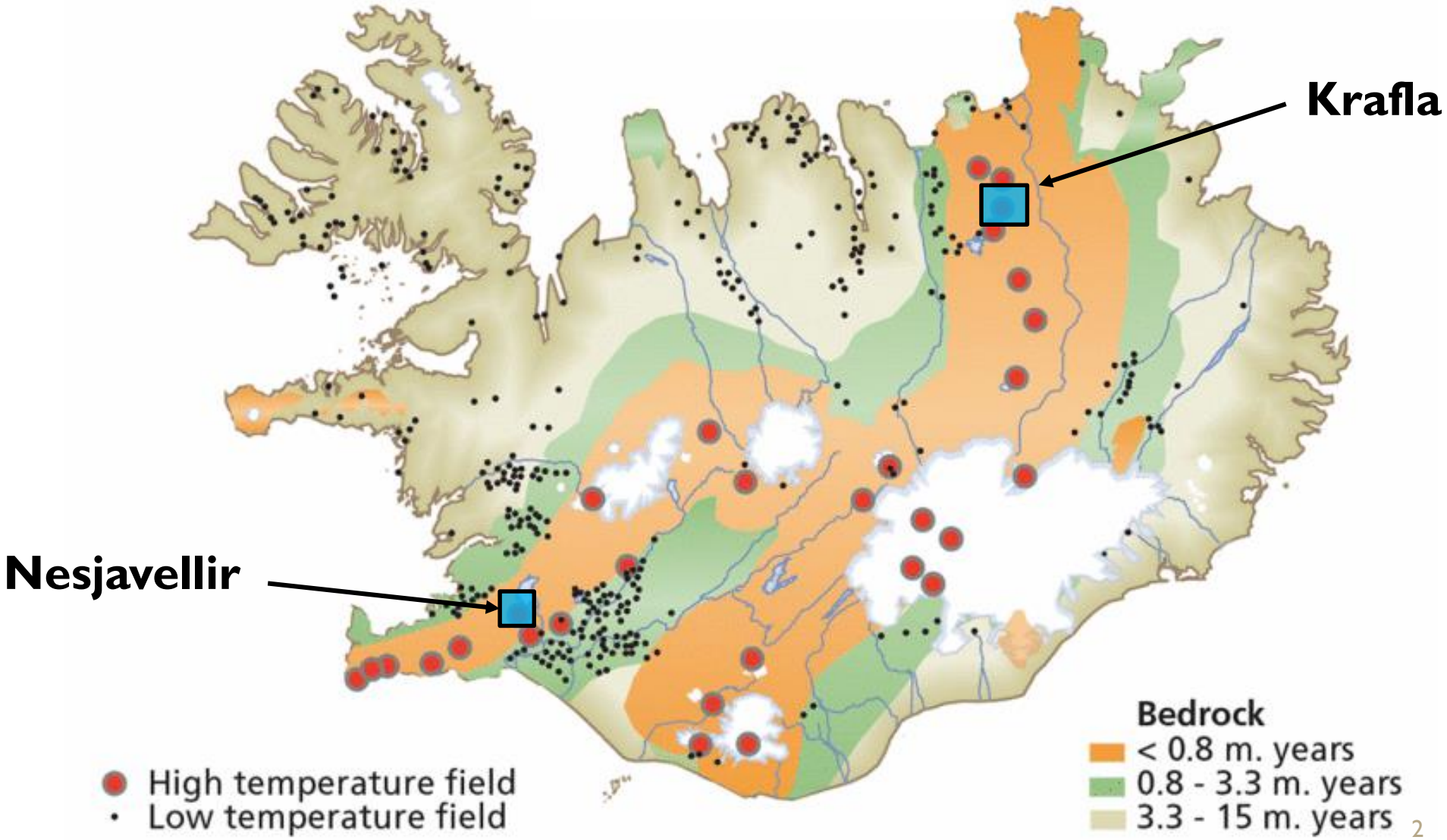
Exploitation de la géothermie haute-température. Enjeux d'exploration et de remédiation en Islande.

Léa Lévy

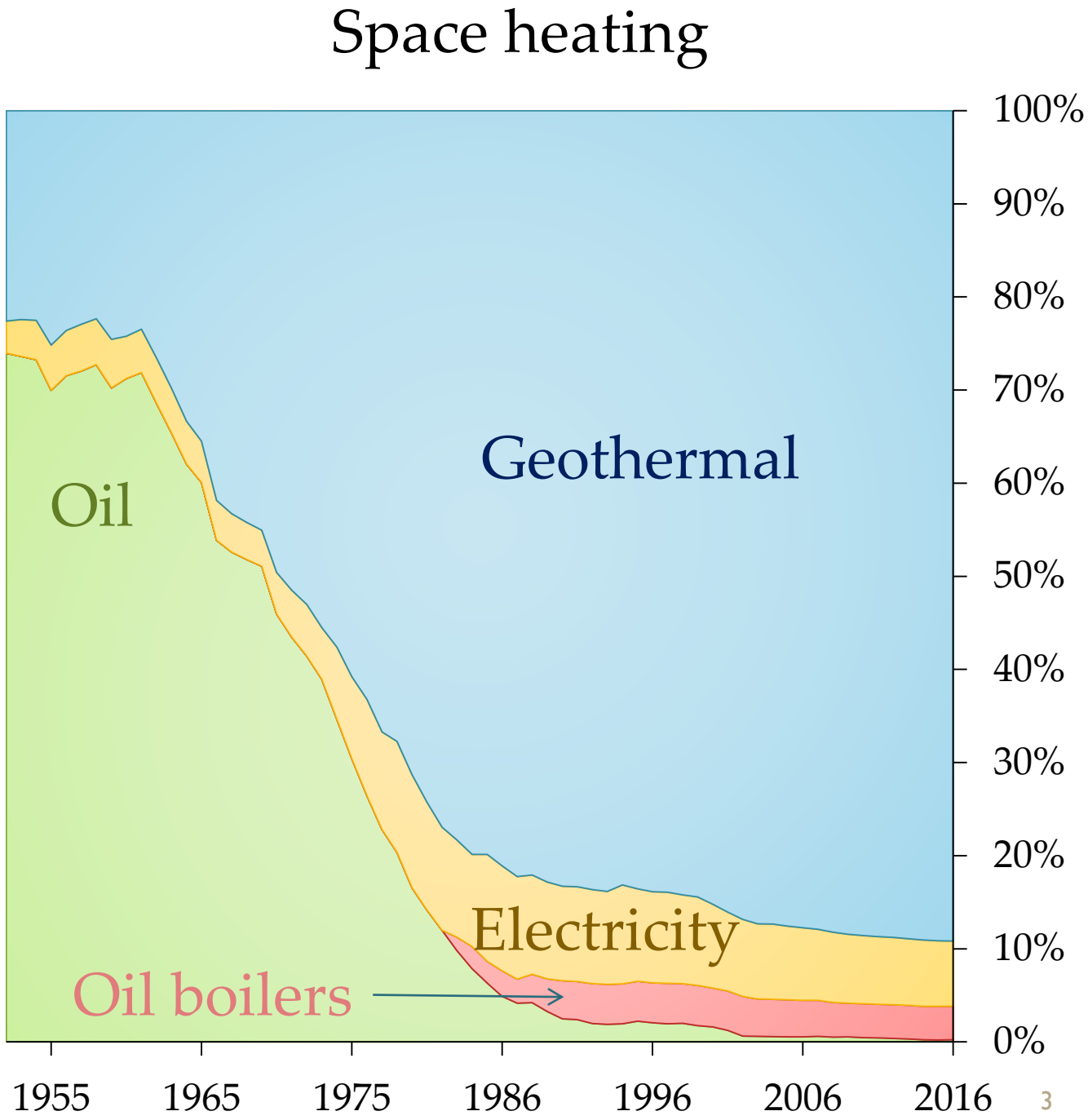
14 juin 2019

Geothermal fields in Iceland

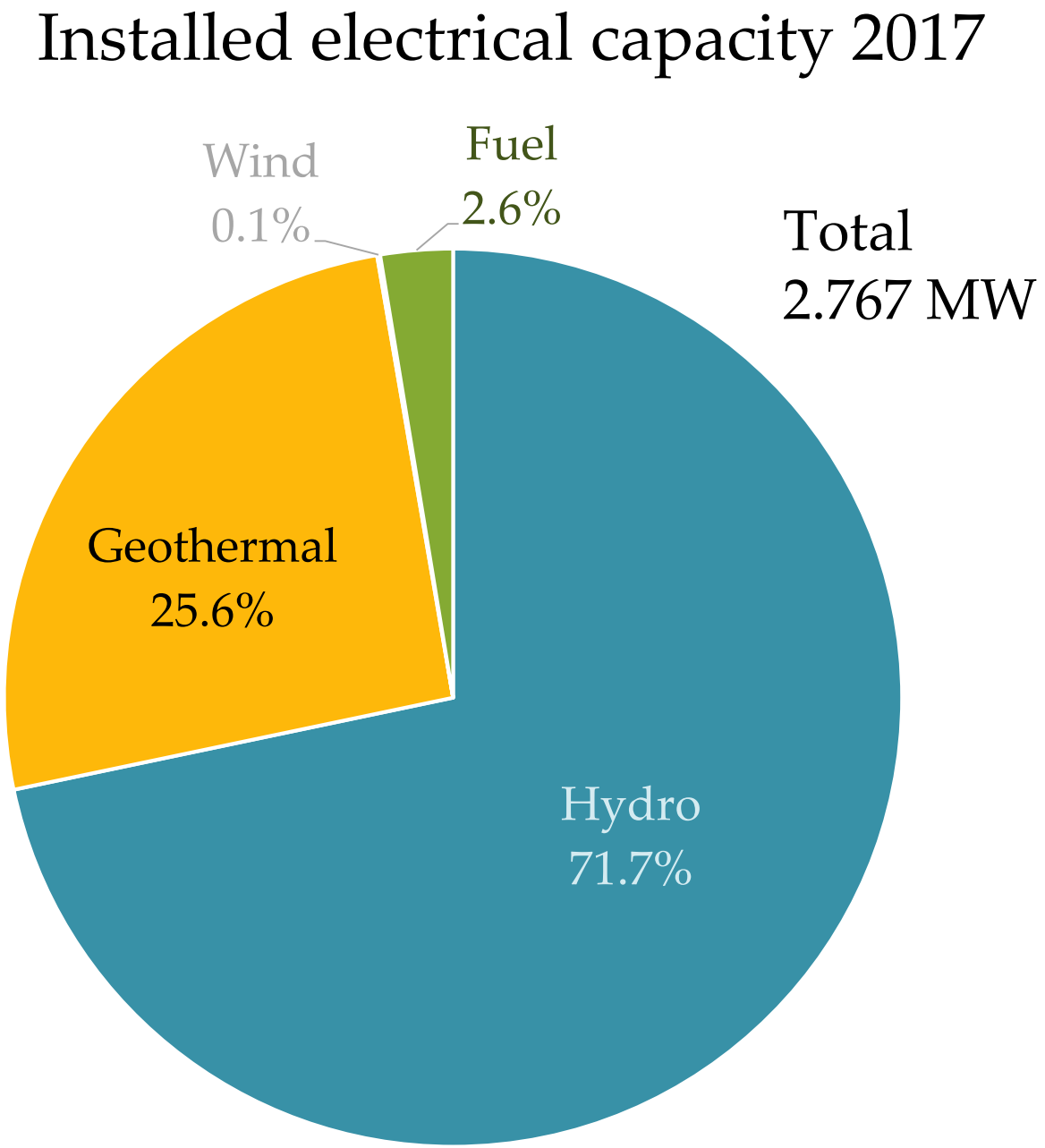


Geothermal energy in Iceland

Data from Orkustofnun repository
(file: OS-2018-T010-01)
https://orkustofnun.is/orkustofnun/gagnasofn/talnaefni/
Figure in L. Lévy (2019, Ph.D thesis)



Geothermal energy in Iceland



Data from Orkustofnun repository
(file: 0S-2018-T006-01)
https://orkustofnun.is/orkustofnun/gagnasofn/talnaefni/
Figure in L. Lévy (2019, Ph.D thesis)

Geothermal energy in Iceland

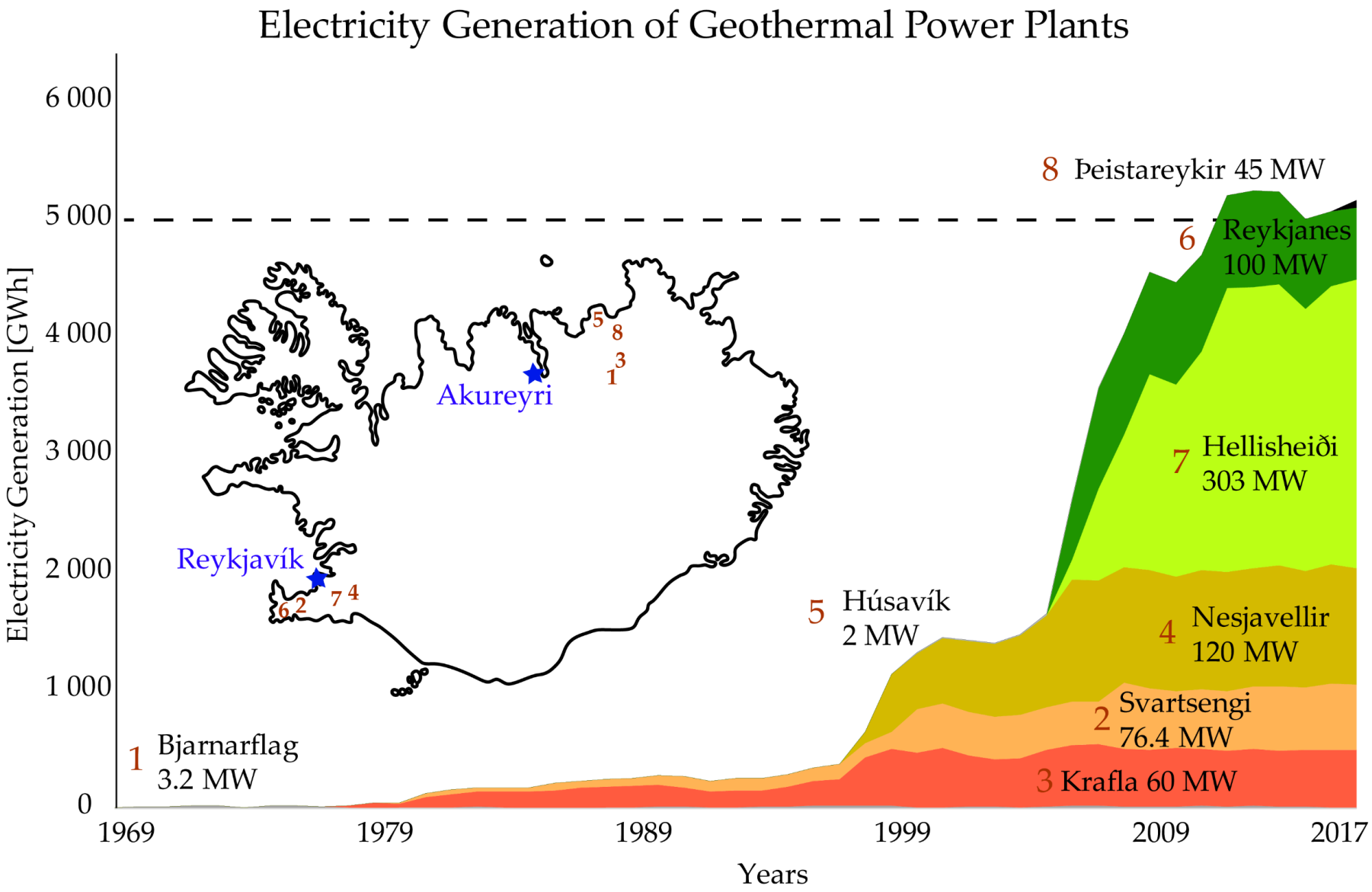


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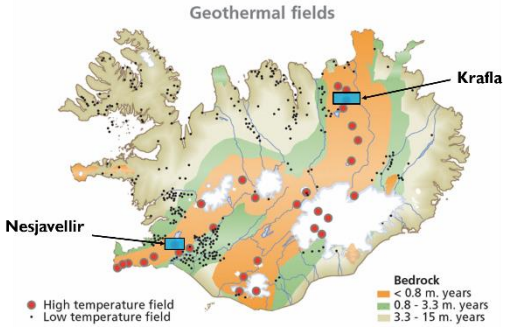
Figure in L. Lévy (2019, Ph.D thesis)

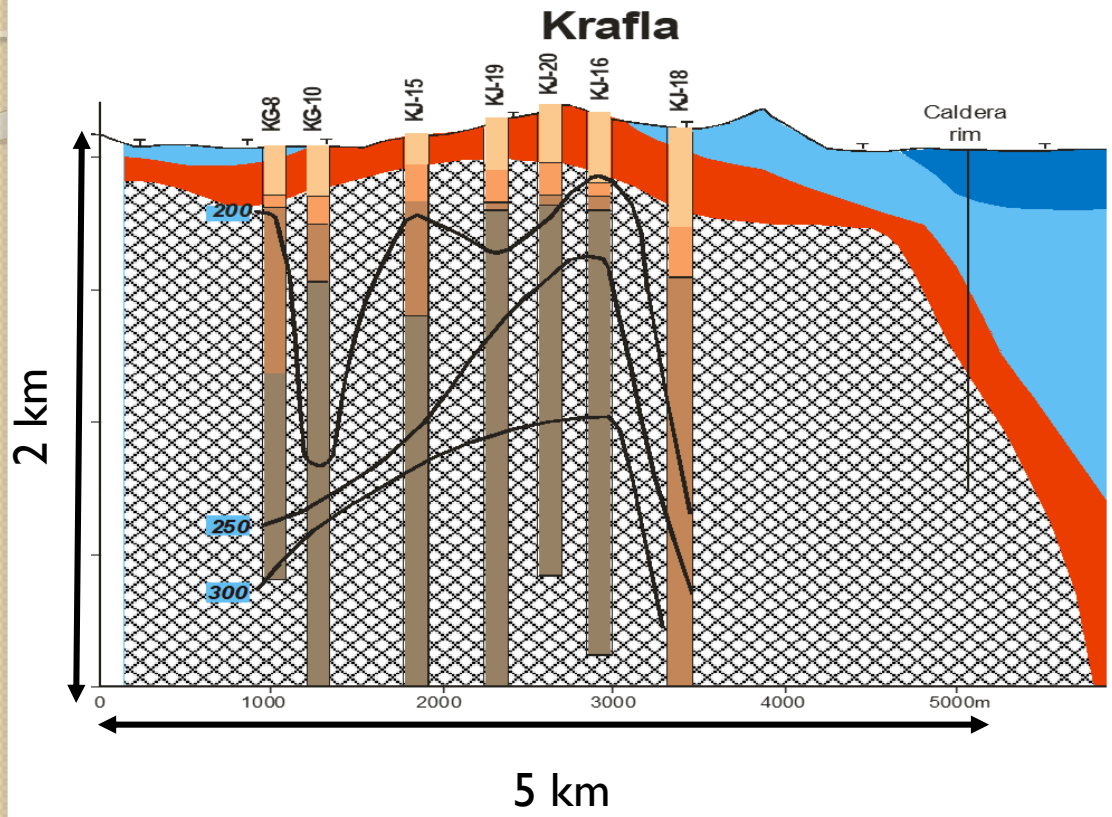
Geothermal energy in Iceland

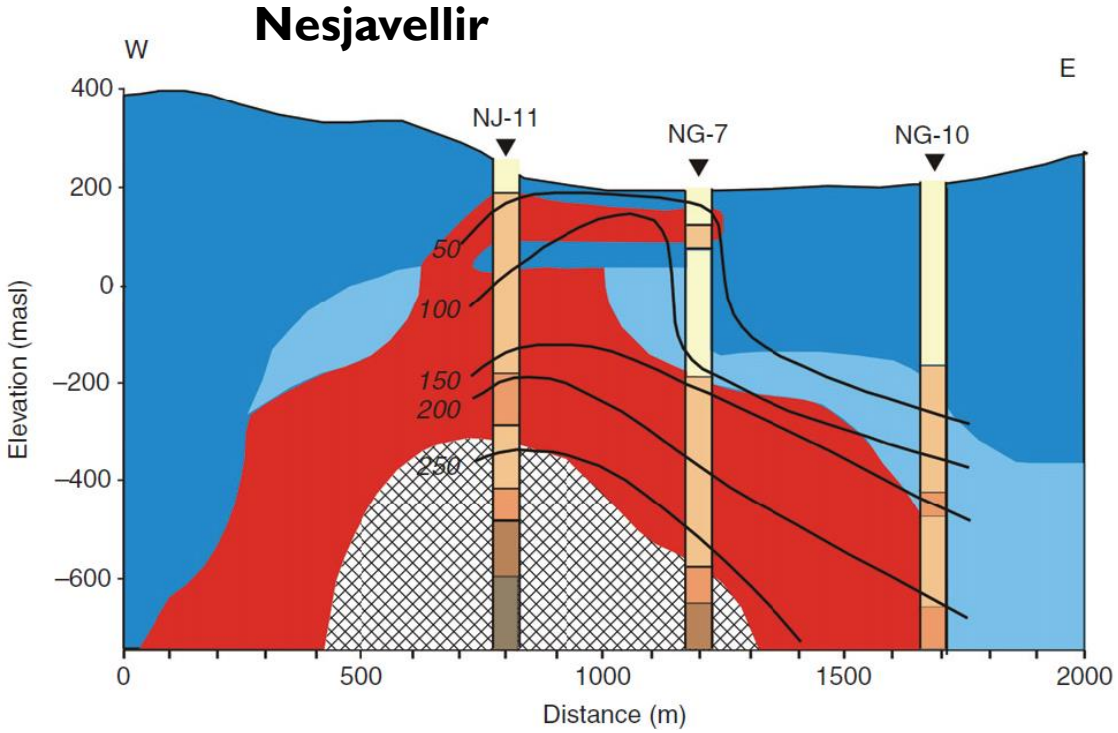
Krafla geothermal power plant (photo by L. Lévy)

ENJEUX ACTUELS DE L'EXPLORATION GEOPHYSIQUE

Geophysical exploration







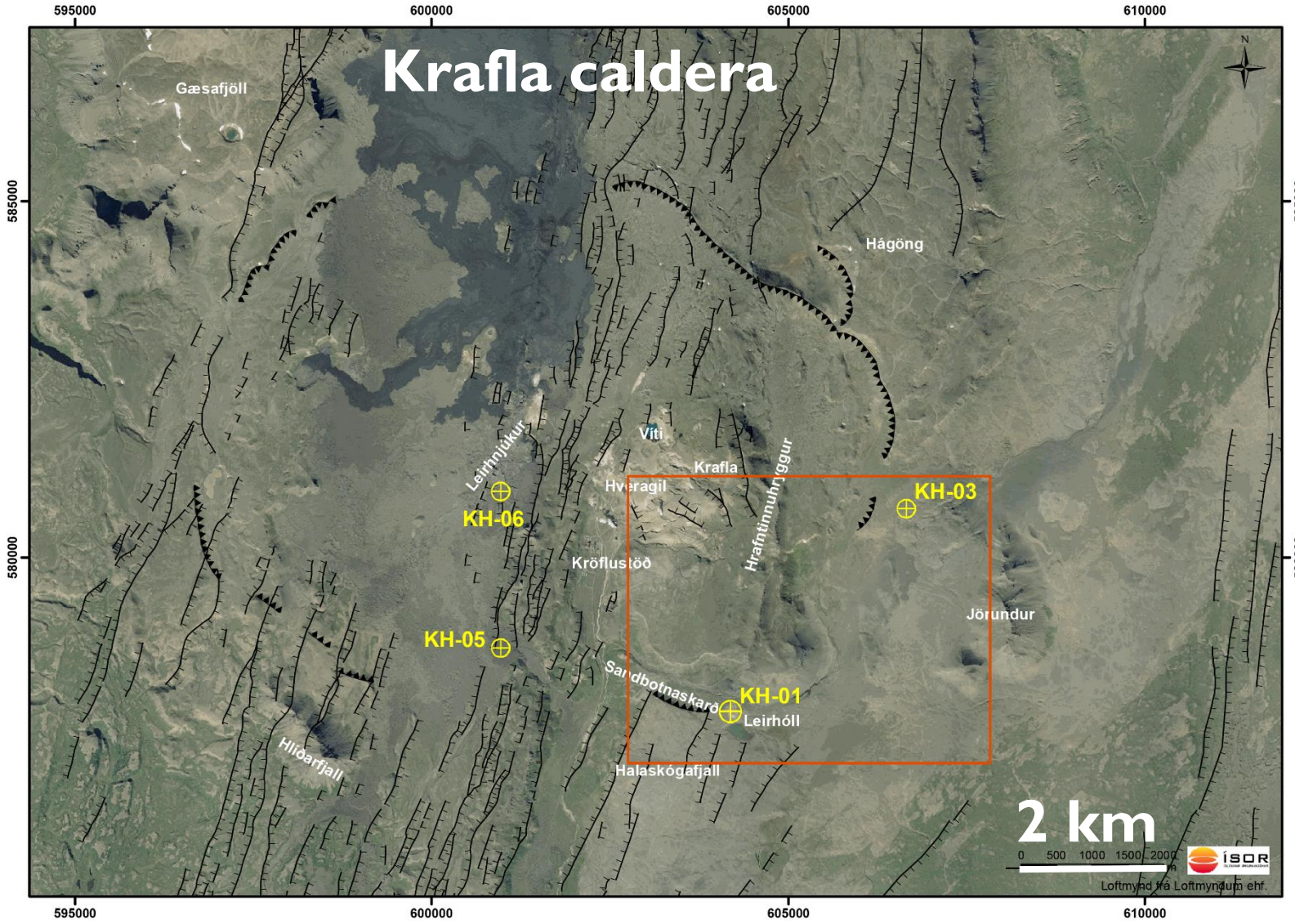
Temperature

Alteration
- Unaltered rocks
- Smectite–zeolite zone
- Mixed-layer clay zone
- Chlorite zone
- Chlorite–epidote zone

Resistivity
- >25 Ωm
- 10–25 Ωm
- 2–10 Ωm, low-resistivity cap
- High-resistivity core

Arnason et al., 1987
Arnason et al., 2008

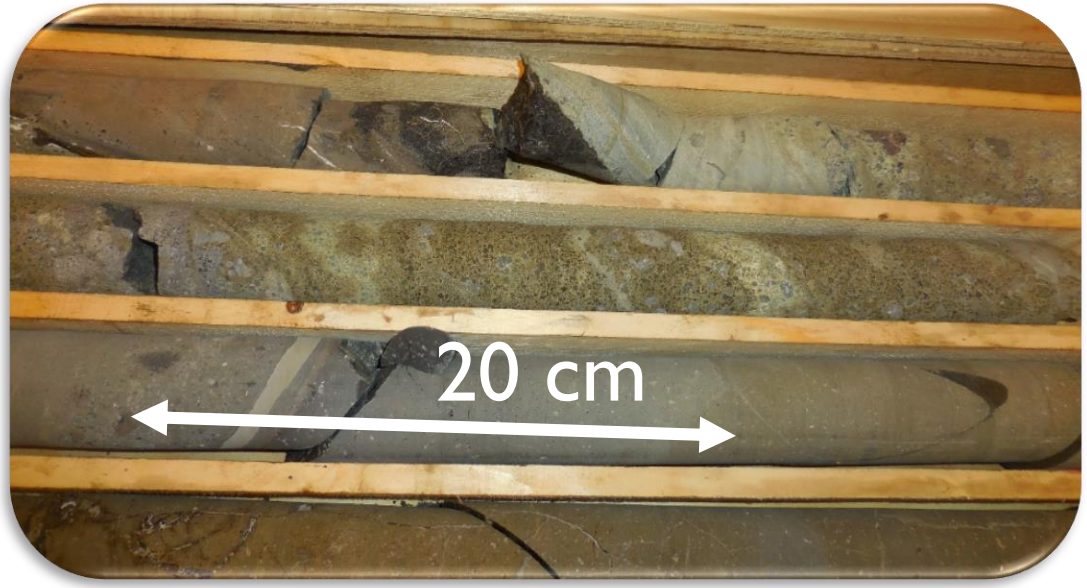
Krafla volcano

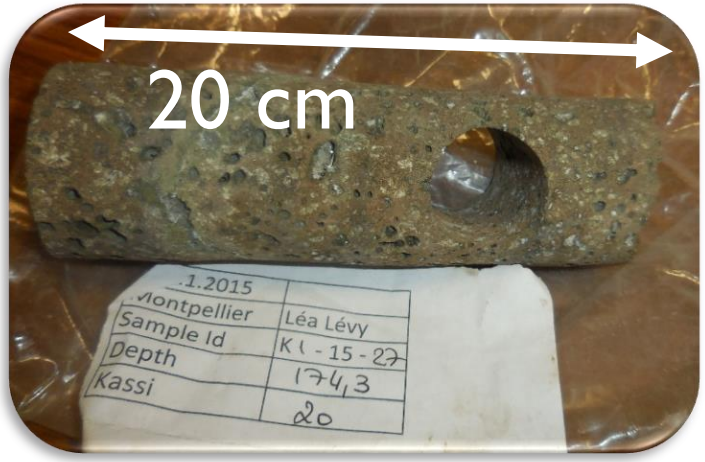


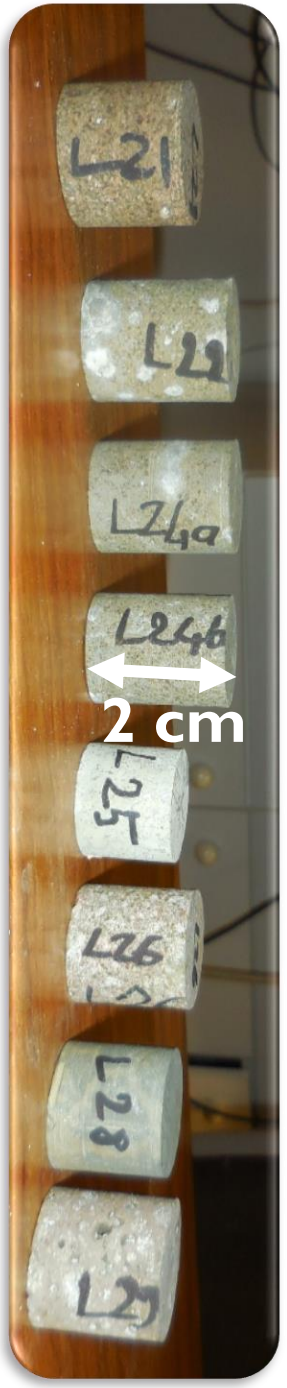
Field measurements

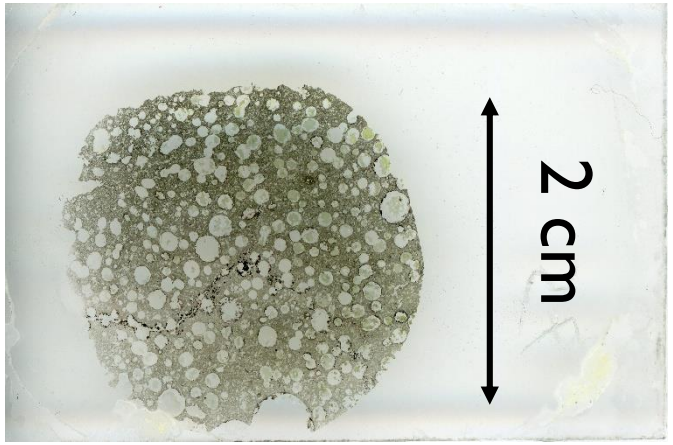
Cored boreholes for samples and logging

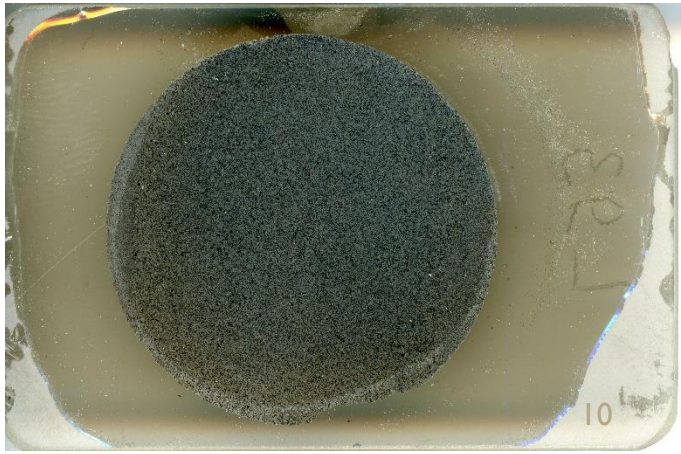
Laboratory samples





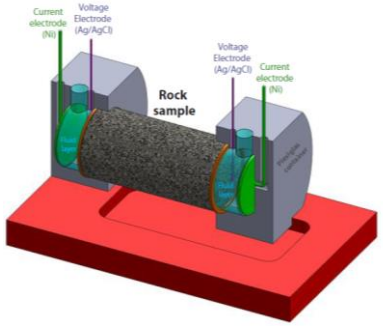


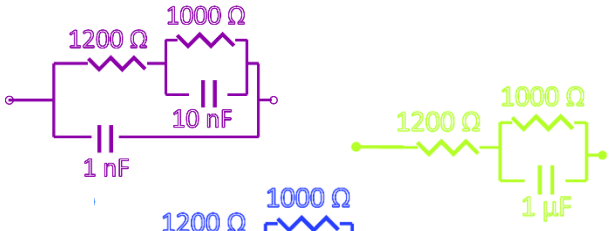


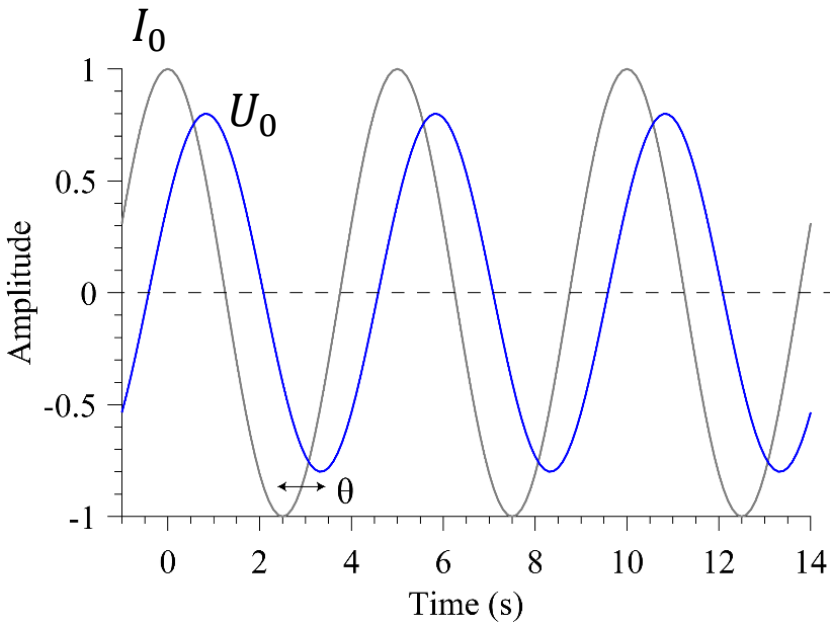


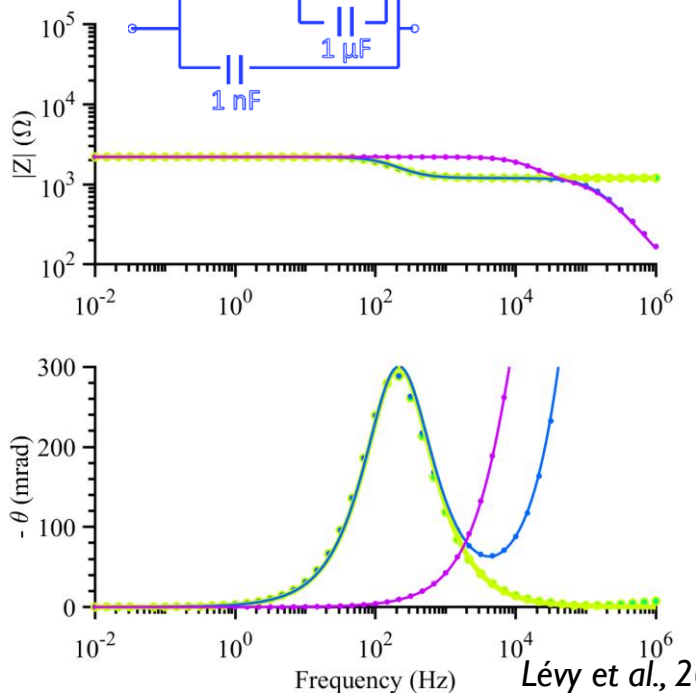
Electrical impedance spectroscopy

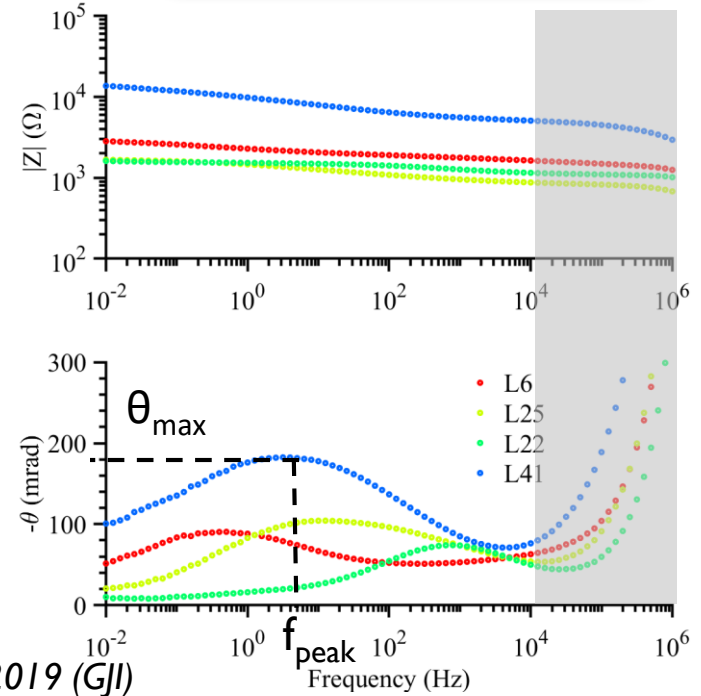
$$Z^* = |Z|e^{i\theta}$$





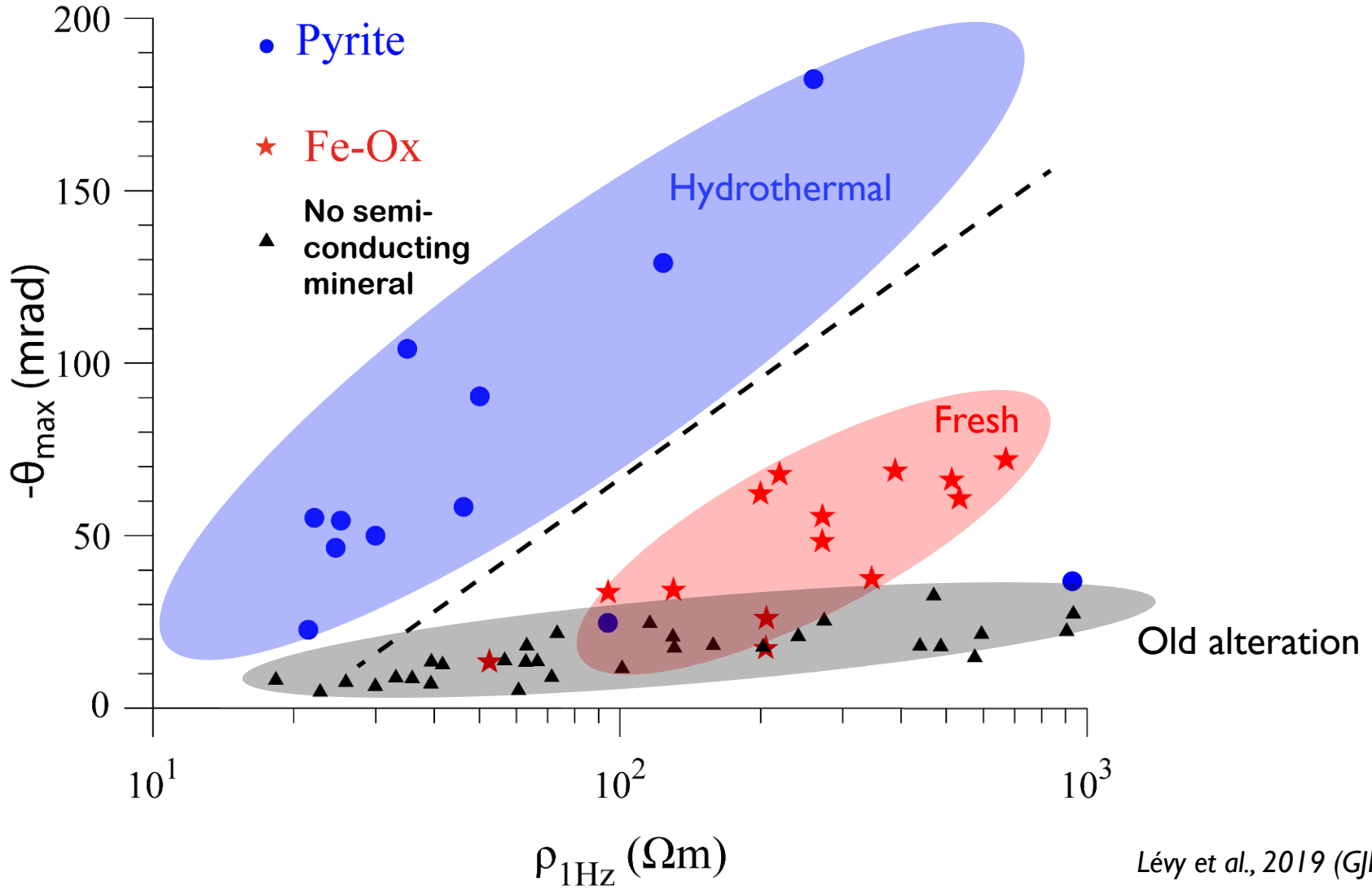






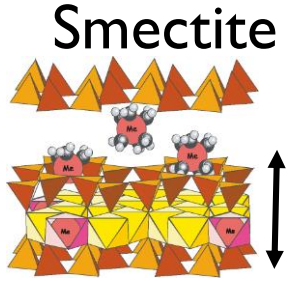
Lévy et al., 2019 (GJI)

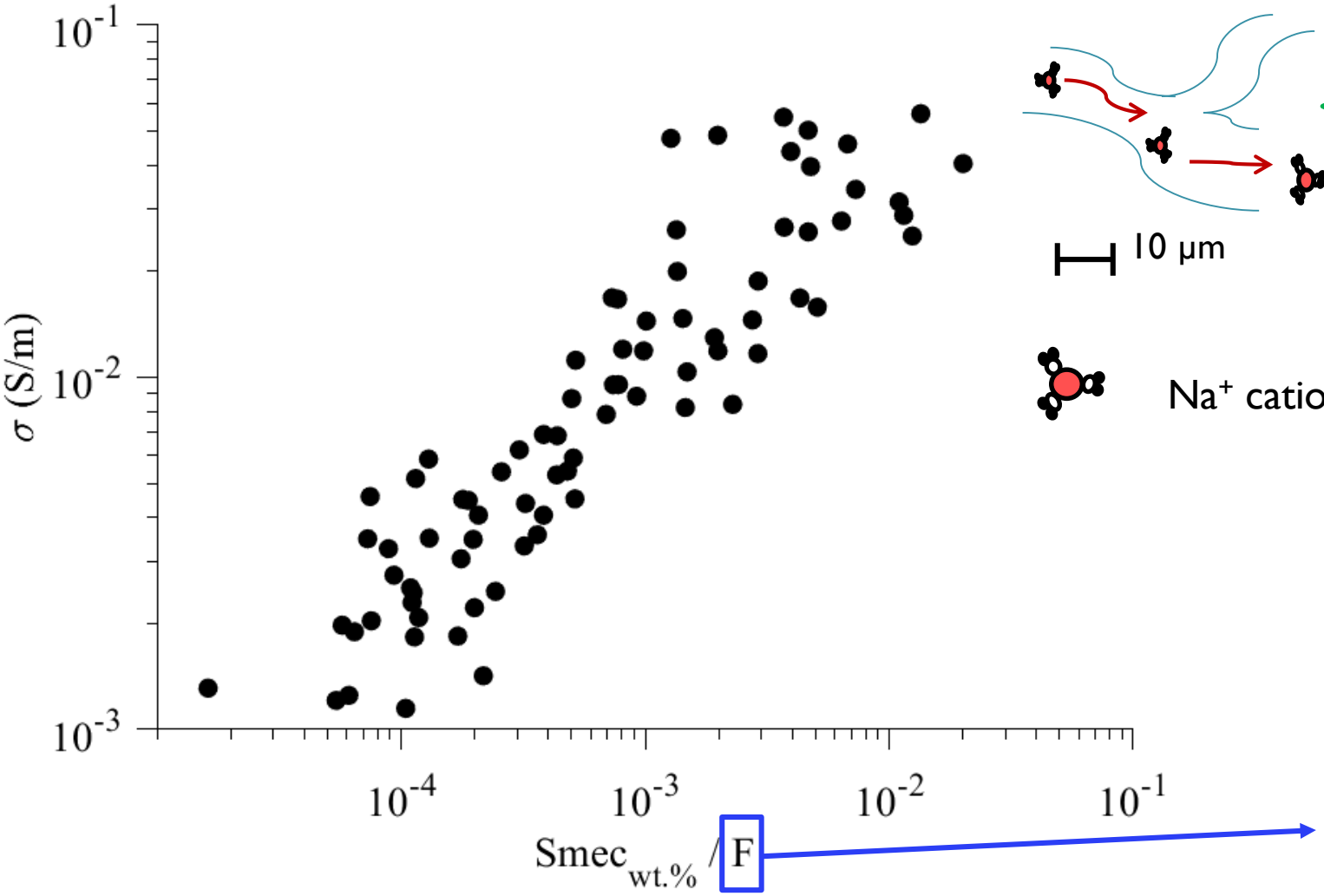
Polarization by semi-conducting minerals

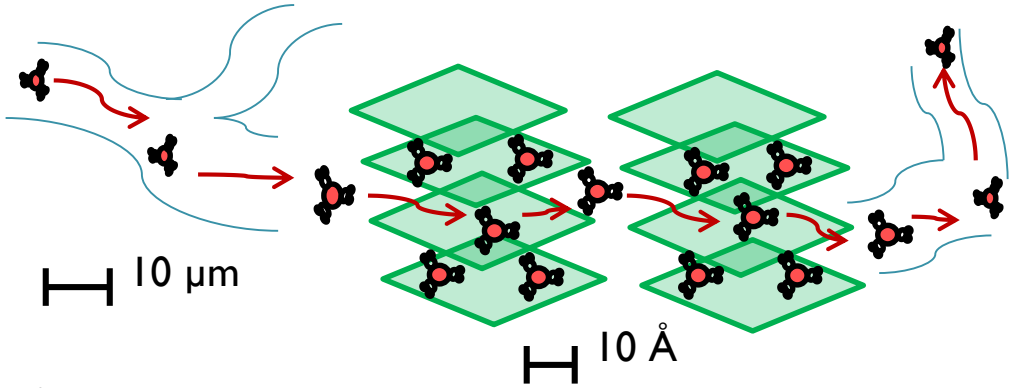


Lévy et al., 2019 (GJI)

Conduction by smectite

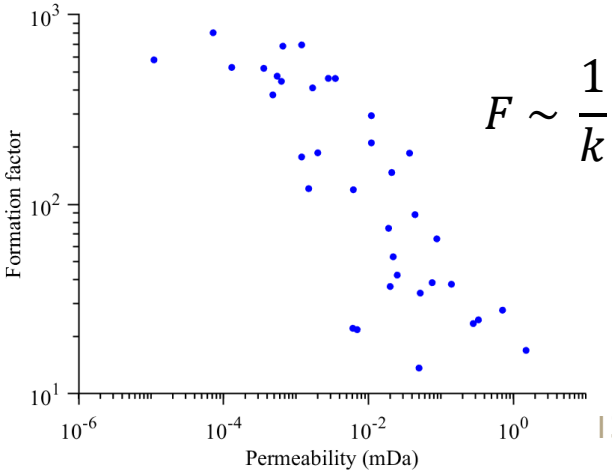






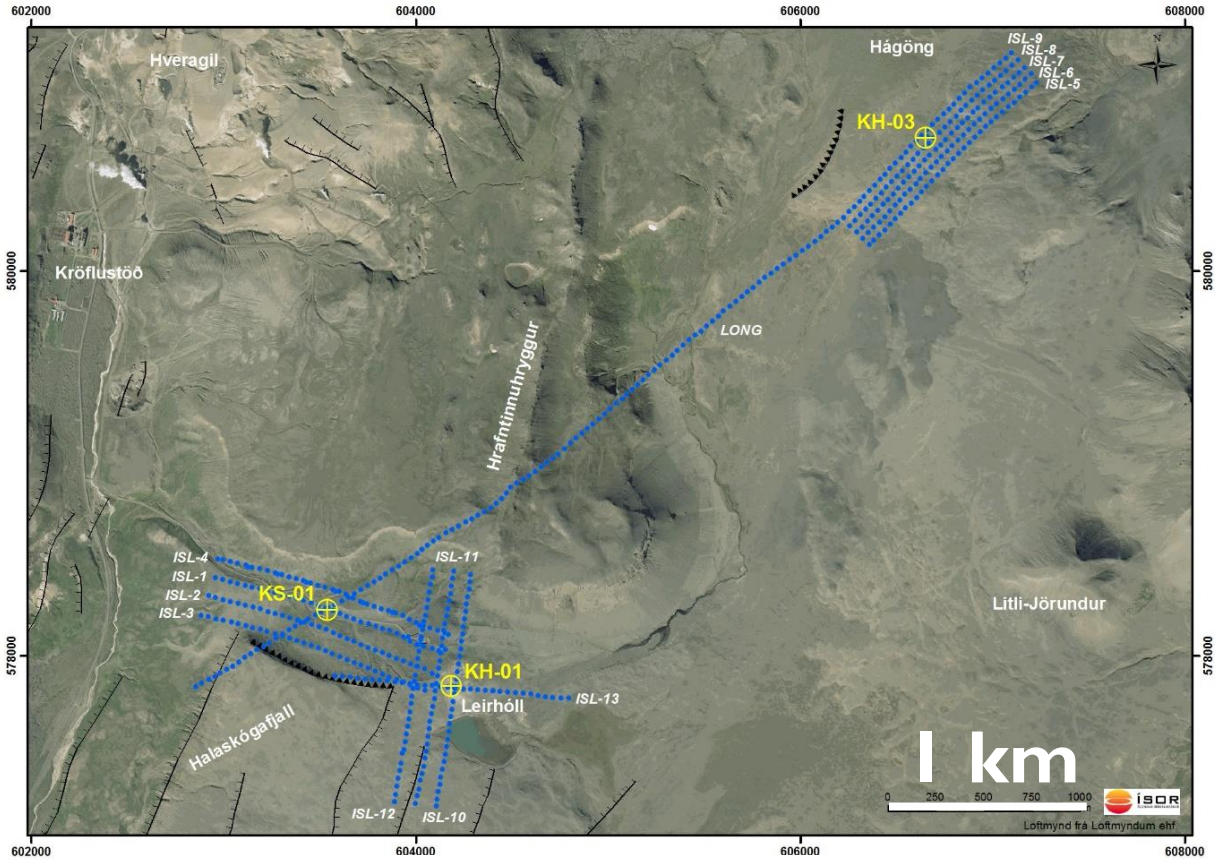
Na^+ cation — Ionic electrical conduction

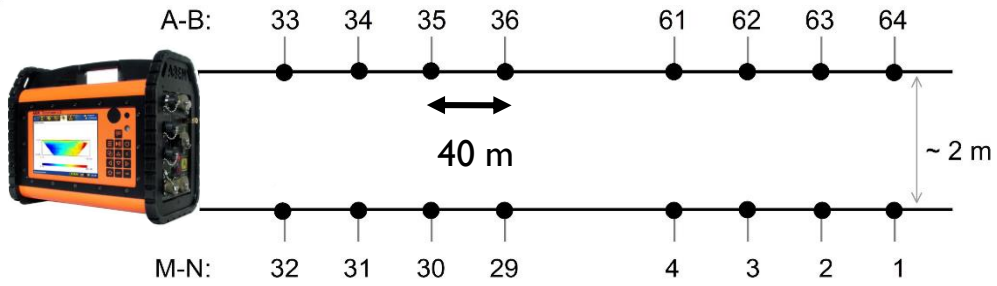
Lévy et al., 2018 (GJI)

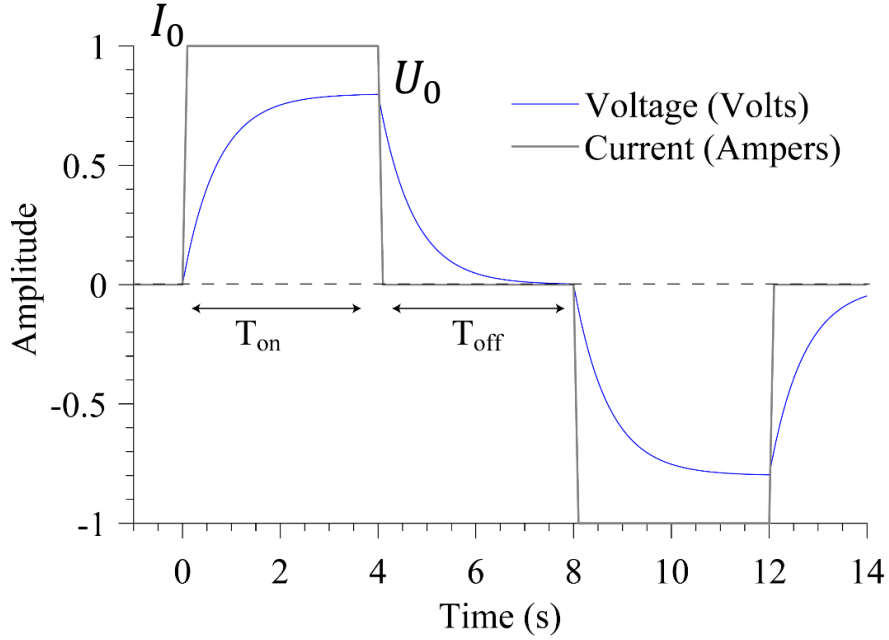


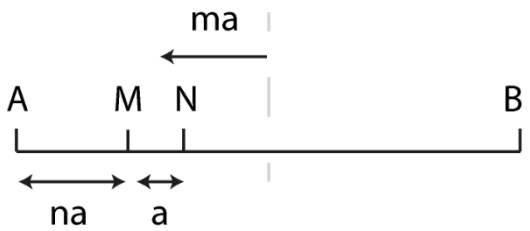
$$F \sim \frac{1}{k}$$

Complex resistivity tomography





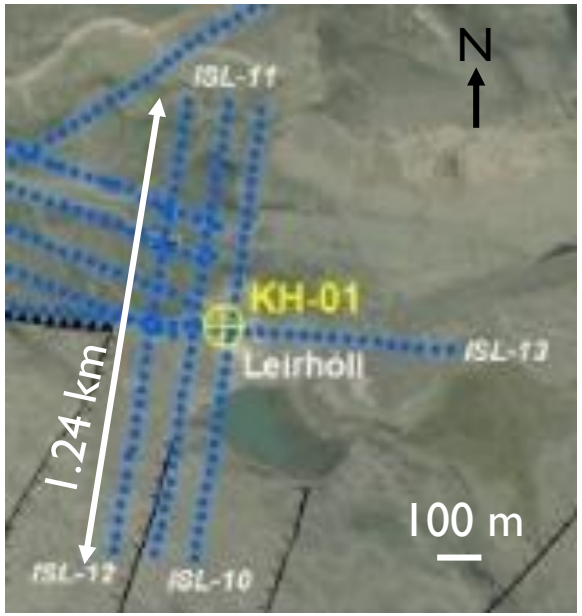


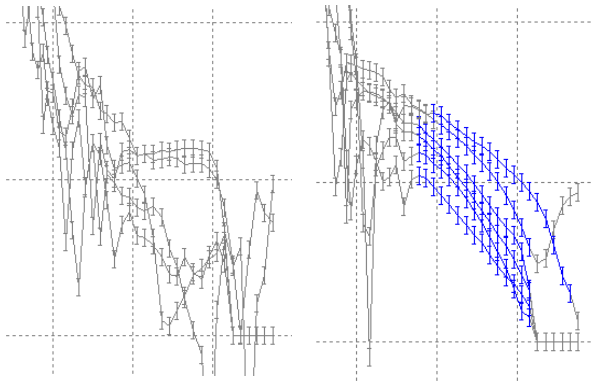


Multi-gradient array

Krafla field campaign

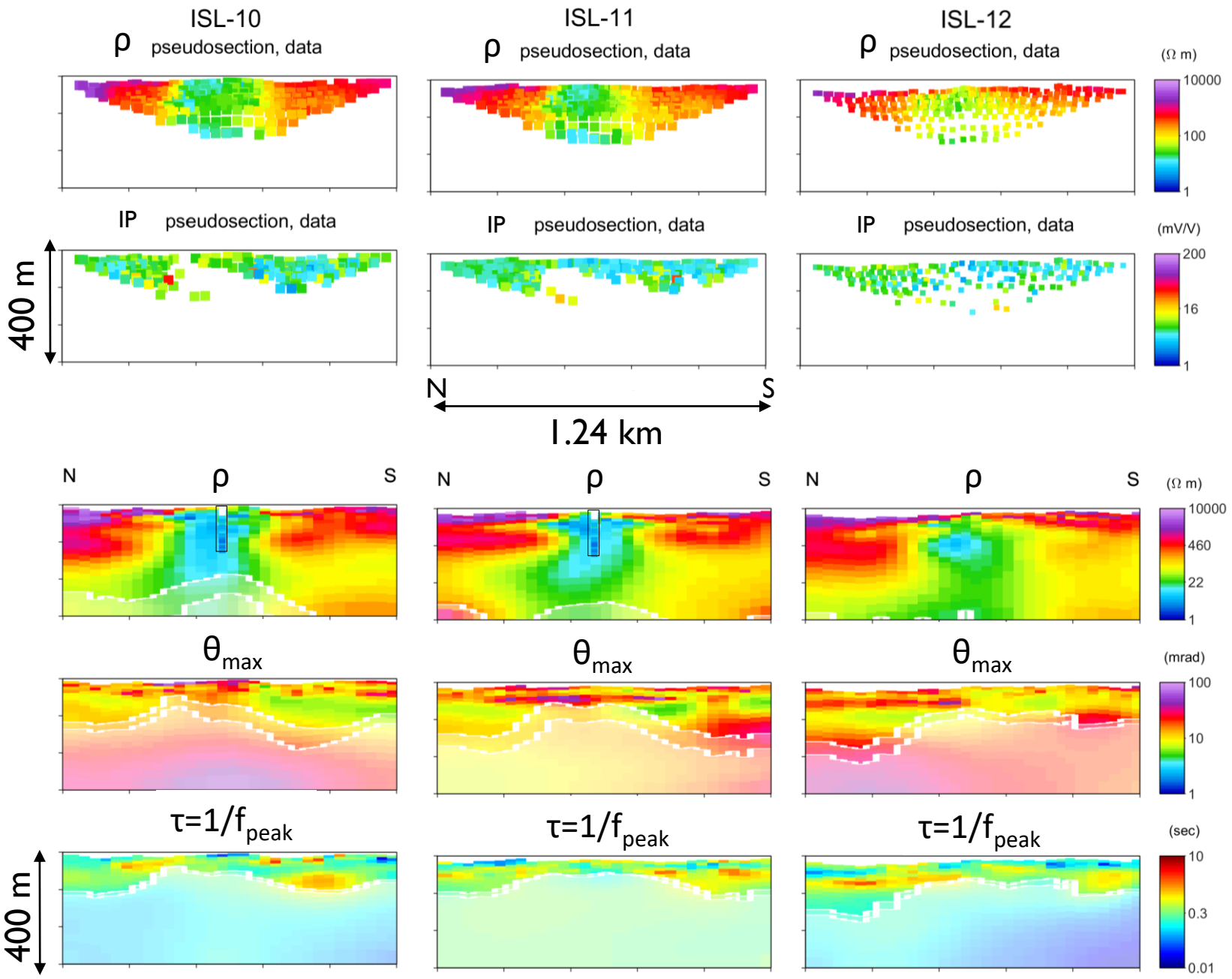
2D inversion



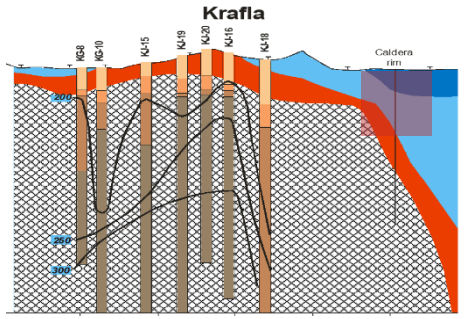


Data inverted

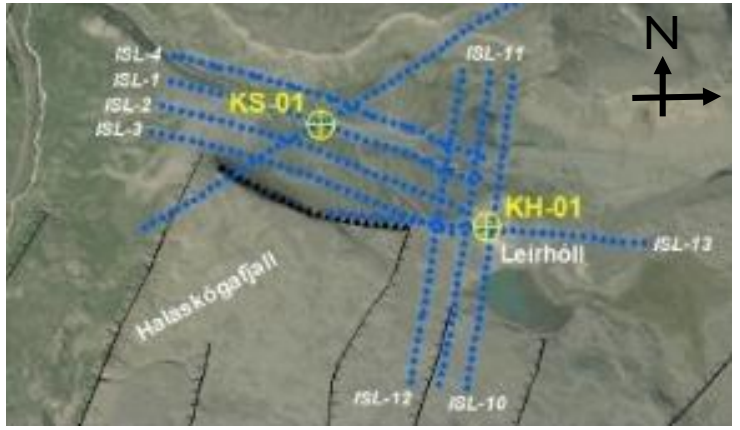
Data filtered out

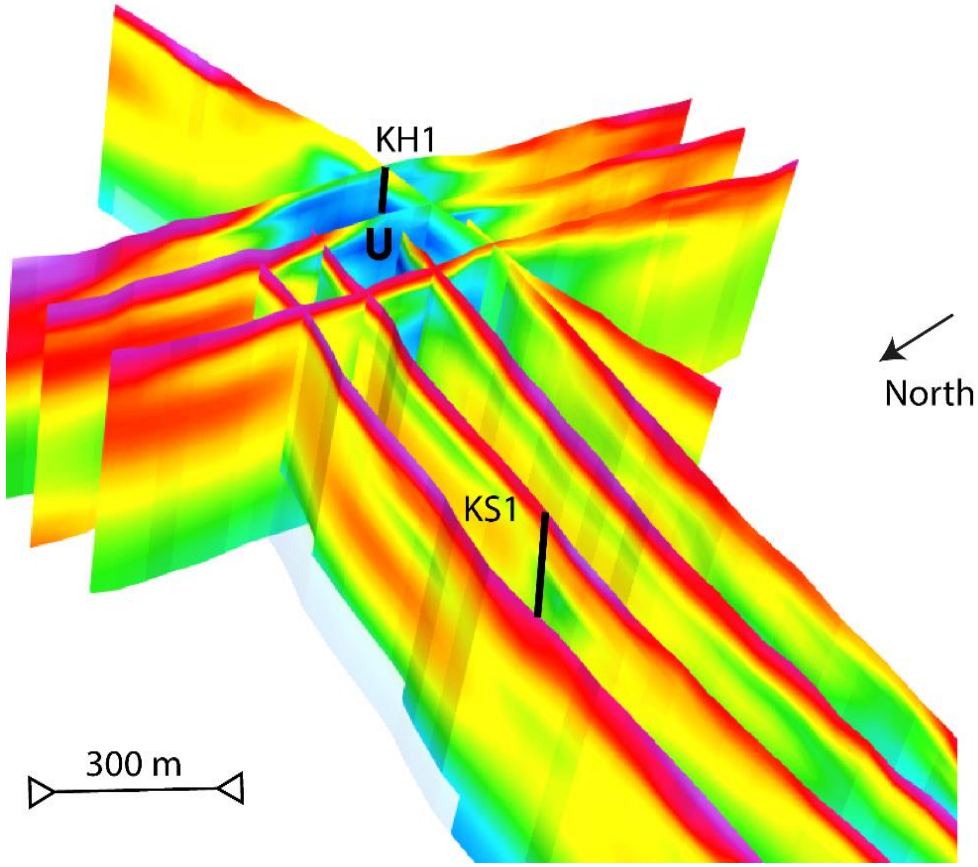


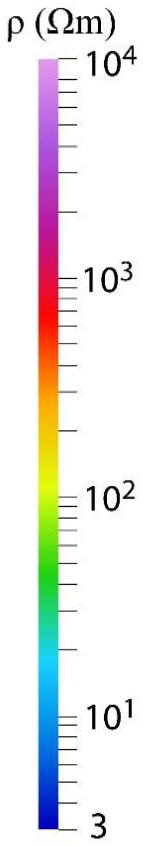
Interpretation of inversion models

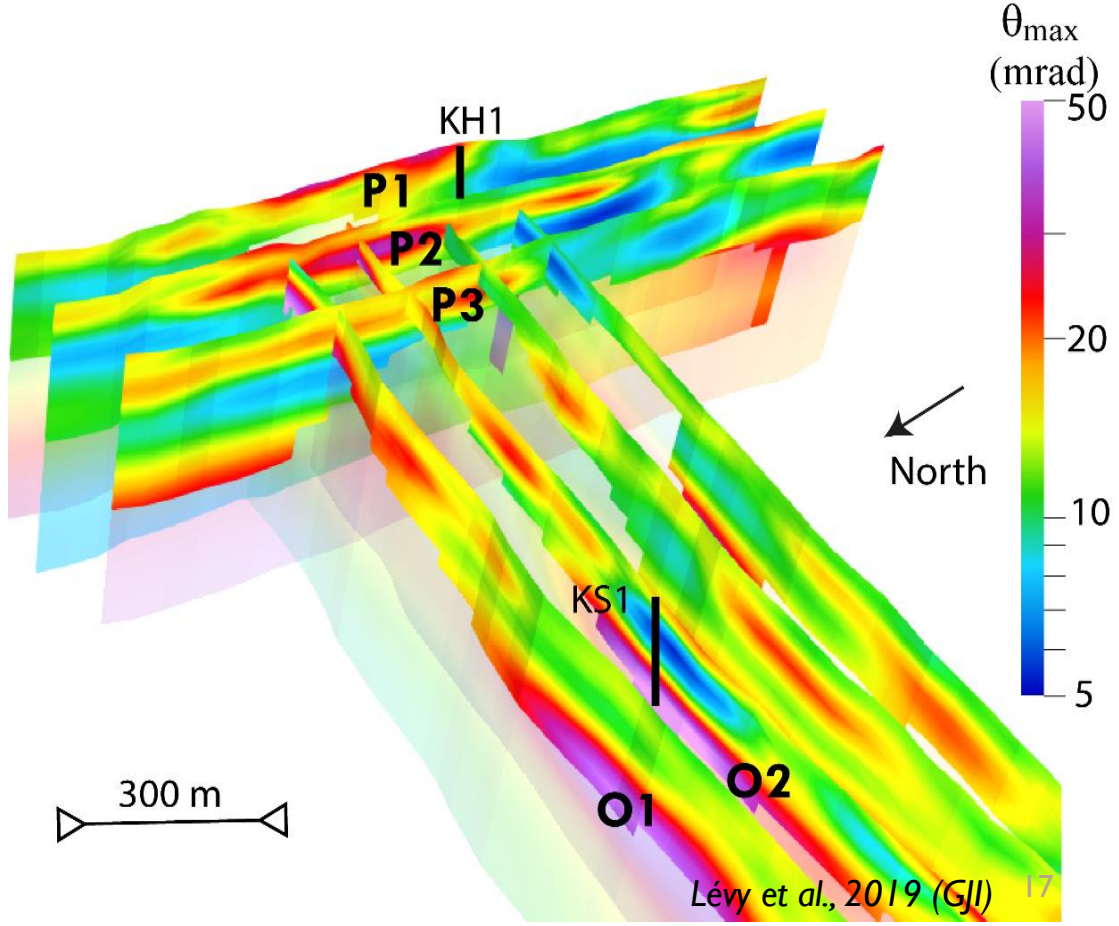


U = up-flow zone, smectite
P1-P3 = pyrite
O1-O2 = oxides



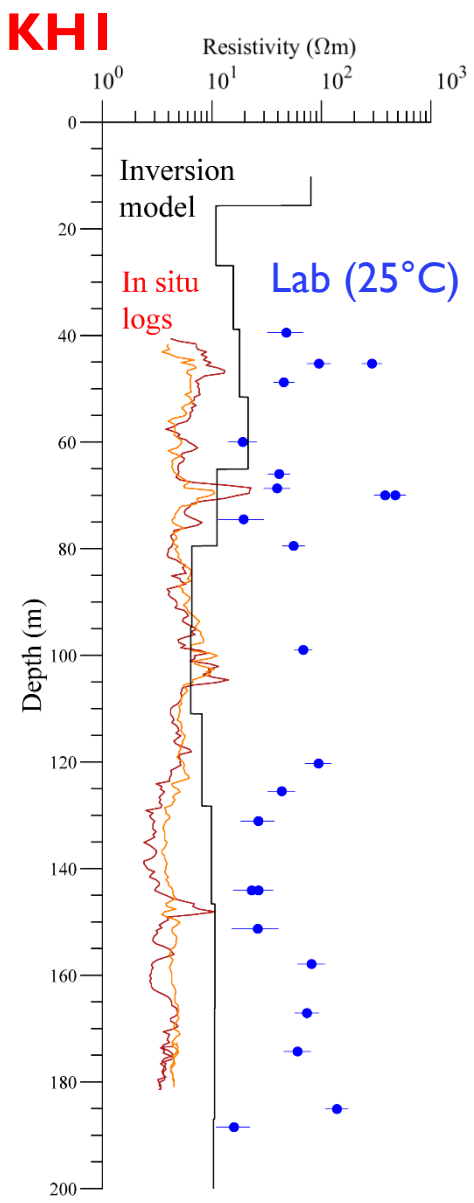


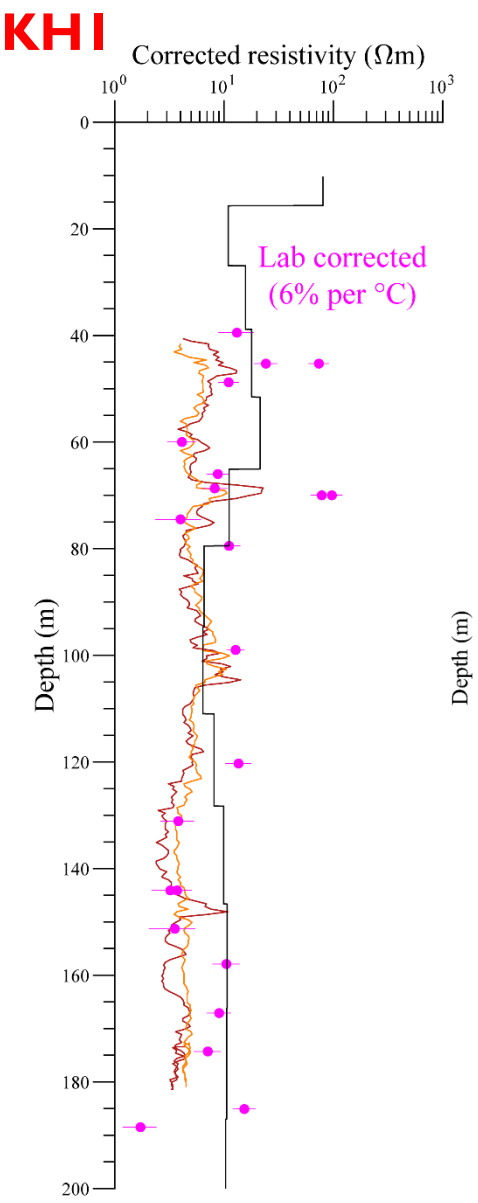


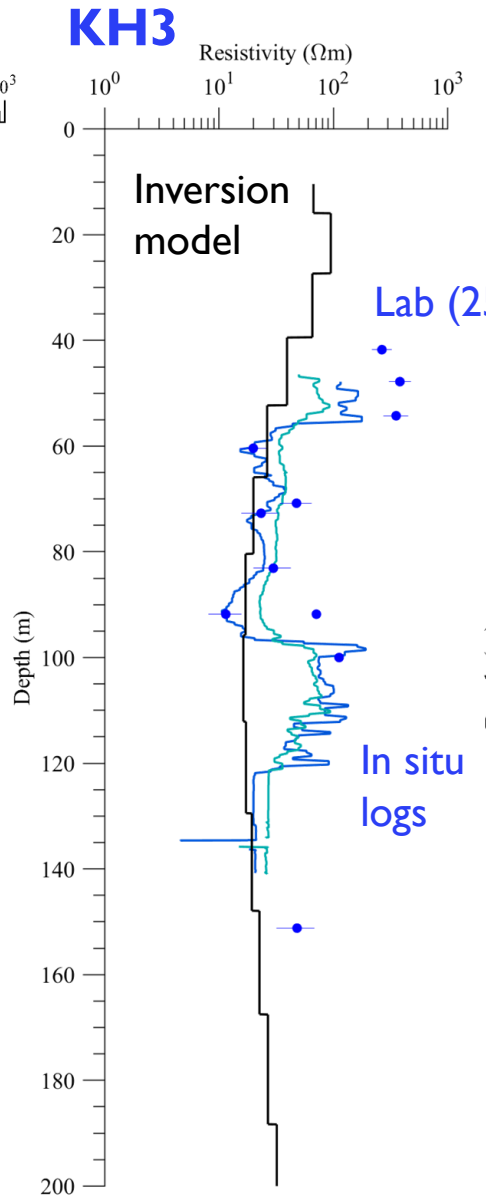


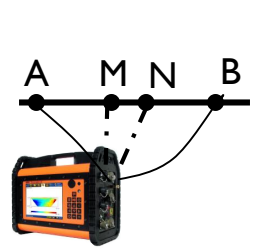
Lévy et al., 2019 (GJI)

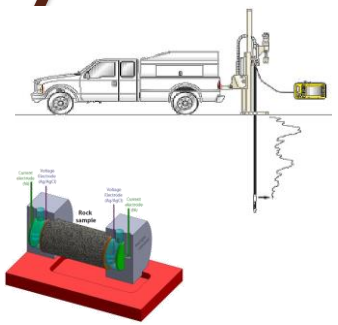
Comparison inversion-logging-laboratory

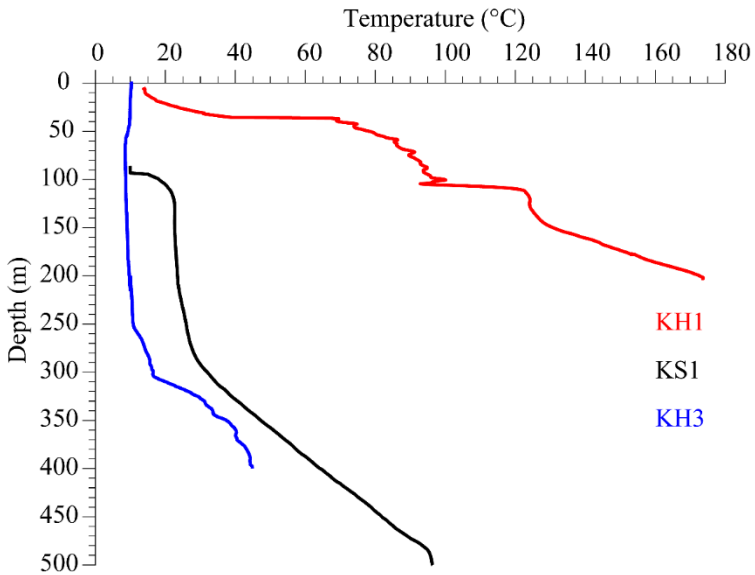






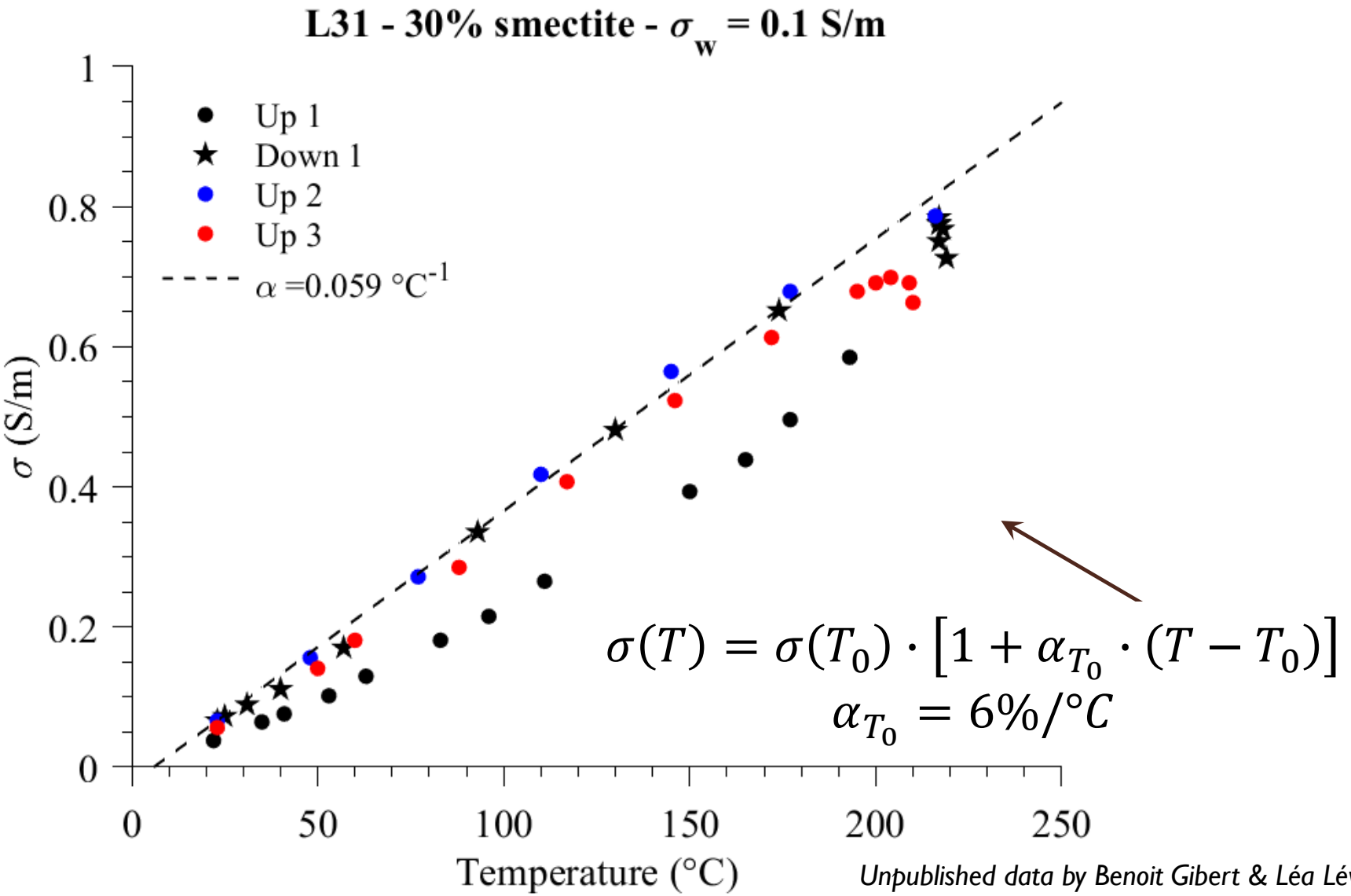






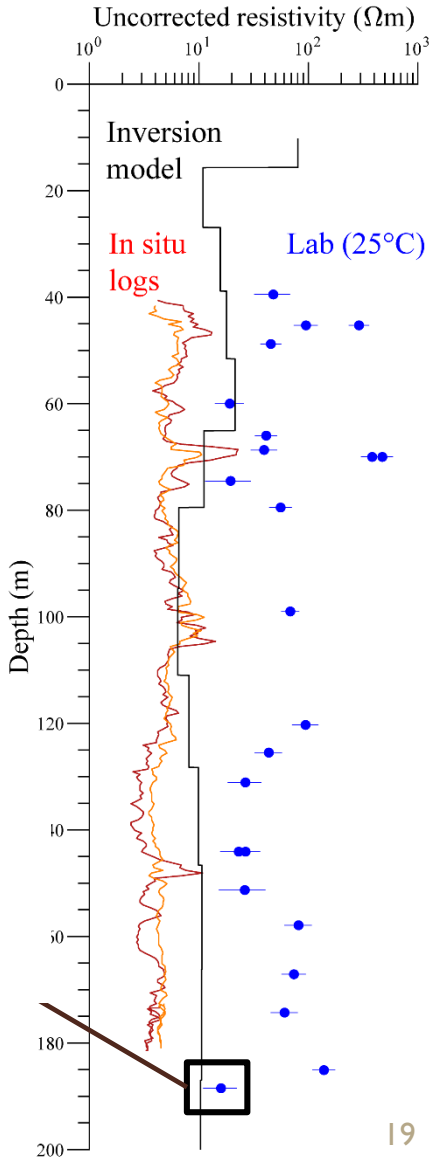
Lévy et al., 2019 (GJI)

Temperature-dependence of conductivity



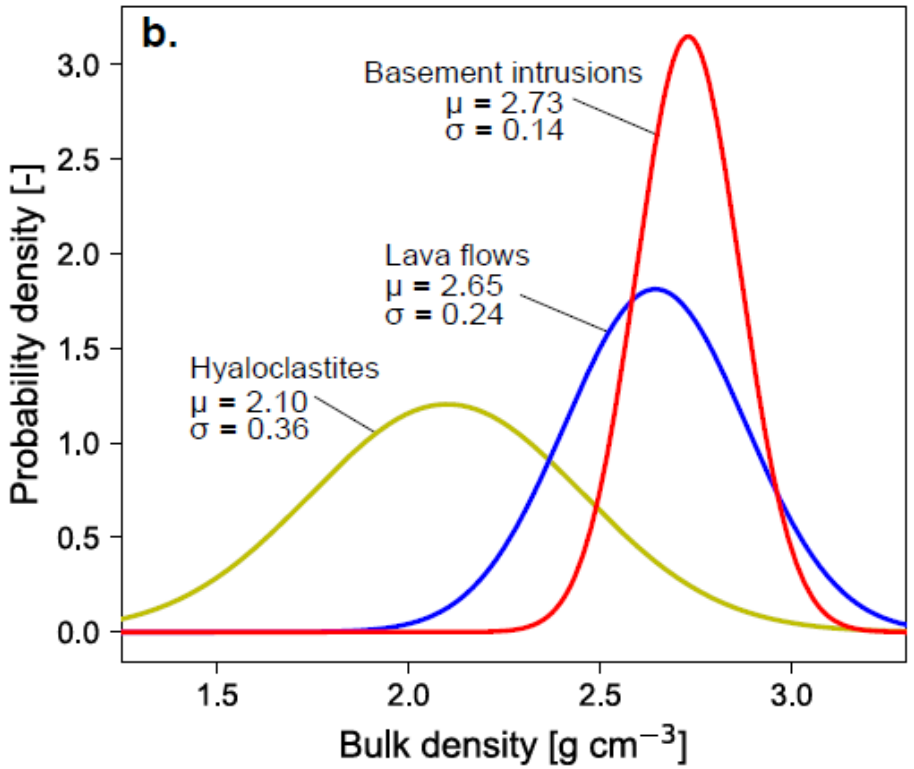
$$\sigma(T) = \sigma(T_0) \cdot \left[1 + \alpha_{T_0} \cdot (T - T_0)\right]$$

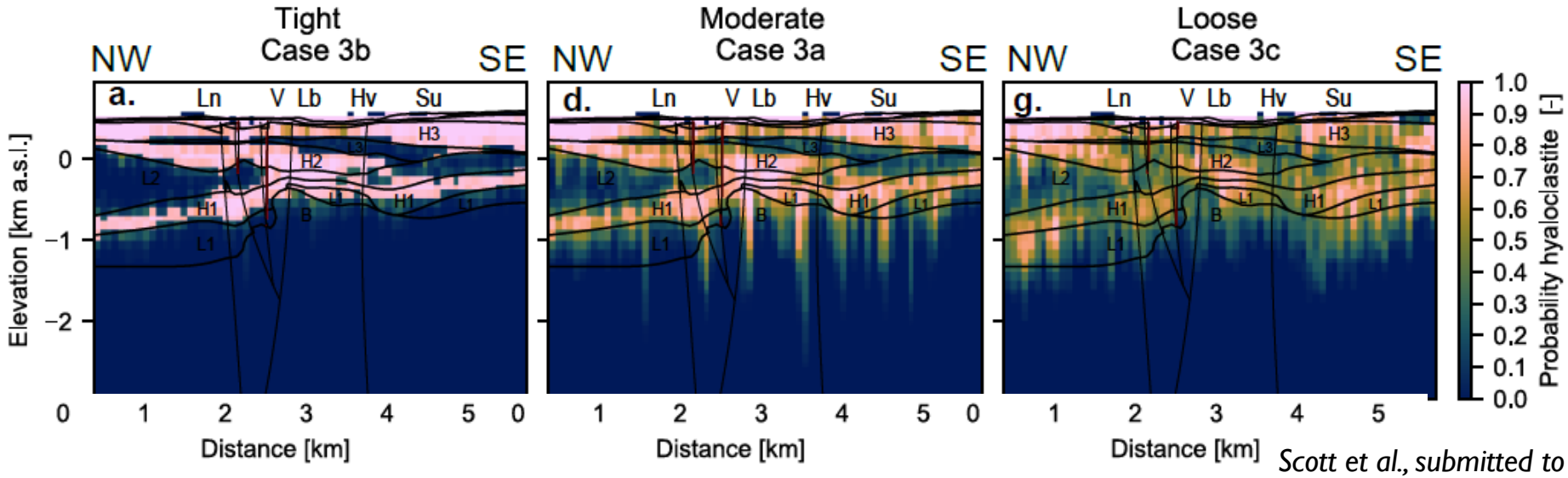
$$\alpha_{T_0} = 6\%/°C$$



Unpublished data by Benoit Gibert & Léa Lévy

Bayesian interpretation of density inversion

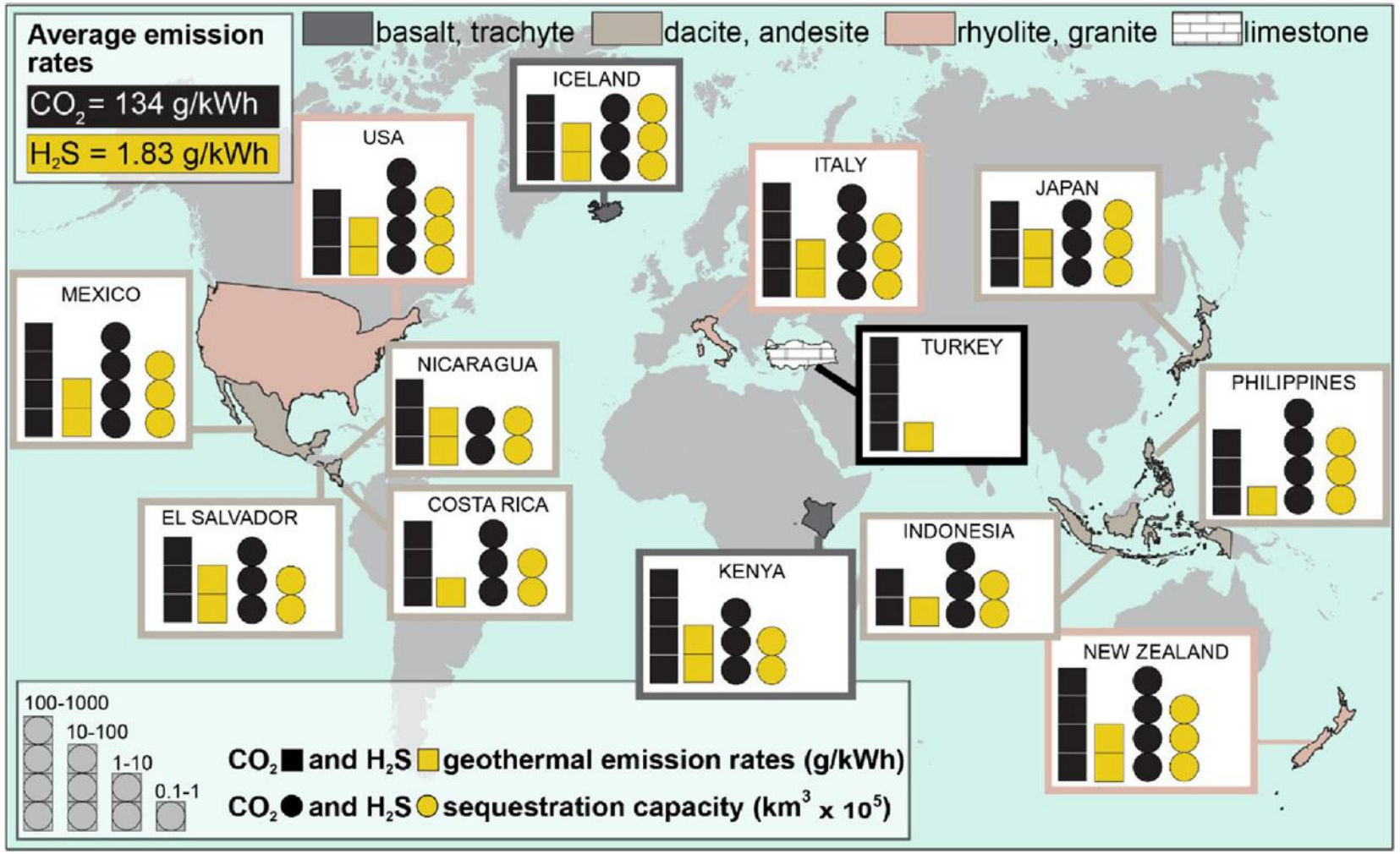




Scott et al., submitted to Geothermal Energy

GESTION DES ÉMISSIONS DE CO_2 ET H_2S (AVAL)

World emissions and storage capacity

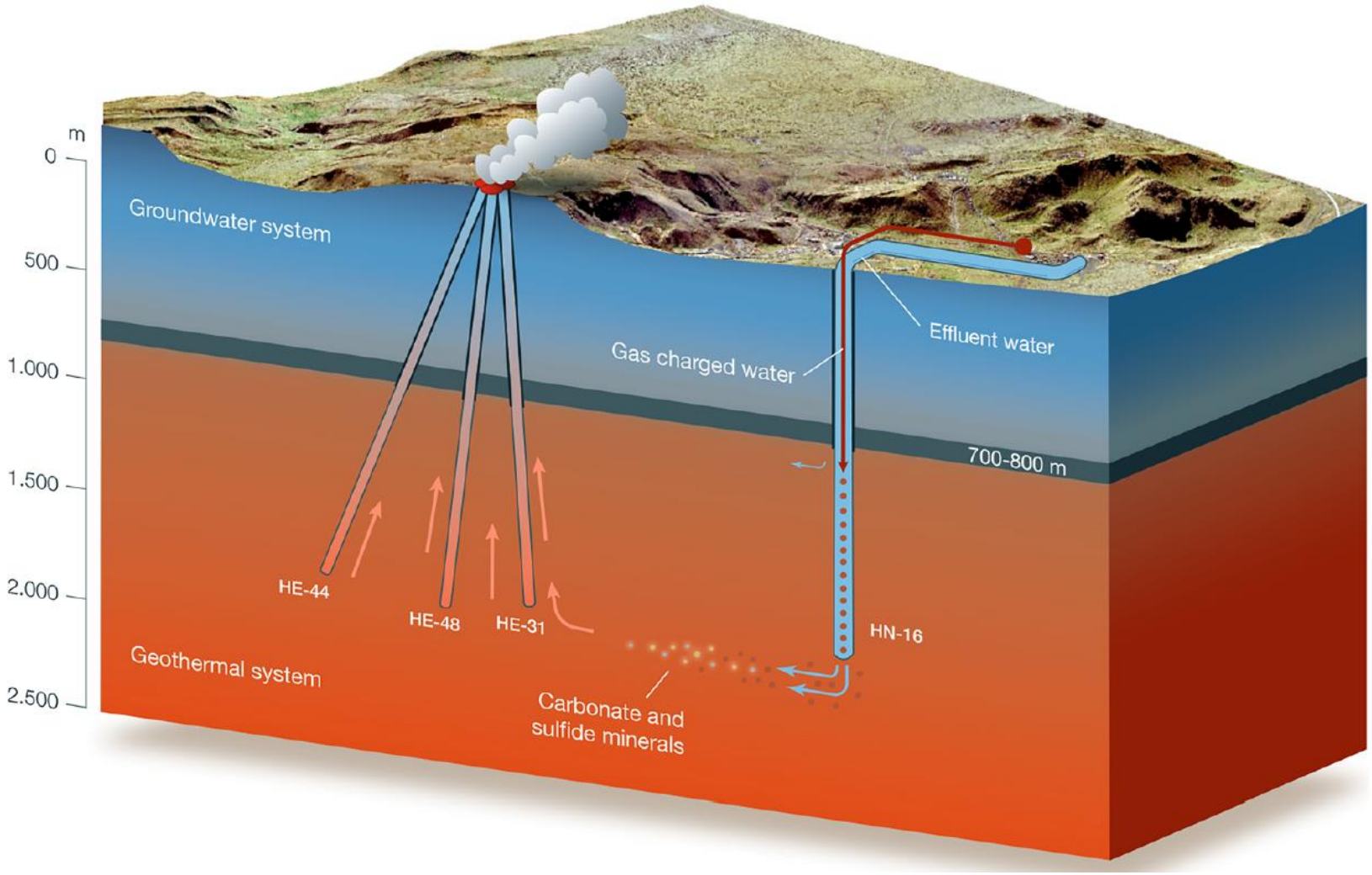


- CO_2 emissions from other electricity sources
  - Coal : 960 g/kWh
  - Gas : 360 g/kWh

(*International Energy Agency, 2019*)

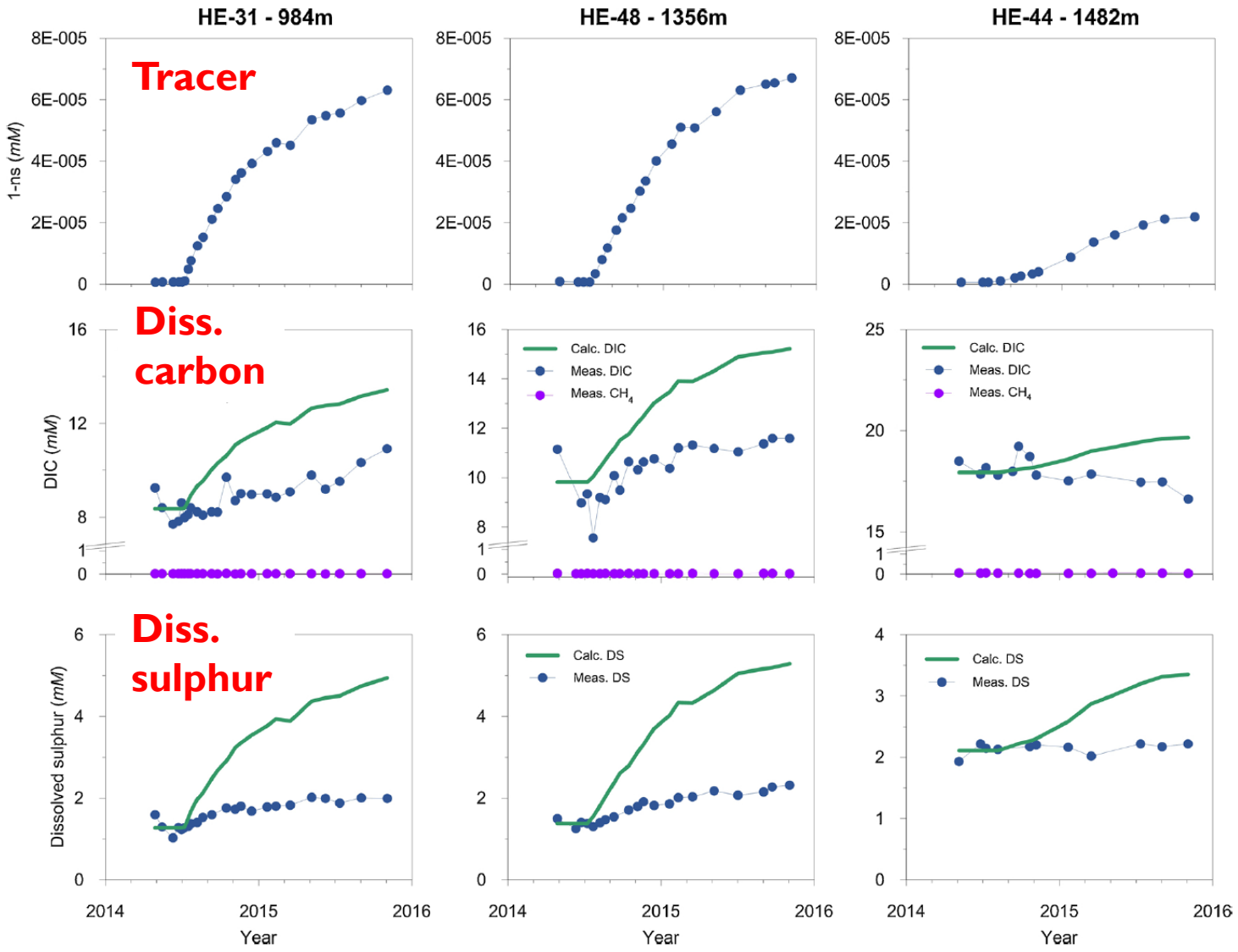
Marieni et al., 2018

CarbFix and SulFix projects



Gunnarsson et al., 2018

Geochemical monitoring



- 3 monitoring wells
- 2 years of monitoring
- Tracer monitoring
- Carbon & Sulphur monitoring << predictions by dilution

Gunnarsson et al., 2018

Geophysical monitoring

- Transformation H2S + basalt → pyrite + smectite
- Time-lapse Resistivity + Induced Polarization
- New project
  - Small scale injection at Nesjavellir
  - 5 electromagnetic / geo-electrical methods combined
  - Issues expected
    - Electromagnetic coupling: power plant, pipelines
    - Will the resolution be sufficient? Reactive transport modelling can help!

Merci !