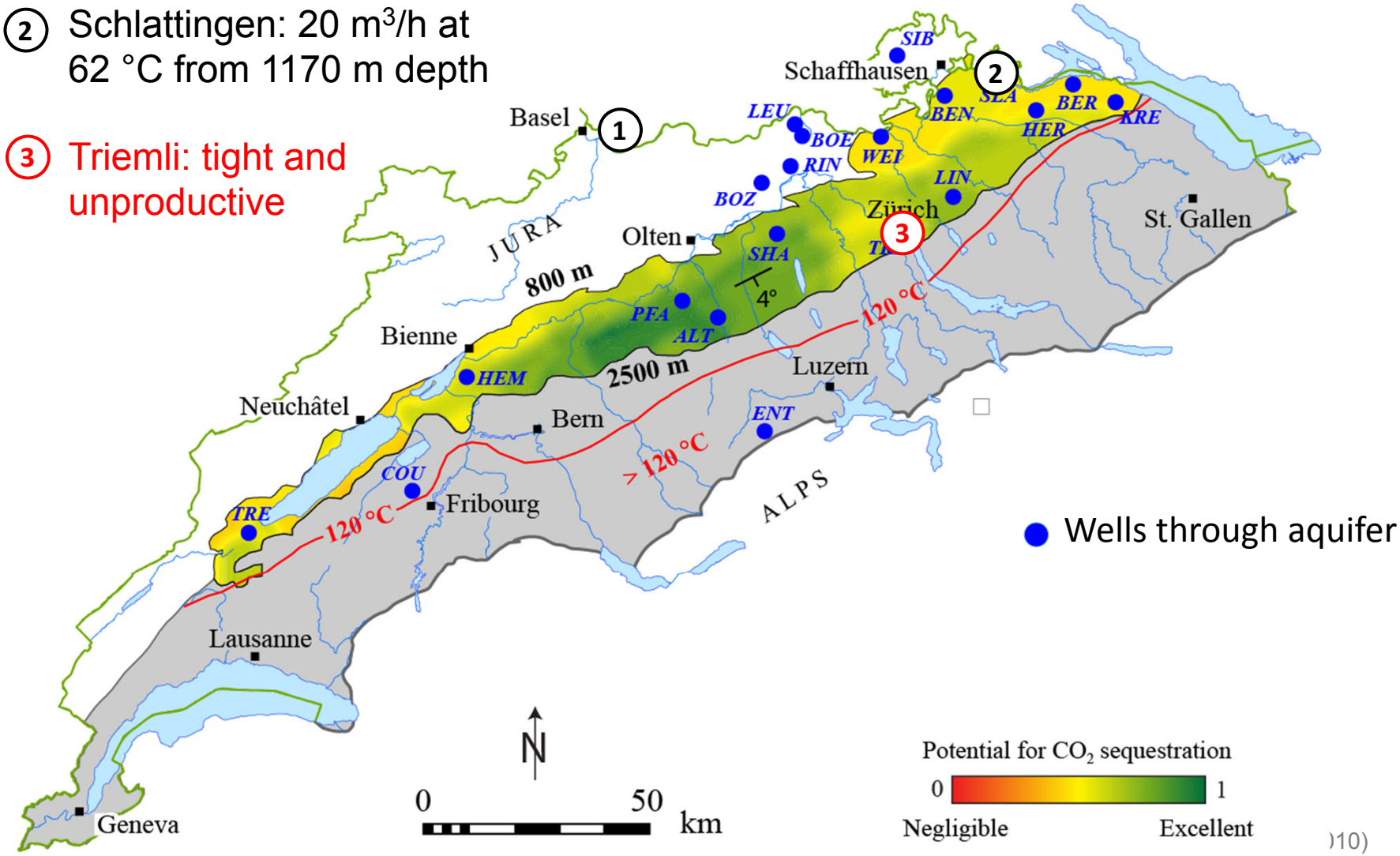
)10)

Geothermal exploration wells in Muschelkalk

① Riehen: 70 m³/h at 65°C from 1550 m depth

② Schlattingen: 20 m³/h at 62 °C from 1170 m depth

③ Triemli: tight and unproductive



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Preliminary appraisal of geoenergy potential

Industry thresholds for fluid injection / extraction:

> 10% porosity

> 10–100 mD permeability

- Wells through aquifer (SEAG, Nagra):
  11 with accessible core
  15 with accessible logs

Potential for CO_2 sequestration

0 — 1

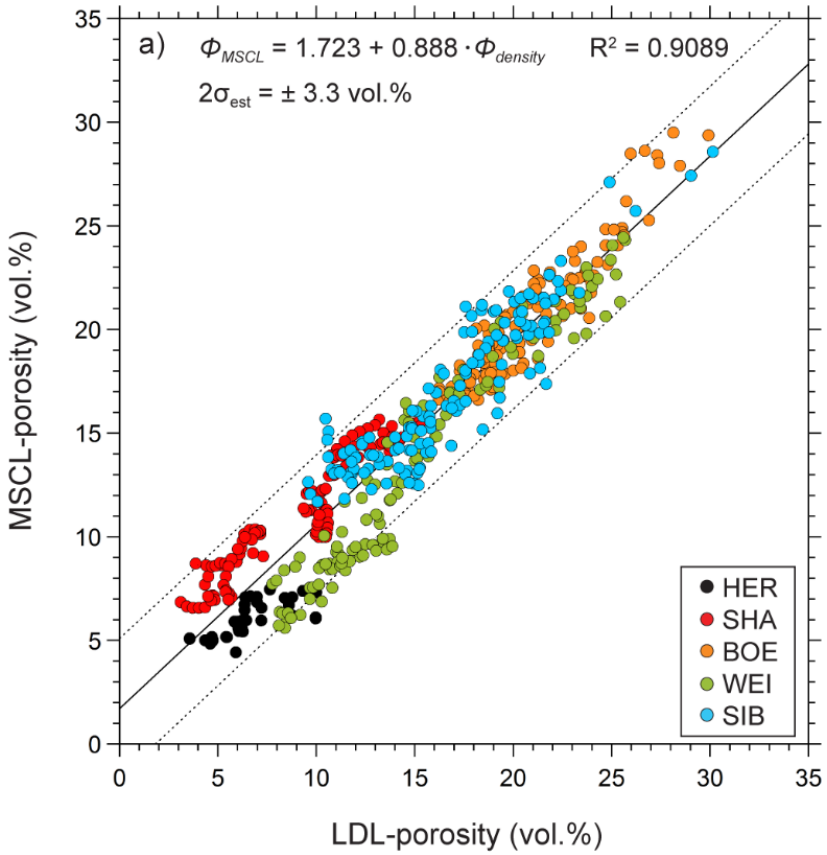
Negligible — Excellent

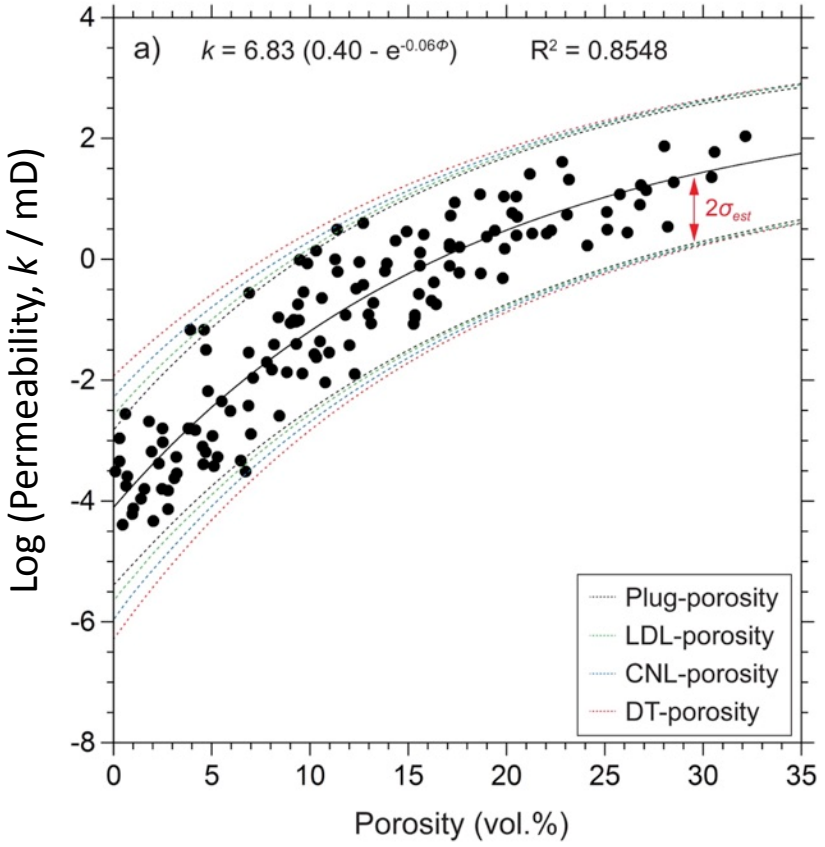
)10)

Predictions for wells without core

Derived correlation of rock-matrix poro–perm from borehole geophysical logs

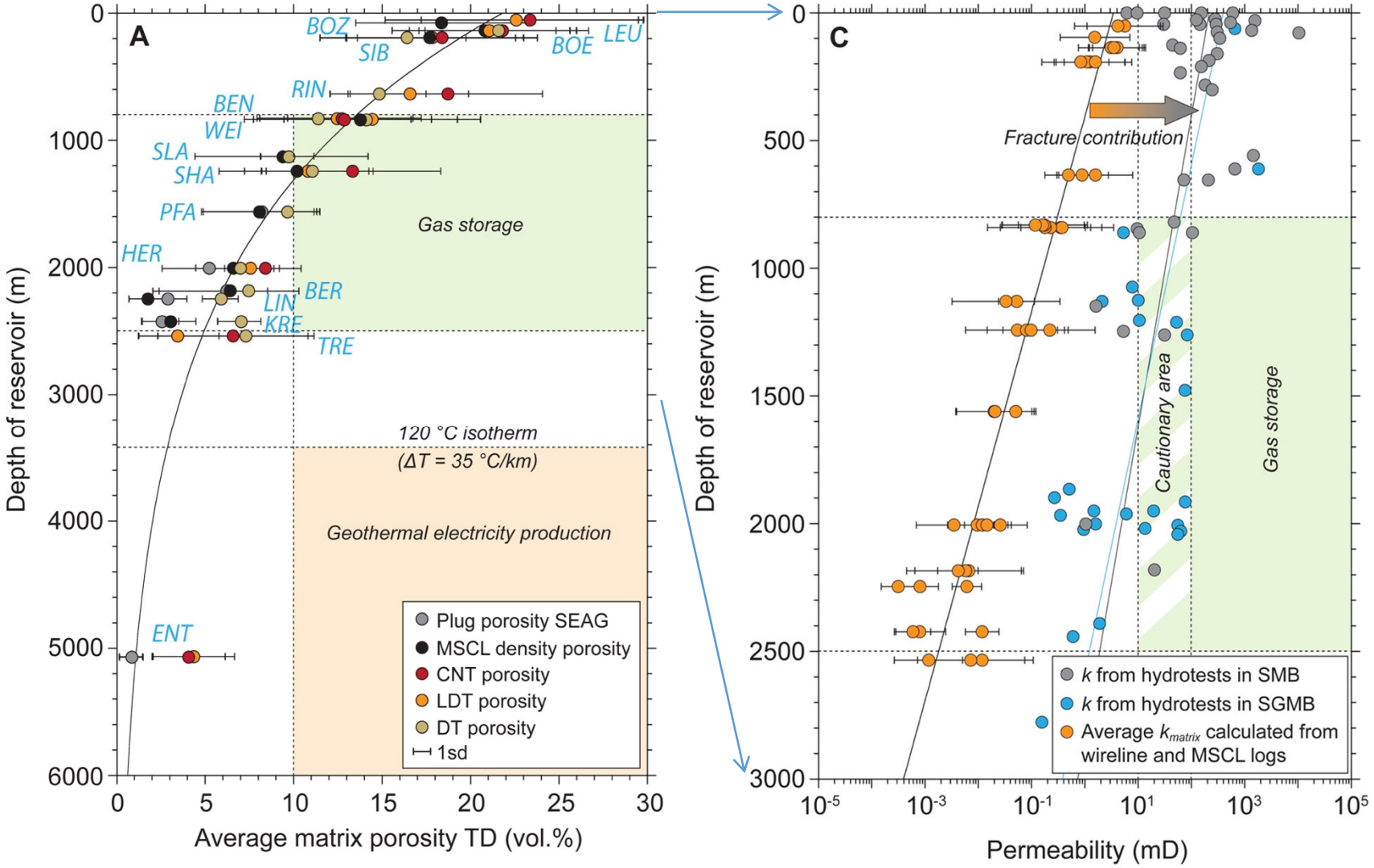
Enables poro–perm interpolation between deep wells in basin



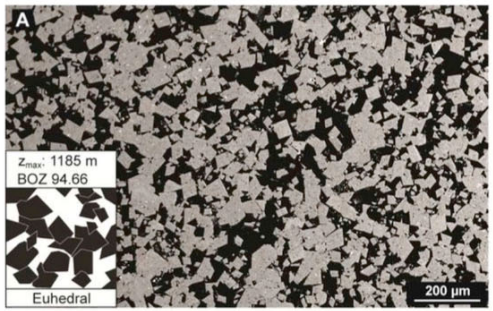


Porosity + permeability results

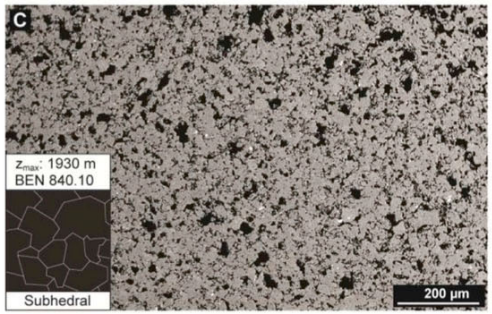
Strong poro–perm reduction with depth



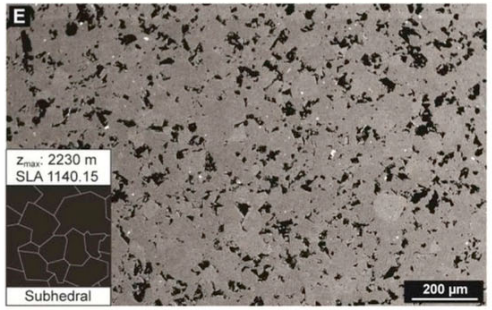
Porosity collapse with depth



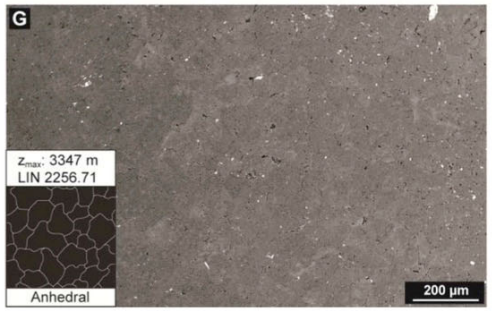
95 m



840 m

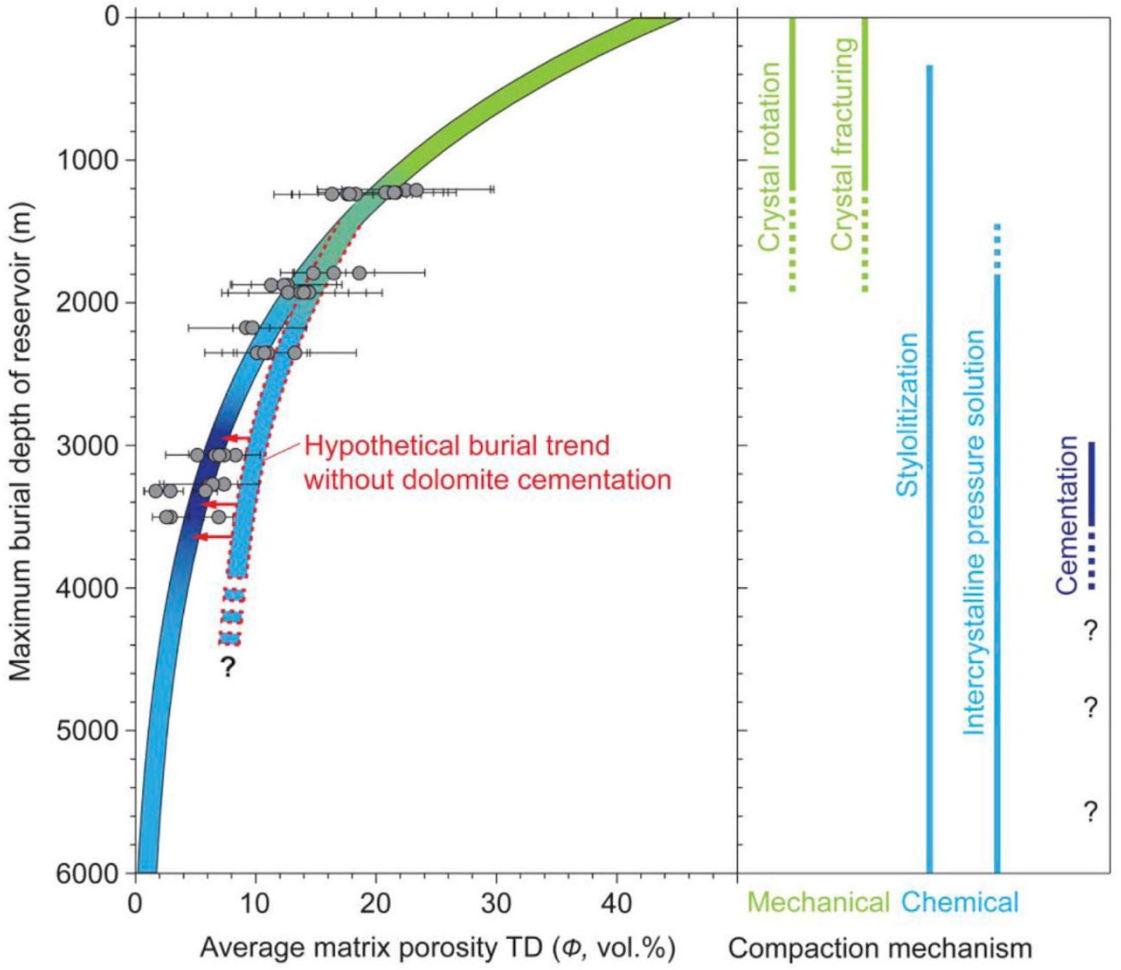


1140 m



2257 m

Understanding of processes enables extrapolation



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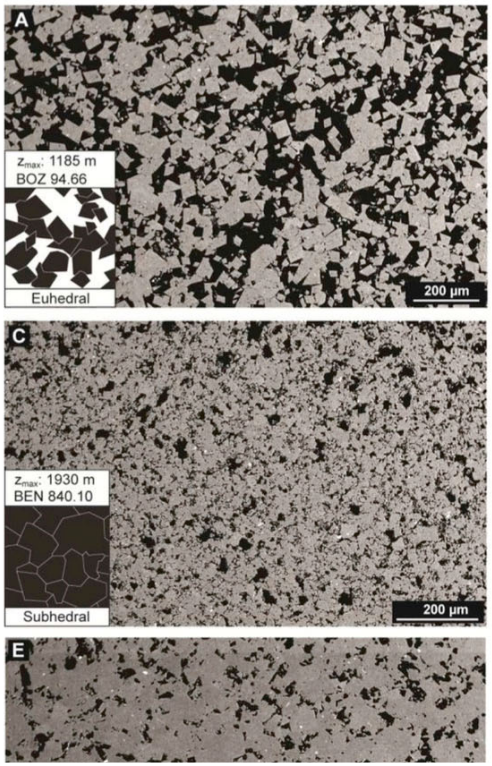

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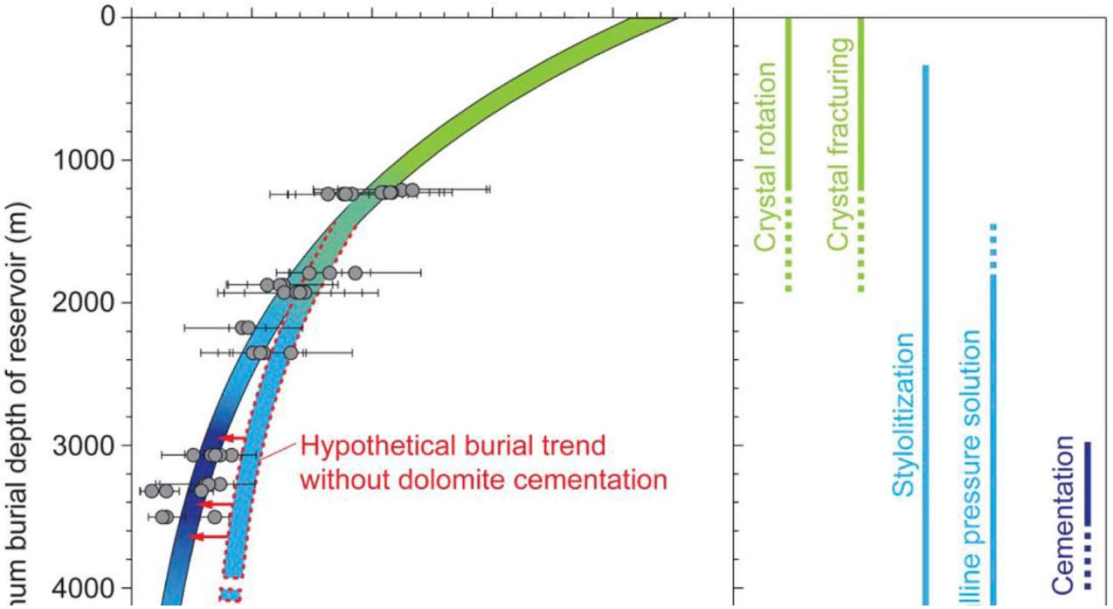
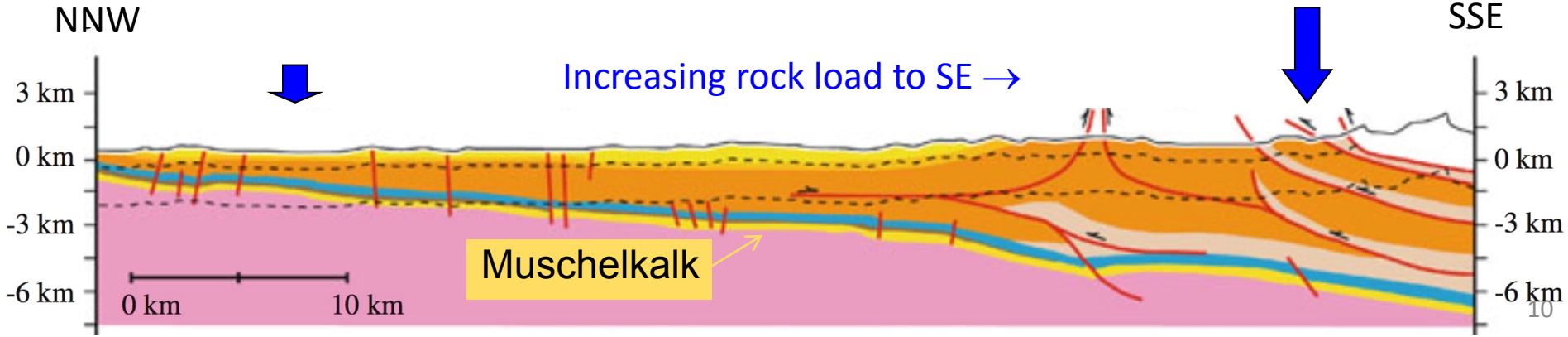
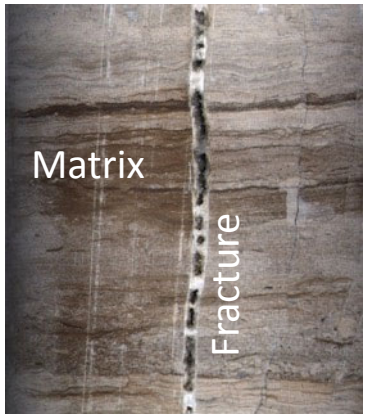




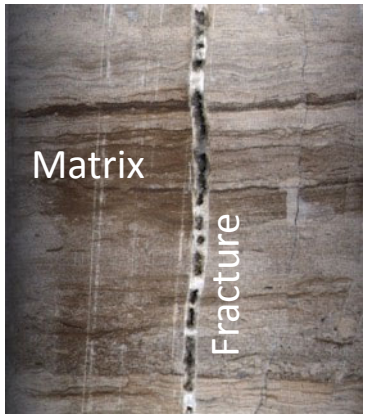
Basin-wide predictions

Rock-matrix porosity



Basin-wide predictions

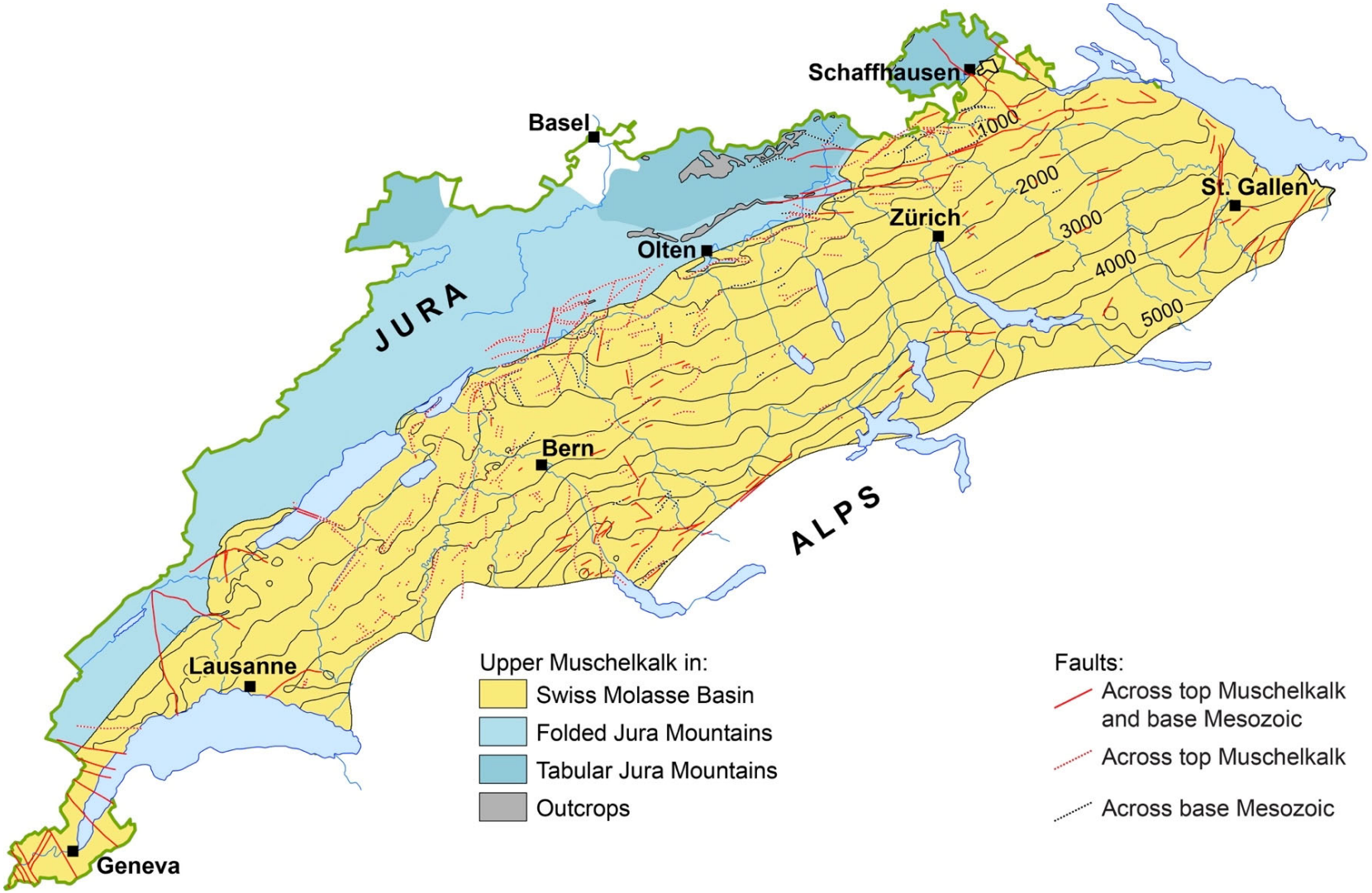
Matrix permeability combined with fracture permeability



Faults in Upper Muschelkalk

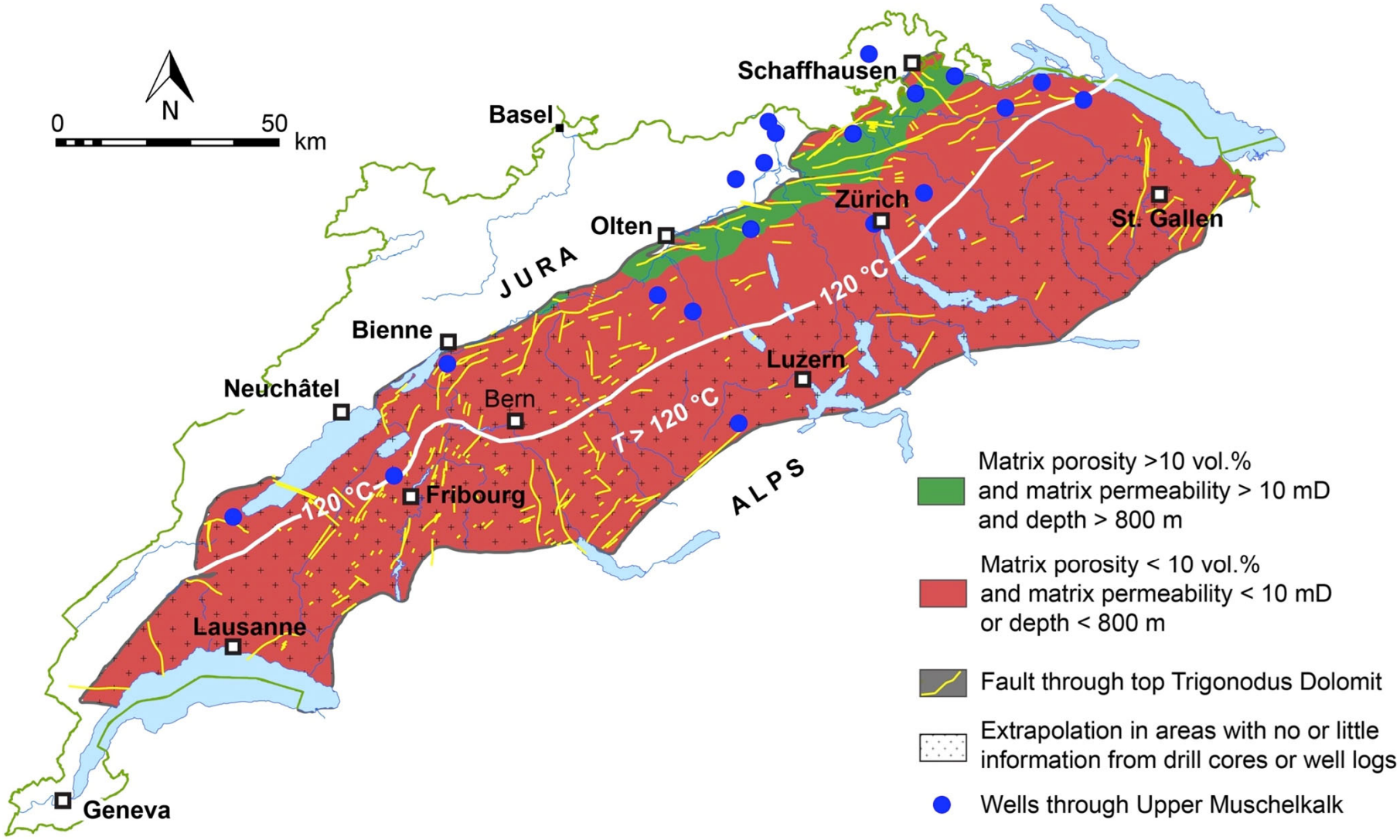
Faults mapped by processing GEOMOL seismic-based DEM

(top Mesozoic + top Muschelkalk)



Summary of Muschelkalk reservoir properties

Map filtered according to industry criteria for fluid injection/extraction

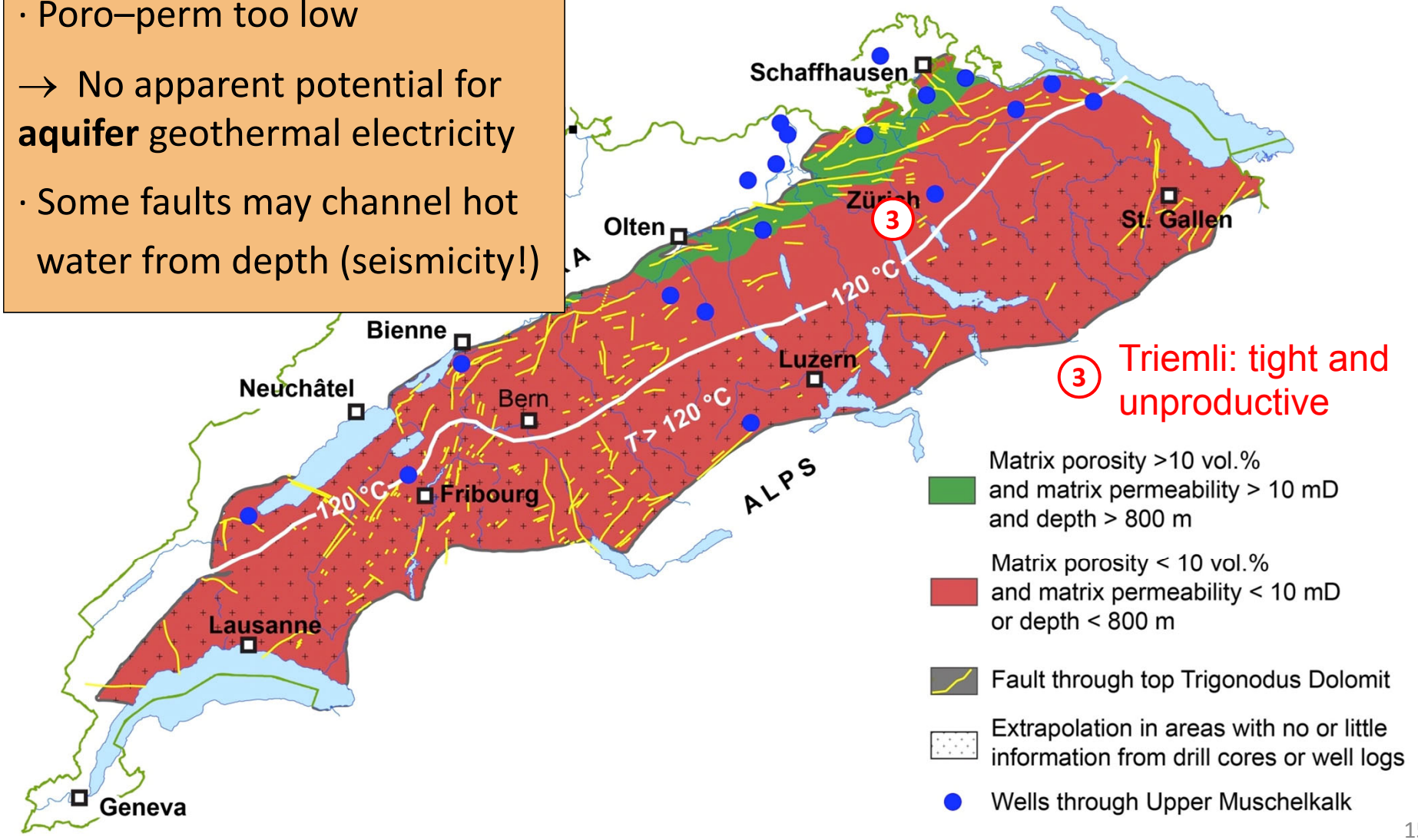


Potential for geothermal electricity

- Area at T > 120 °C (electricity threshold) > 3400 m depth
- Poro–perm too low

→ No apparent potential for **aquifer** geothermal electricity

- Some faults may channel hot water from depth (seismicity!)

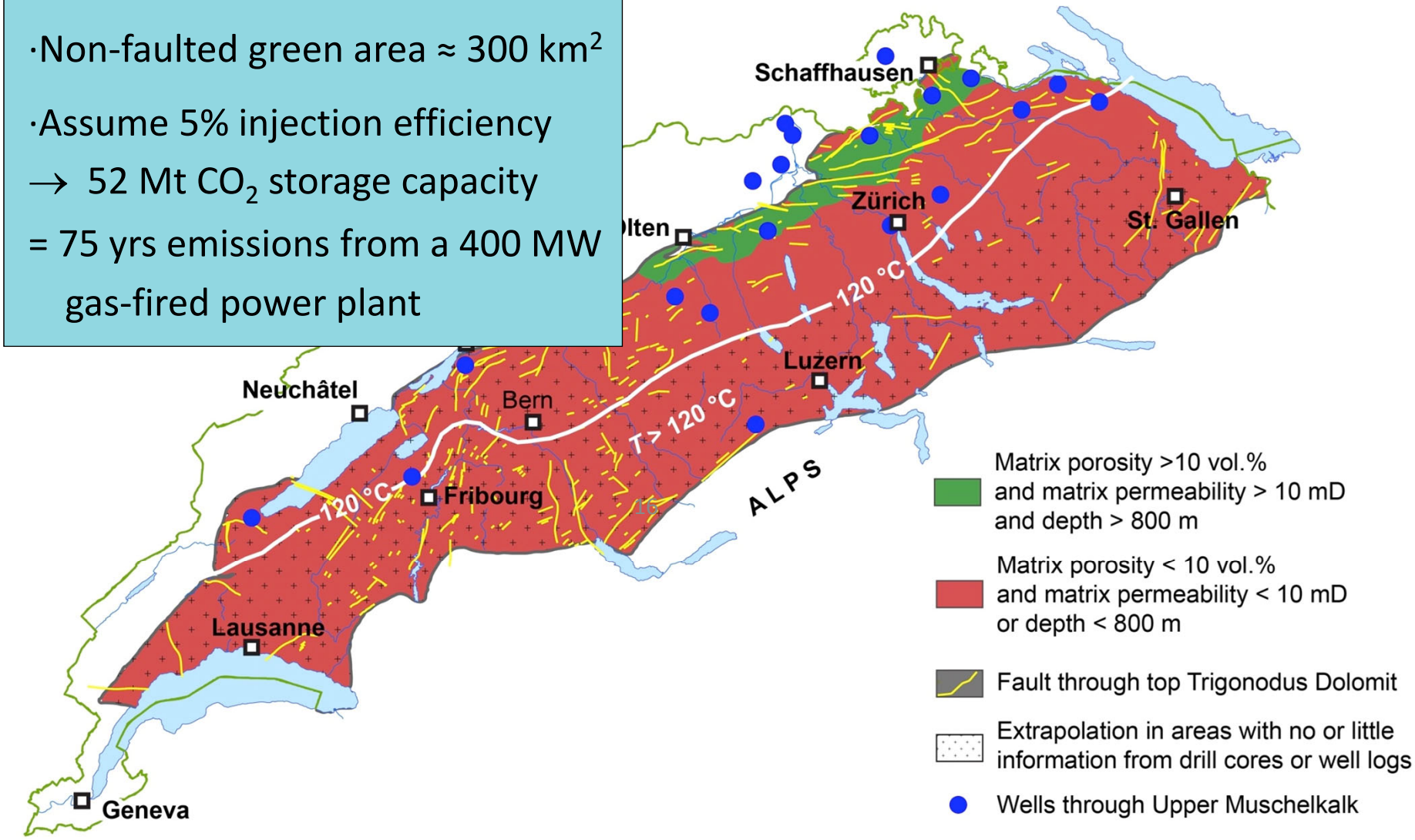


Potential for CO_2 storage

- Total green area = 640 km^2
- Faults may or may not leak CO_2
- Non-faulted green area ≈ 300 km^2
- Assume 5% injection efficiency

→ 52 Mt CO_2 storage capacity

= 75 yrs emissions from a 400 MW gas-fired power plant



Publications

Adams, A. and Diamond, L.W. (2017) Early diagenesis driven by widespread meteoric infiltration of a Central European carbonate ramp: A reinterpretation of the Upper Muschelkalk. *Sedimentary Geology* 362, 37–52.

Adams, A., Diamond, L.W. and Aschwanden, L. (2019) Dolomitization by hypersaline reflux into dense groundwaters as revealed by vertical trends in Sr- and O-isotopes: Upper Muschelkalk, Switzerland. *Sedimentology* 66, 362–390.

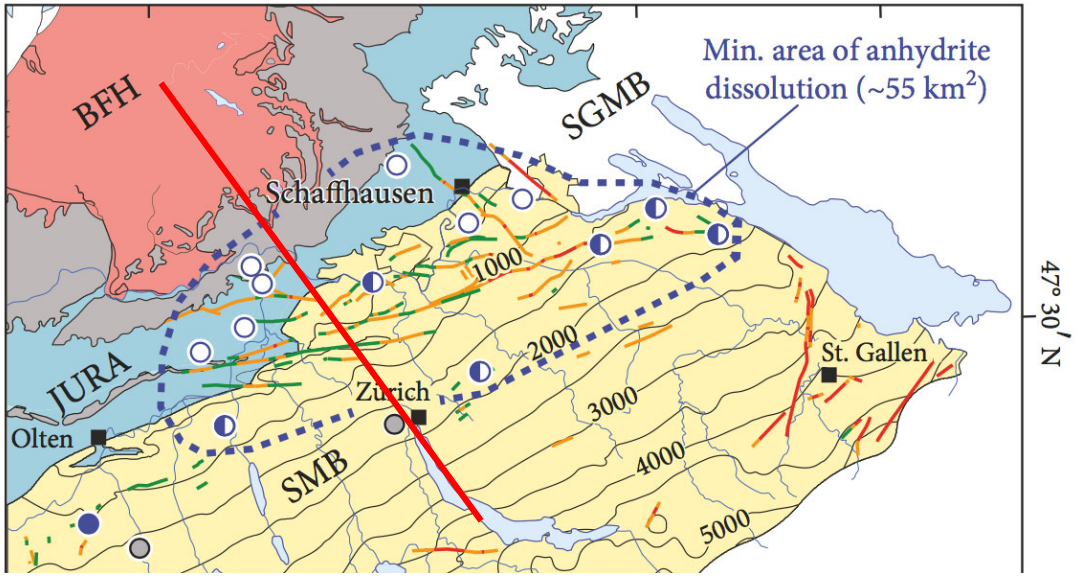
Adams, A. and Diamond, L.W. (2019) Facies and depositional environments of the Upper Muschelkalk (Schinznach Formation, Middle Triassic) in northern Switzerland. *Swiss Journal of Geosciences*. DOI: 10.1007/s00015-019-00340-7

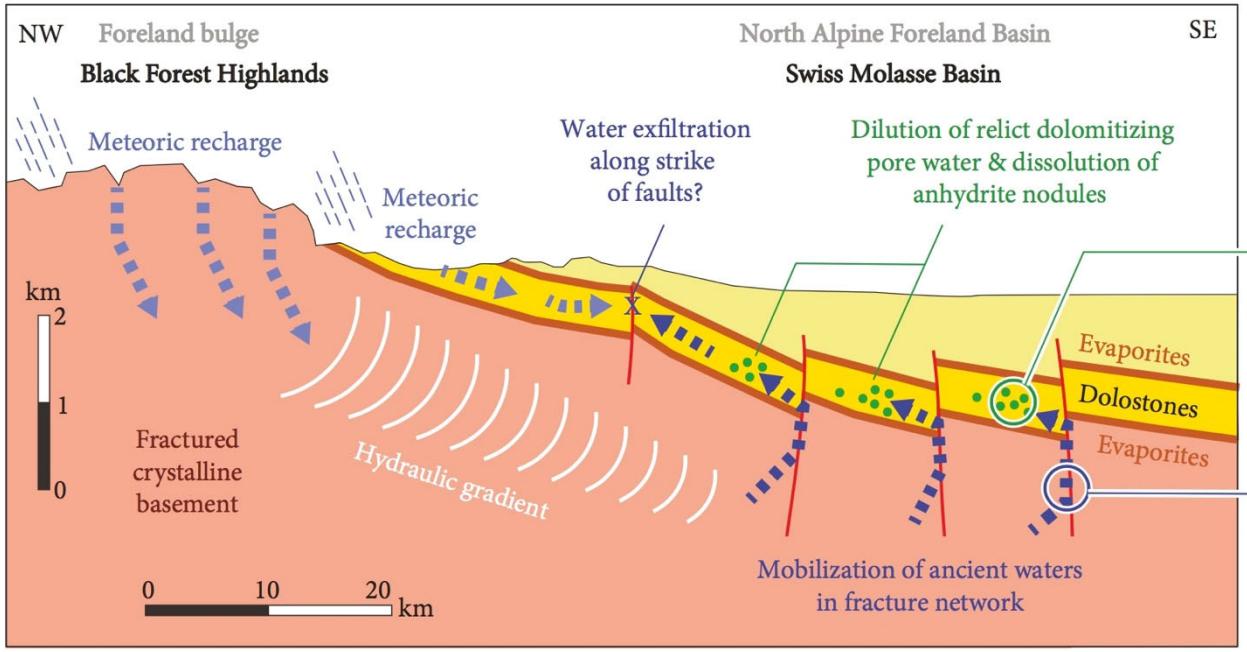
Aschwanden, L., Diamond , L.W. and Adams, A. (2019) Effects of progressive burial on matrix porosity and permeability of dolostones in the foreland basin of the Alpine Orogen, Switzerland. *Marine and Petroleum Geology* 100, 148–164.

Aschwanden, L., Diamond, L.W., Mazurek, M. and Davis, D.W. (2019) Creation of Secondary Porosity in Dolostones by Upwelling Basement Water in the Foreland of the Alpine Orogen. *Geofluids* 2019, 1-23.

Aschwanden, L., Diamond, L.W., Mazurek, M. and Davis, D.W. (submitted) Correlation of matrix porosity and permeability of dolostones based on wireline logs: Middle- and Upper Muschelkalk, Swiss Molasse Basin. *AAPG Bulletin*.

Enhanced poro-perm in NE sector of SMB





Anhydrite-dissolving water
T = 40 to 90°C
$^{86}Sr/^{87}Sr \leq 0.716$
Salinity = 0.2 to 6.5 wt.%
$\delta^{18}O$ = –7 to 5‰
$\delta^{2}H$ = –54 to –67‰
Qtz–calcite–kaolinite equilib.
U/Pb age = 11.5 to 16.8 Ma

Basement water
T = 65 to 110°C
$^{86}Sr/^{87}Sr = \leq 0.717$
Salinity = 0.2 to 6.4 wt.%
$\delta^{18}O$ = –10.7 to –5‰
$\delta^{2}H$ = –64 to –71‰
Qtz–calcite–kaolinite equilib.
U/Pb age = 8.3 to 13.3 Ma