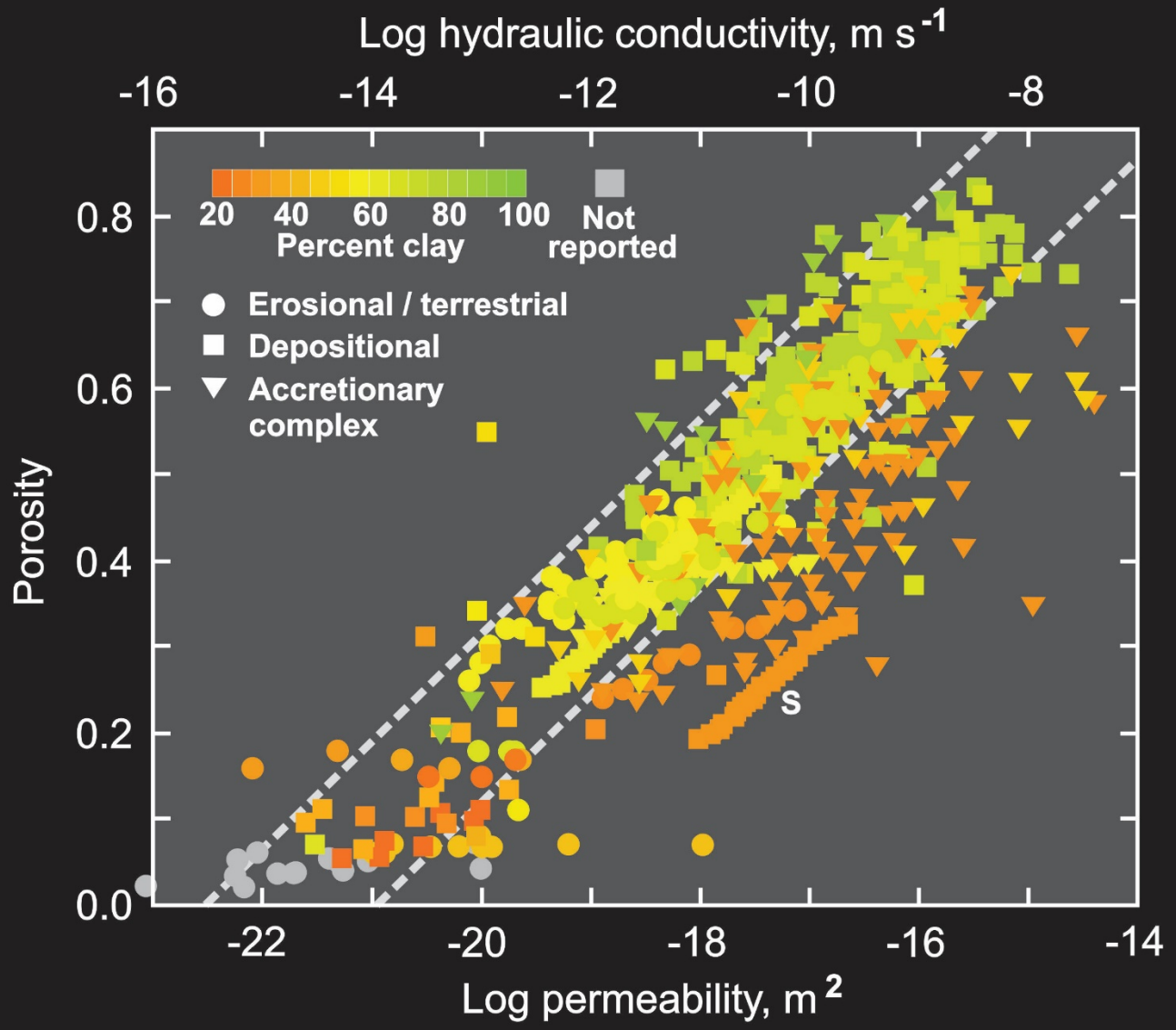
Argillaceous formations as barriers to flow: Knowns and unknowns

Chris Neuzil

Argillaceous formations: Knowns

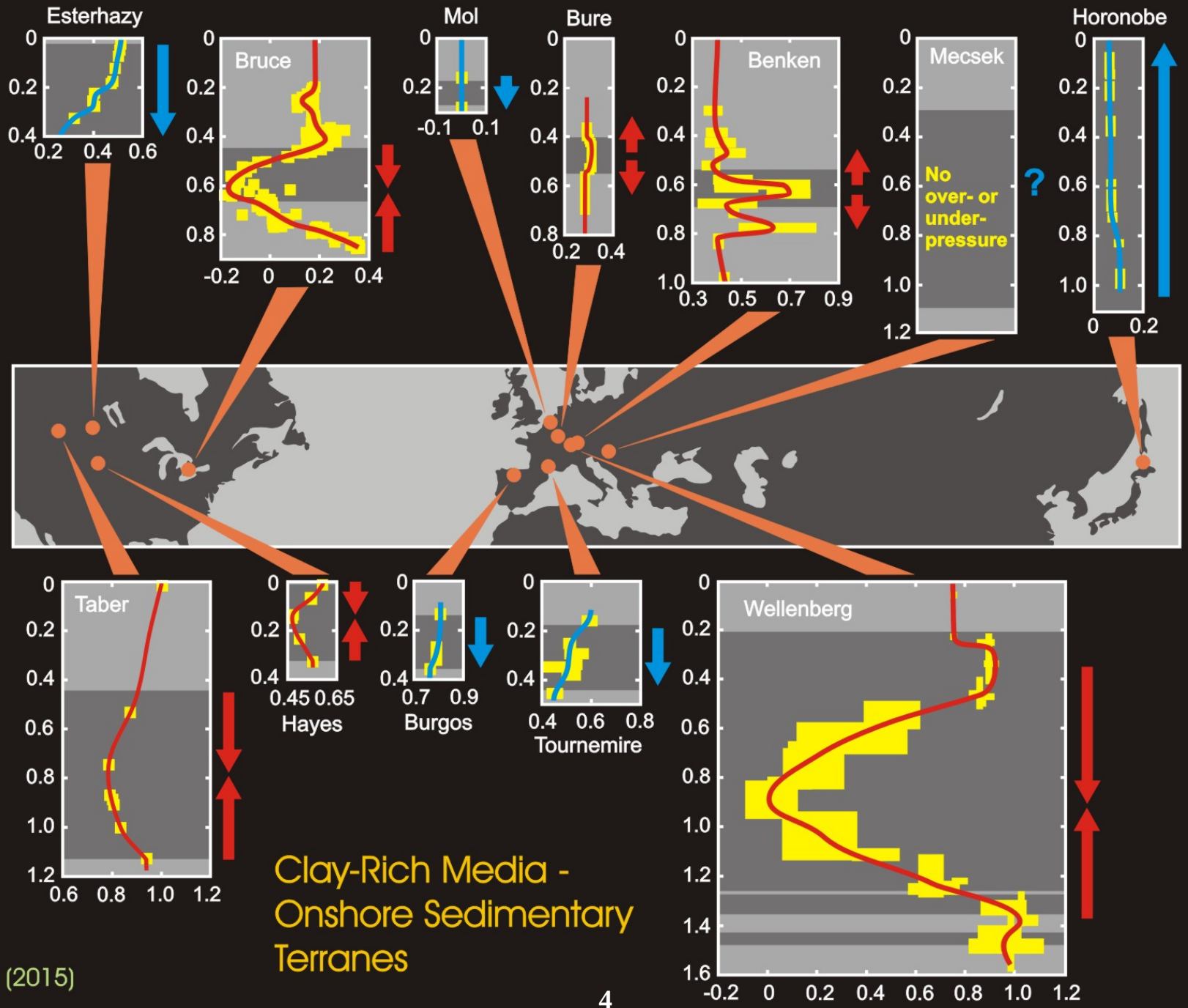
- Low matrix permeability
- Apparent pressure anomalies surprisingly common
- Appear to be hydrodynamic responses to forcing
- Plausible forcing can *usually* be identified
- Imply matrix permeability at local formation scale

Clay and Shale Matrix Permeability



Various sources

Neuzil AREPS (2019)


Esterhazy
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No over- or under-pressure
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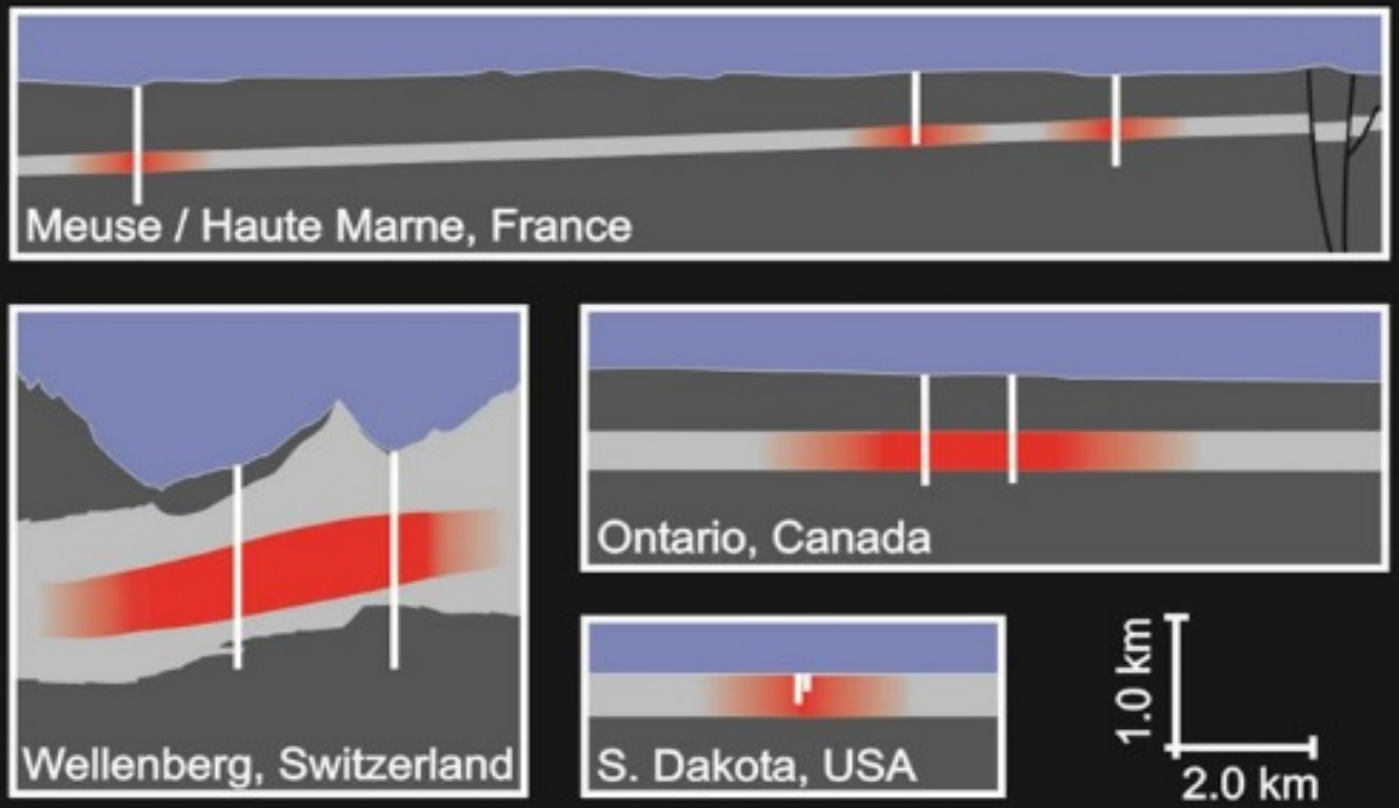
Clay-Rich Media - Onshore Sedimentary Terranes

Neuzil (2015)

Anomalies Defined by Multiple Boreholes



Gonçalvès et al. (2004)
NAGRA (2002)
Intera Eng. Ltd. (2011)
Neuzil (1993)

Steady forcing model
Anomaly present when

$$\frac{|\Gamma|\,\ell}{K} \geq 1$$

where K is hydraulic conductivity (L / T)
ℓ is formation half-thickness (L)
Γ is forcing rate (1 / T)

Neuzil (1995)

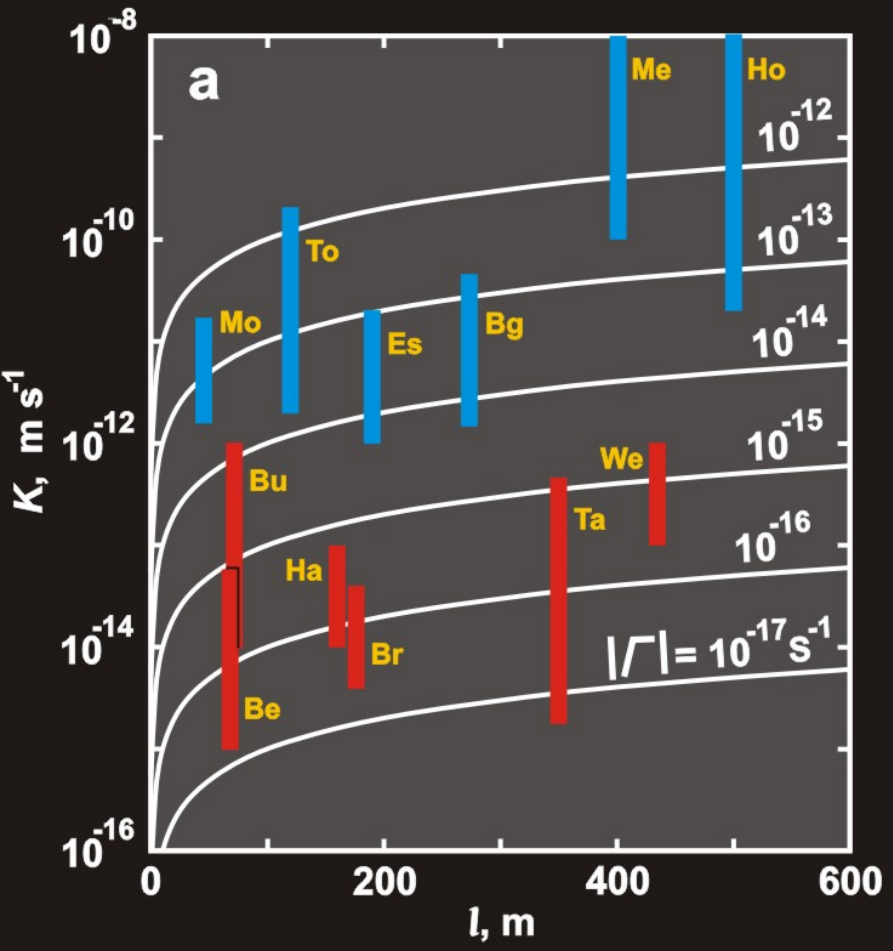
Decaying perturbation model
Anomaly persists until

$$t \approx 0.4\, \ell^2\, (S_s / K)$$

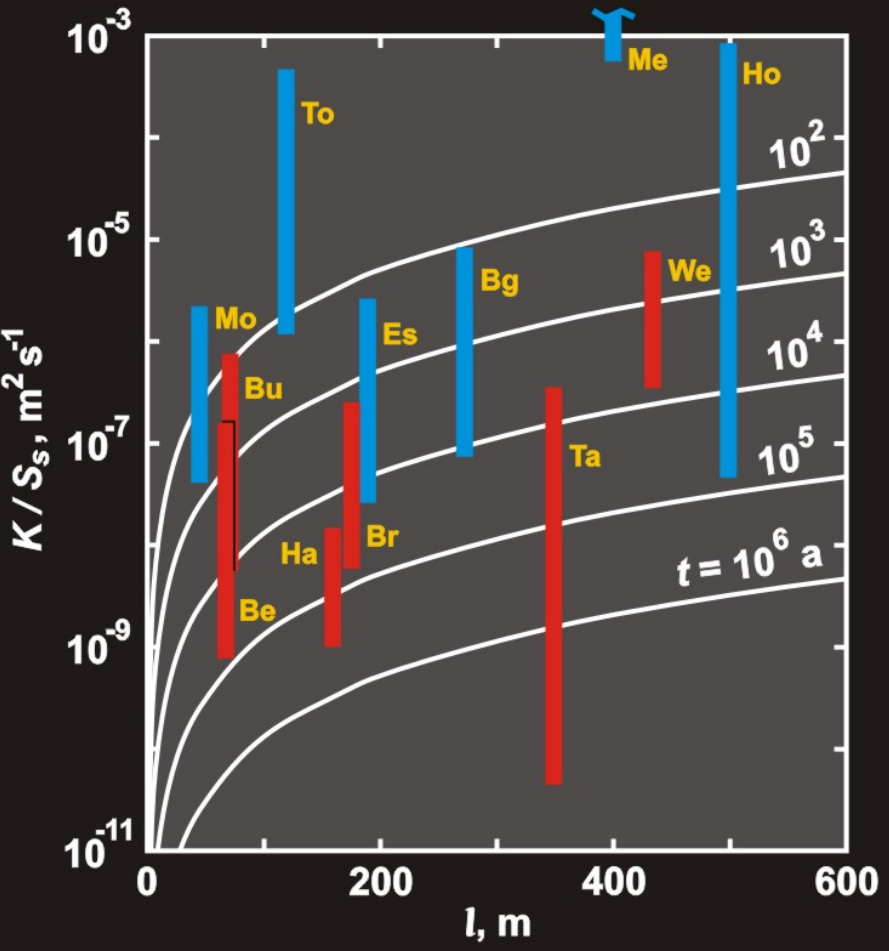
where K is hydraulic conductivity (L / T)
ℓ is formation half-thickness (L)
S_s is specific storage (1 / L)

Terzaghi (1923)

Active forcing

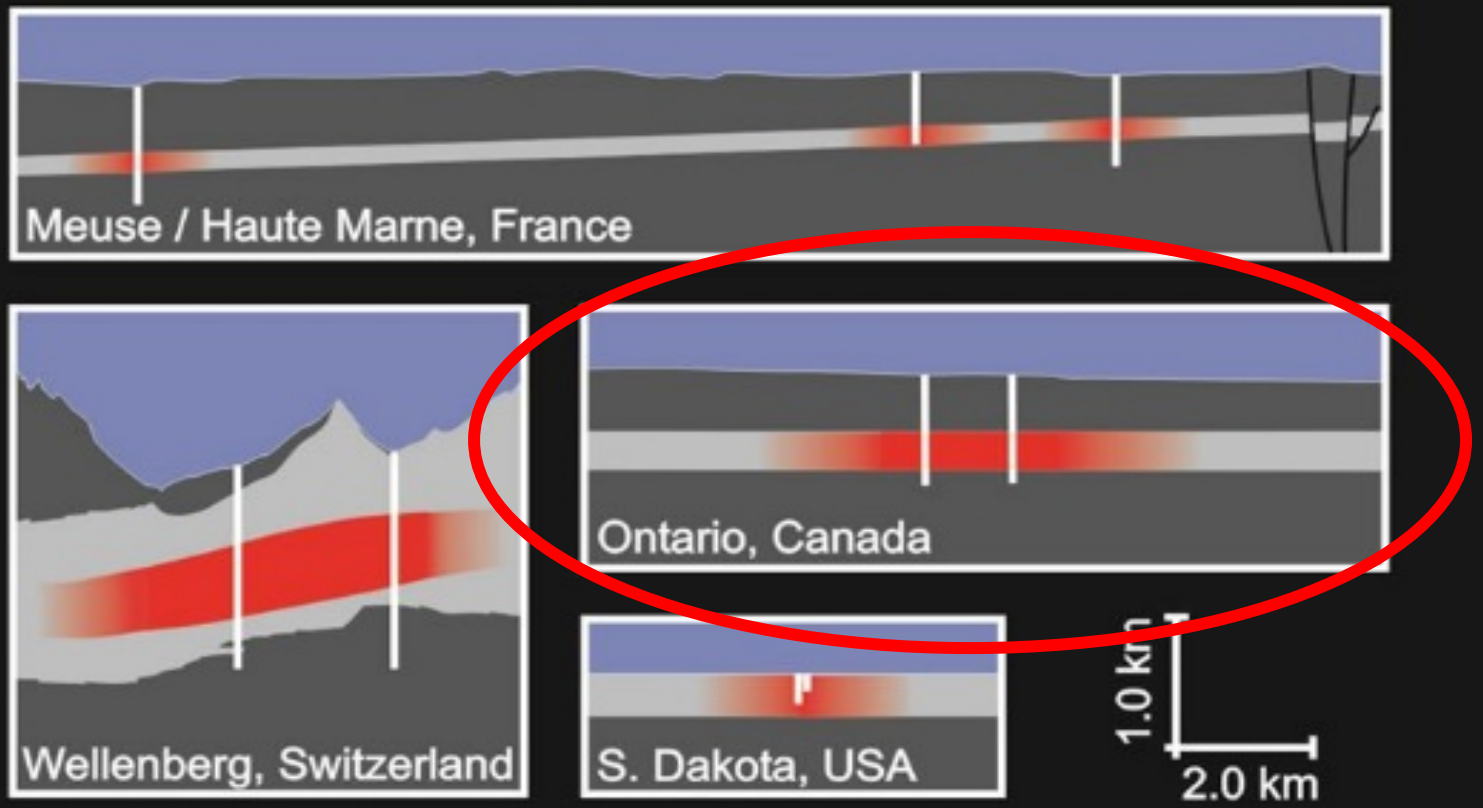


Past forcing



Neuzil (2015)

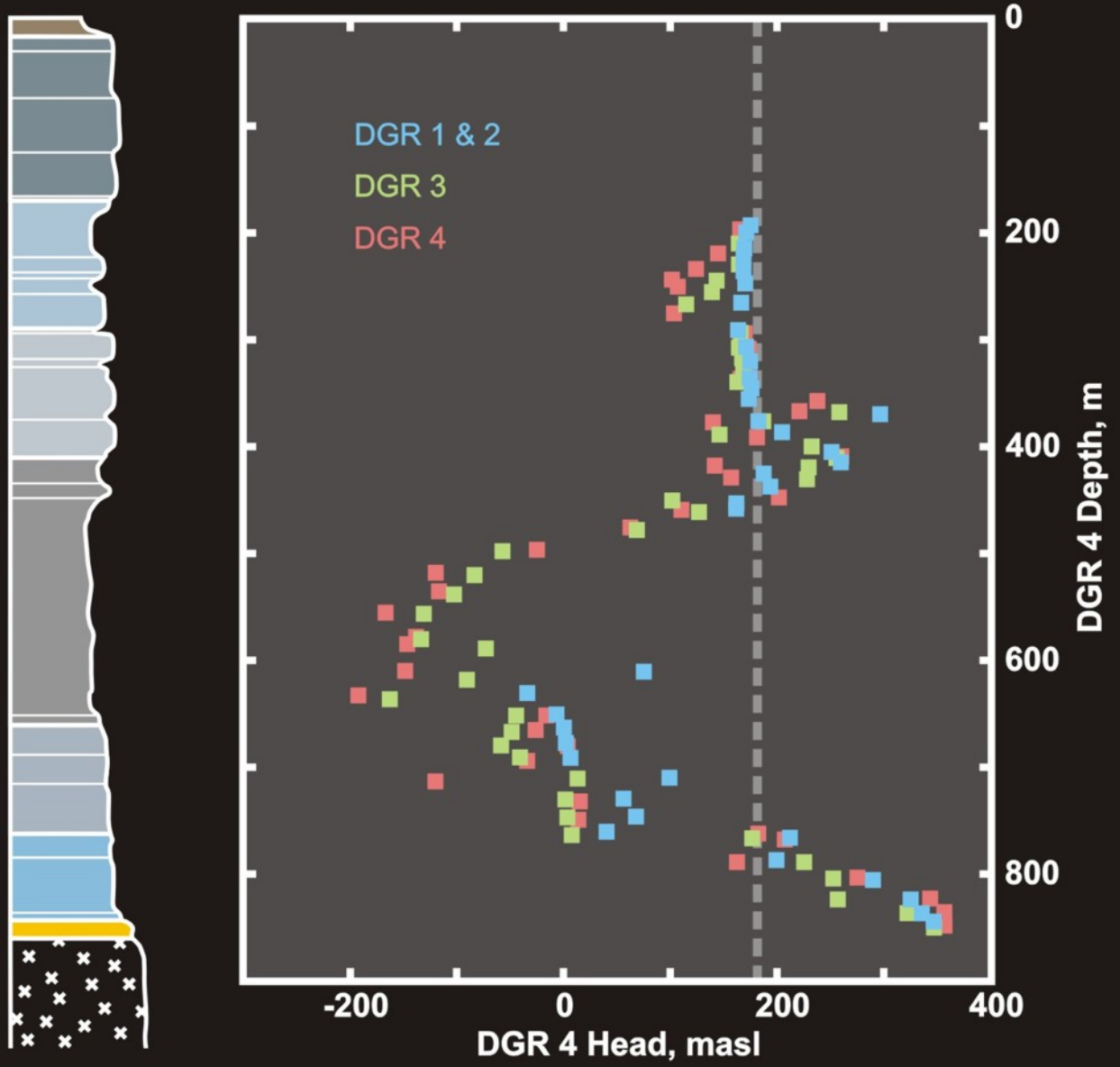
Anomalies Defined by Multiple Boreholes



Gonçalvès et al. (2004)
NAGRA (2002)
Intera Eng. Ltd. (2011)
Neuzil (1993)

Neuzil (2019)

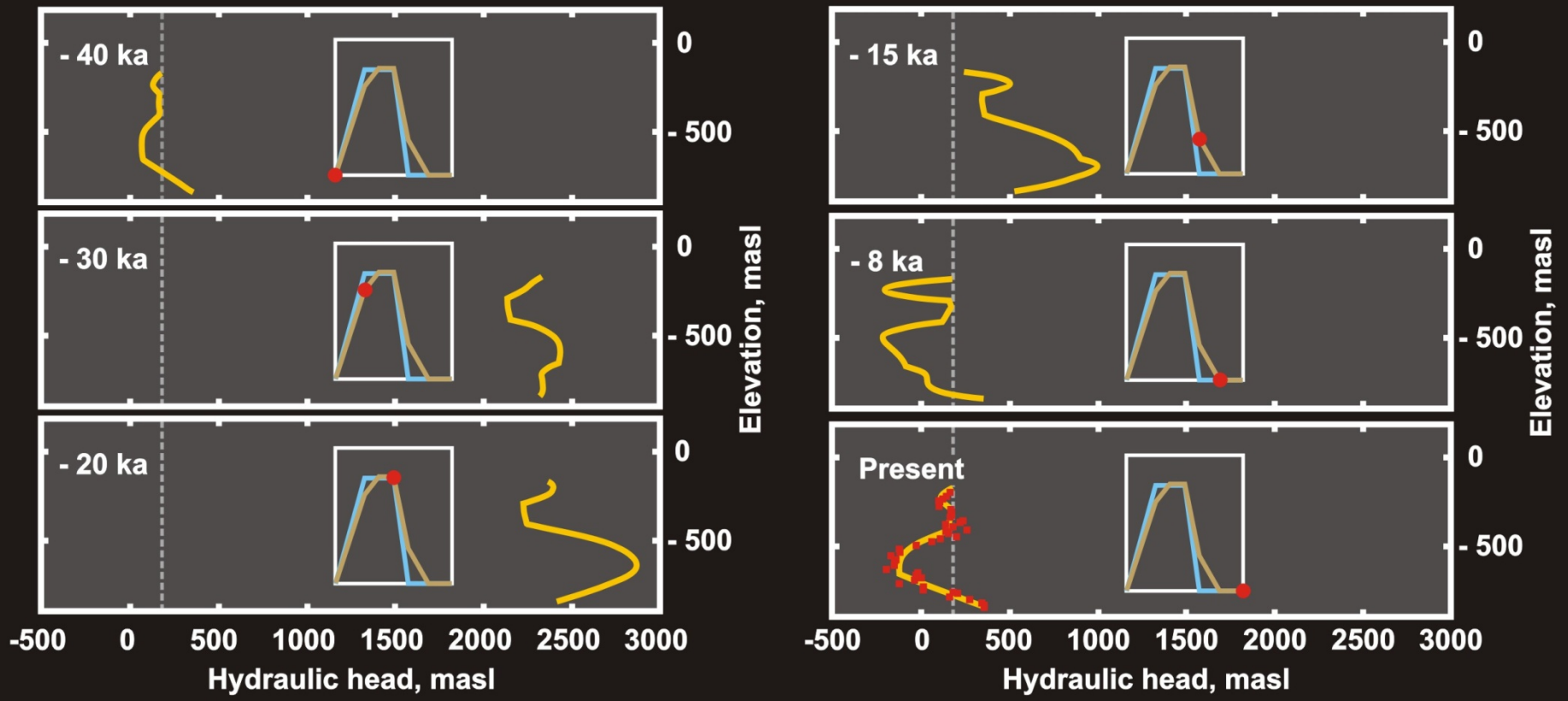
Bruce Site - Hydraulic Head



Neuzil and Provost (2014)

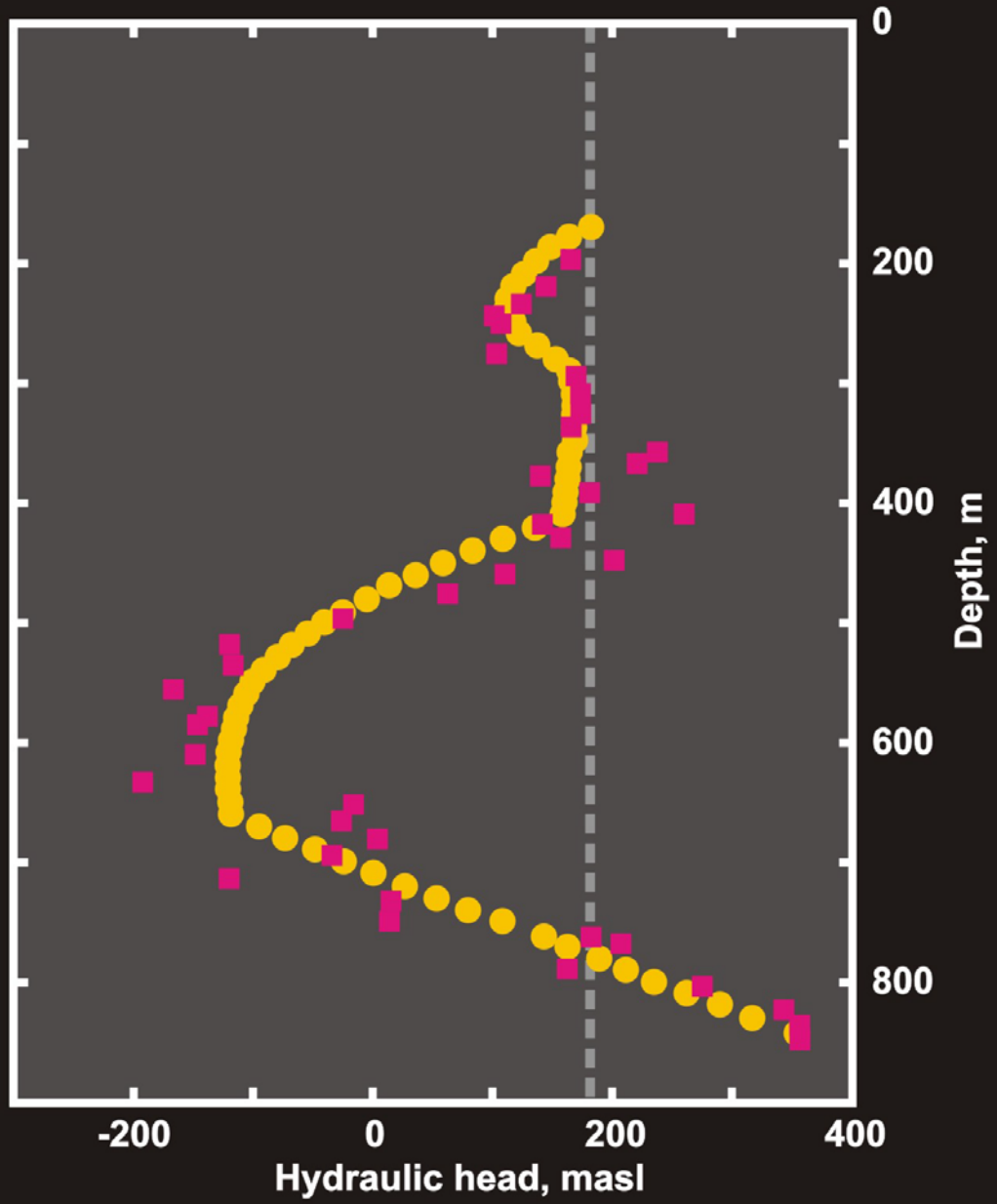
Adapted from NWMO (2011)

Bruce Site - Simulated History



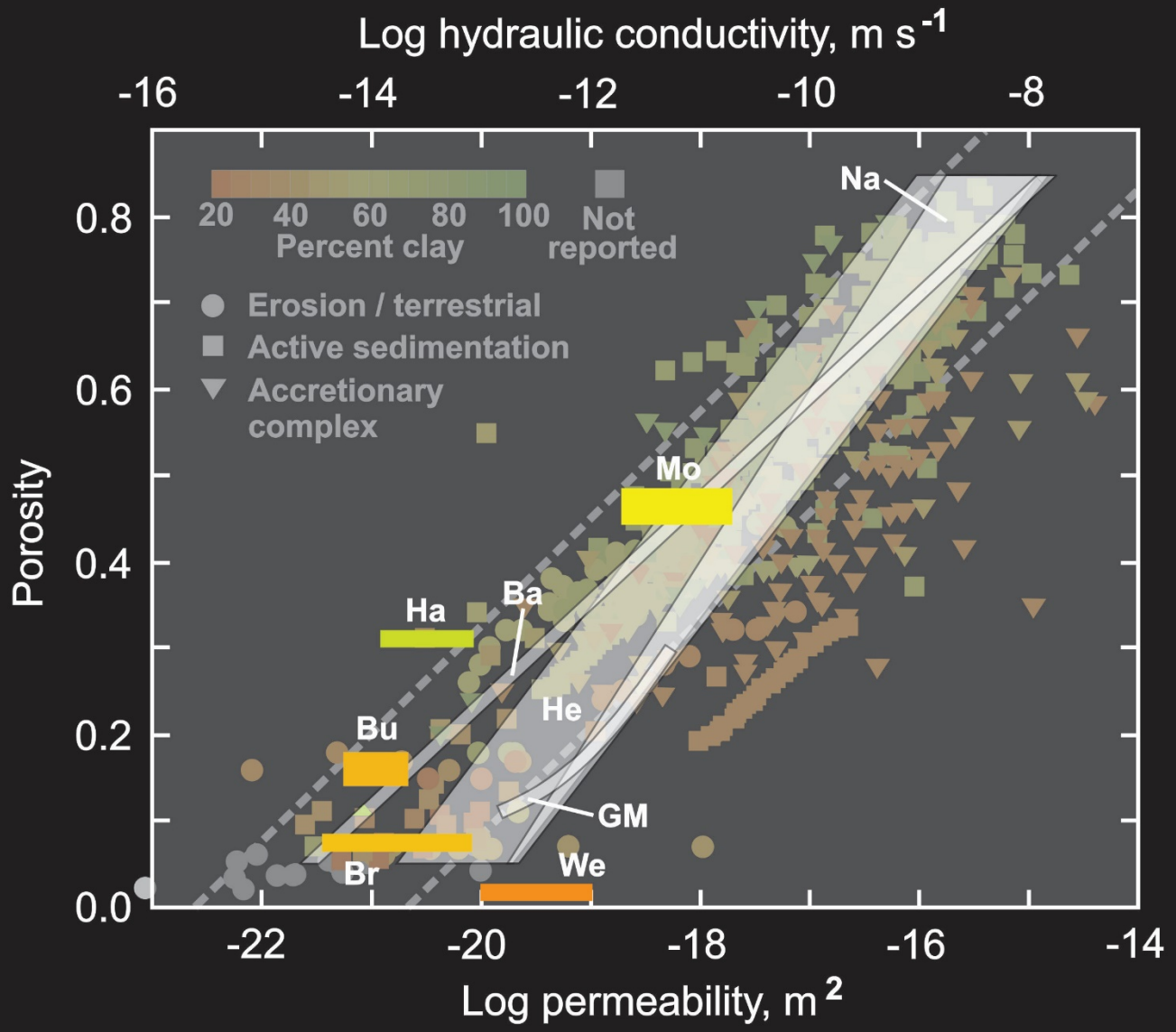
Neuzil and Provost (2014)

Bruce Site - Simulated Head



Neuzil and Provost (2014)

Pressure Anomaly Permeability Overlay

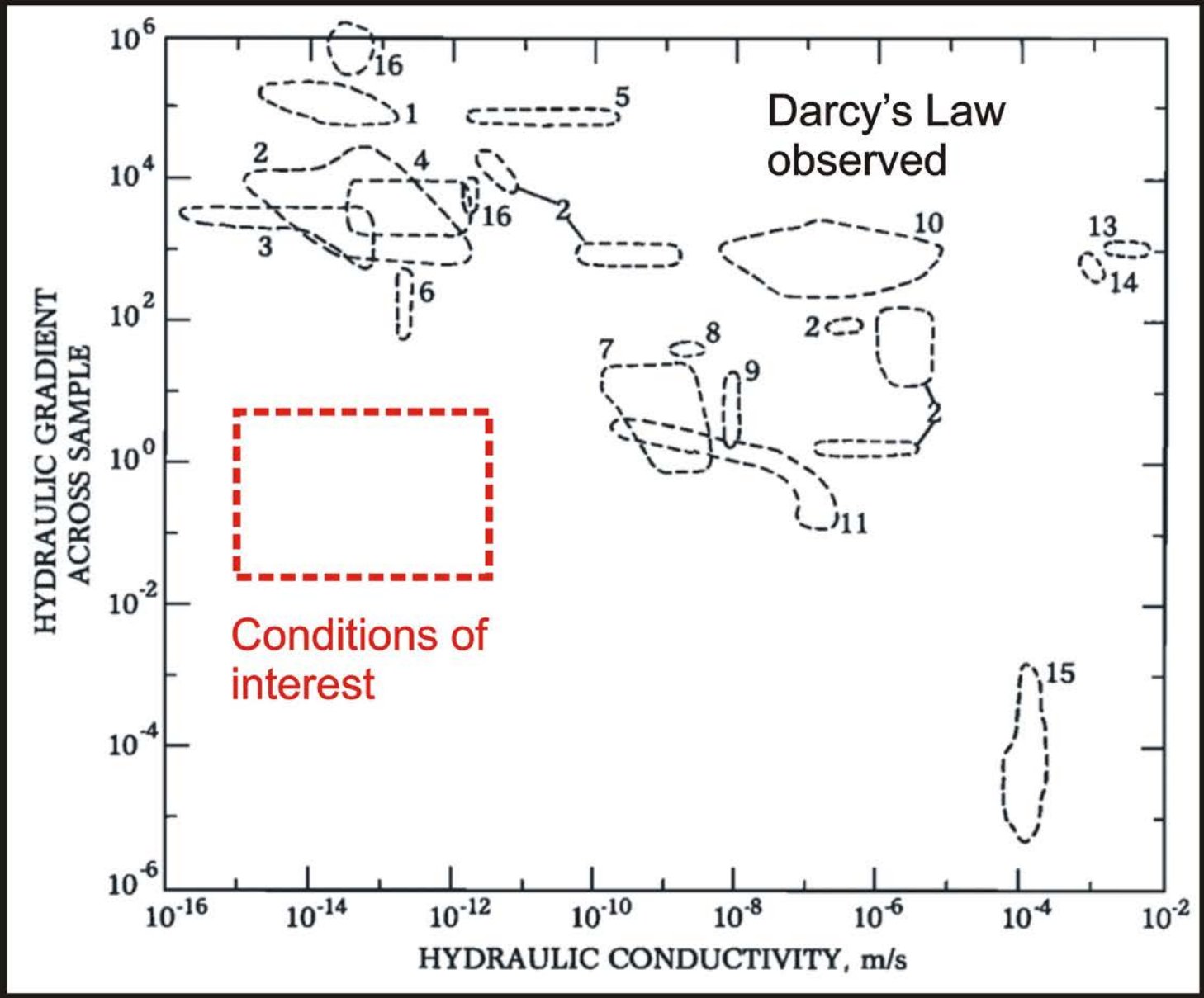


Various sources

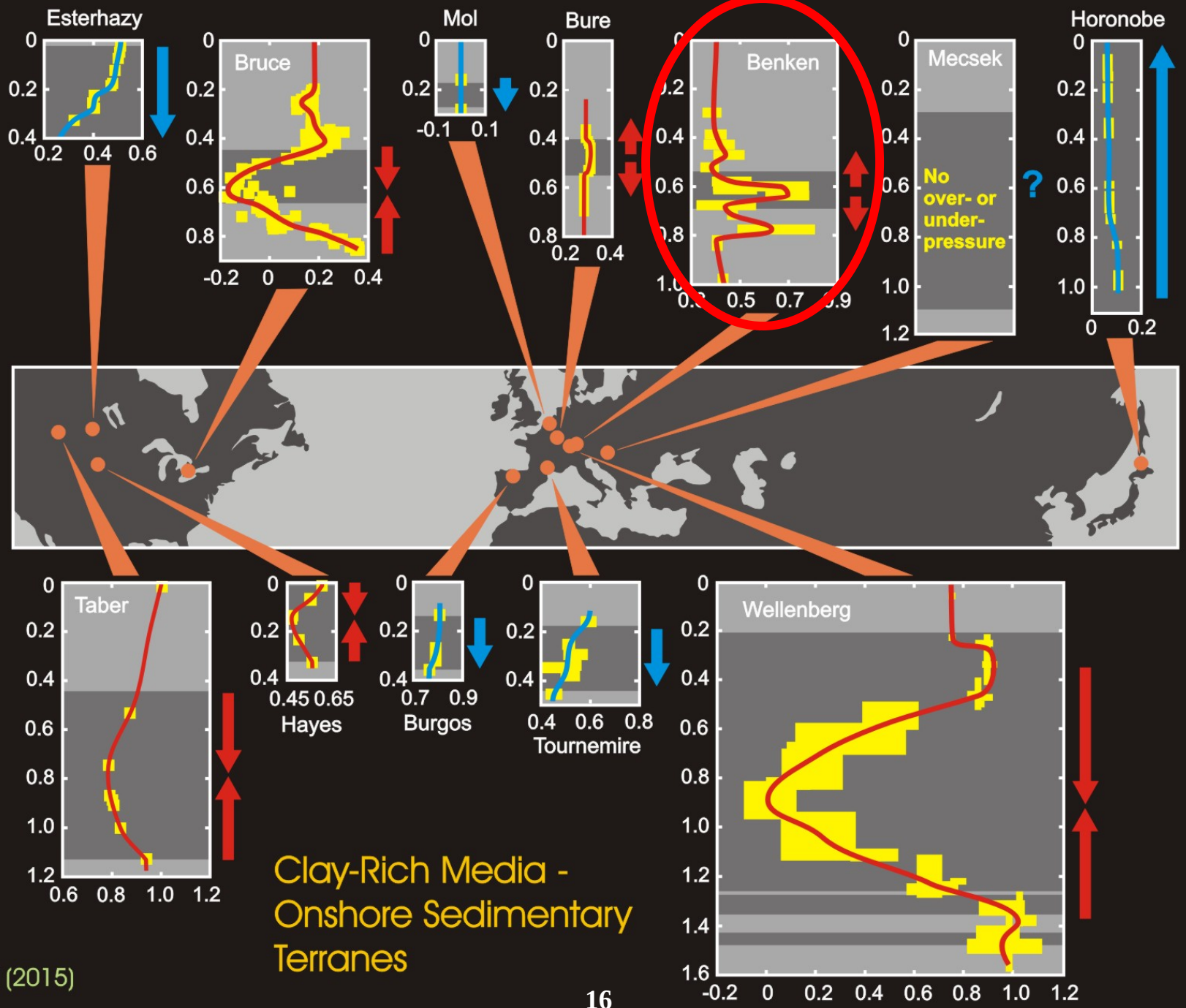
Neuzil AREPS (2019)

Argillaceous formations: Unknowns

- Constitutive flow law - Darcian?
- Reliability of pressure and other data
- Role of gas phase methane
- Plausible forcing can't *always* be identified
- Dynamic permeability



Modified from Neuzil (1986)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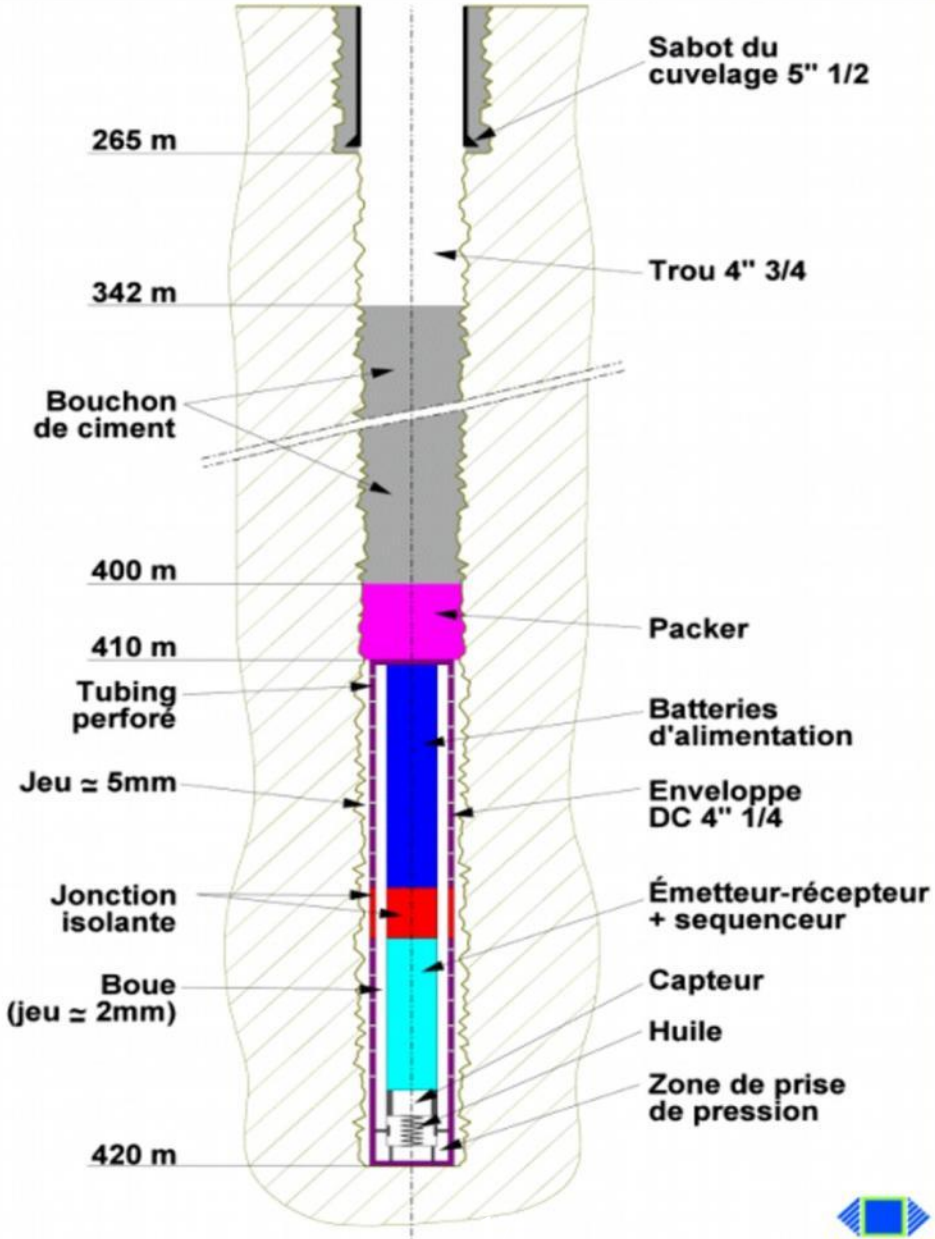
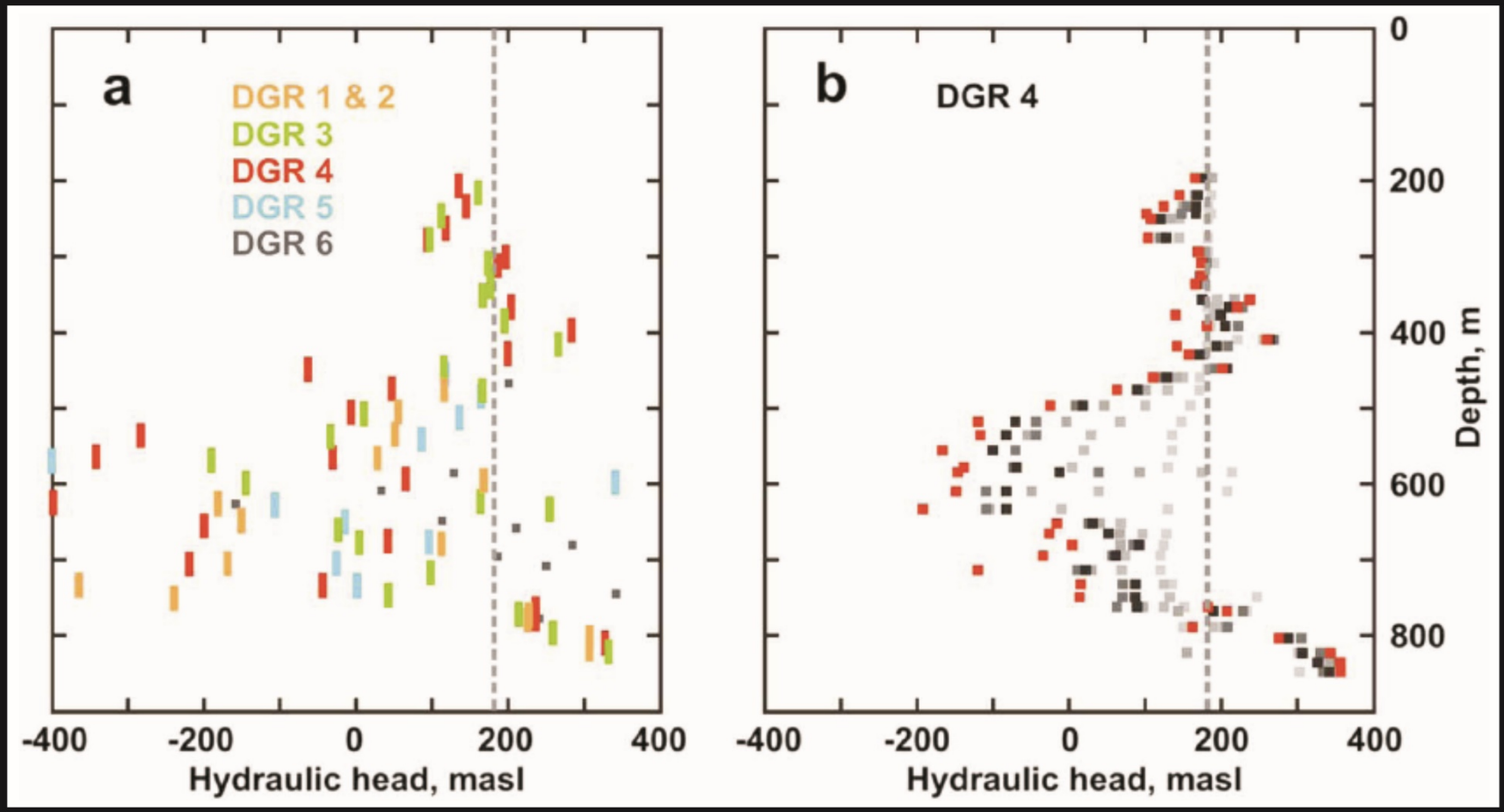
Neuzil (2015)

Schéma du dispositif EPG et implantation dans le forage EST107

D PL ADPE 03-0476 / A



ANDRA

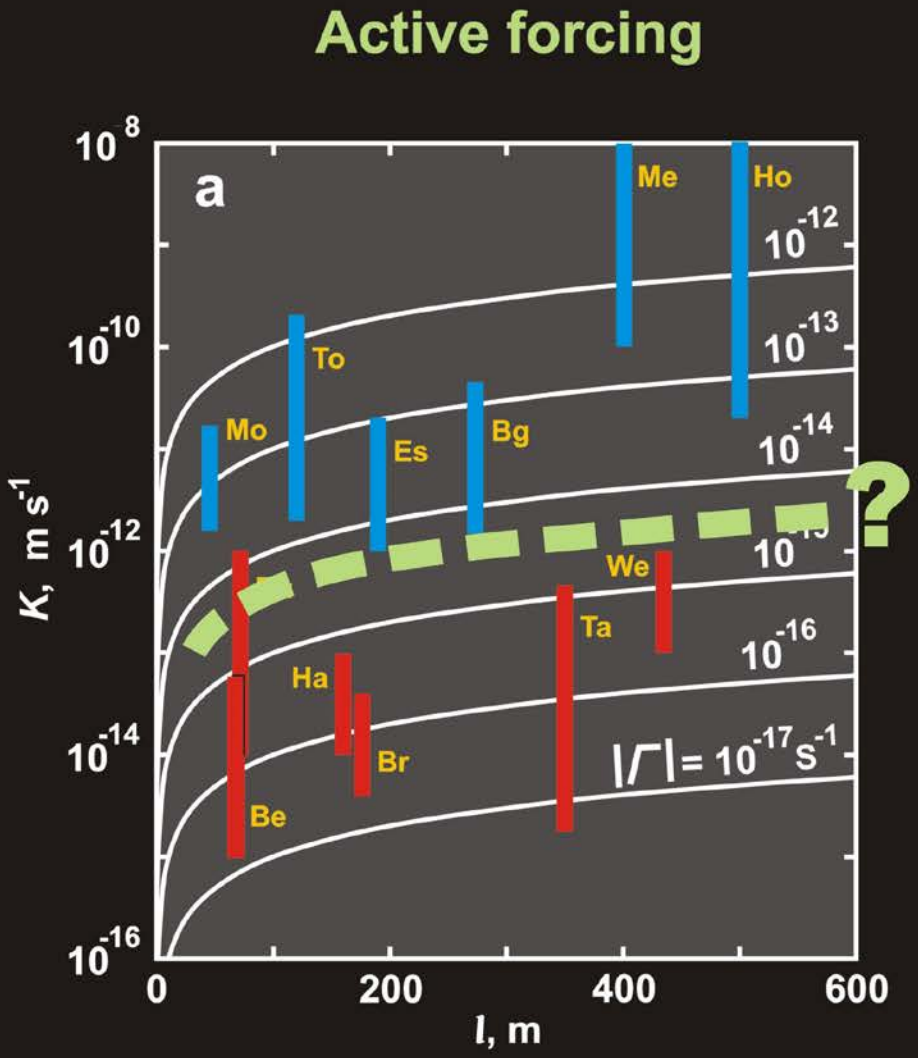


Pressure (as head) derived from transient behavior.

Pressure (as head) as measured.

Bruce site

Neuzil and Provost (2014)


Active forcing
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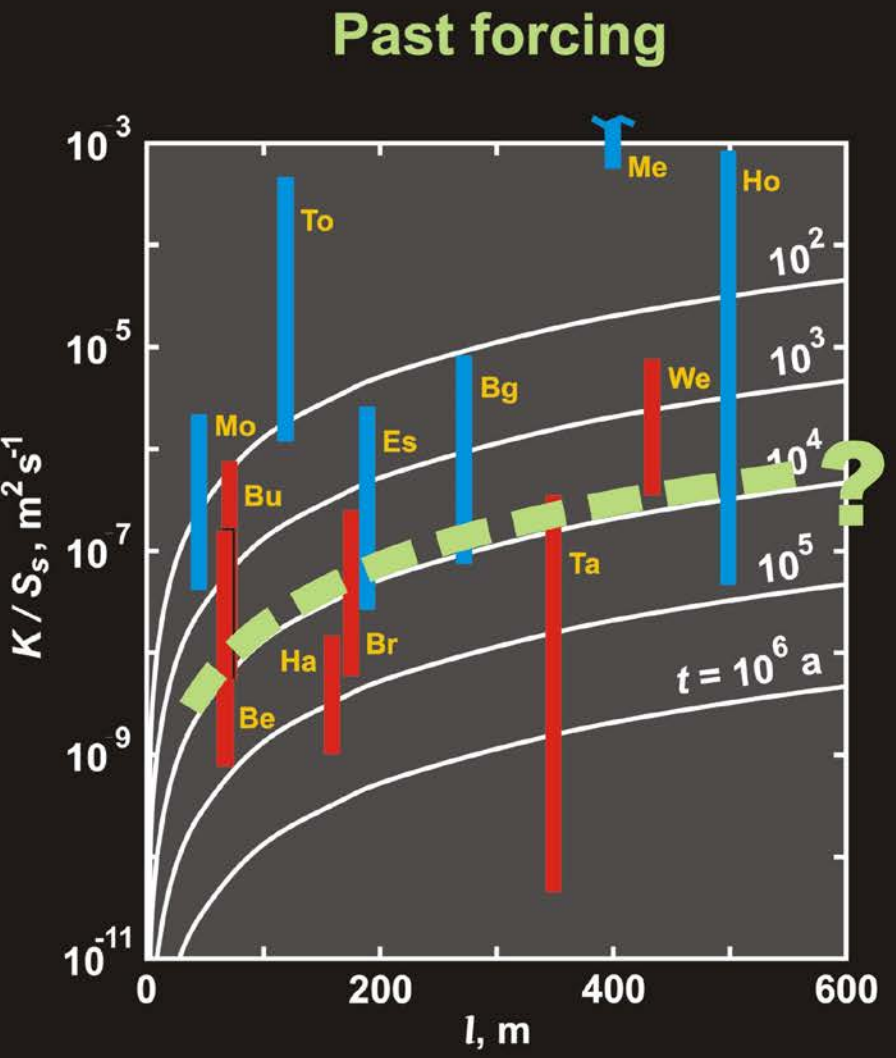
K, m s^{-1}
0
200
400
600
l, m


Past forcing
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10^{3}
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$t = 10^{6}$ a
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10^{-5}
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10^{-9}
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K / S_s, m^2 s^{-1}
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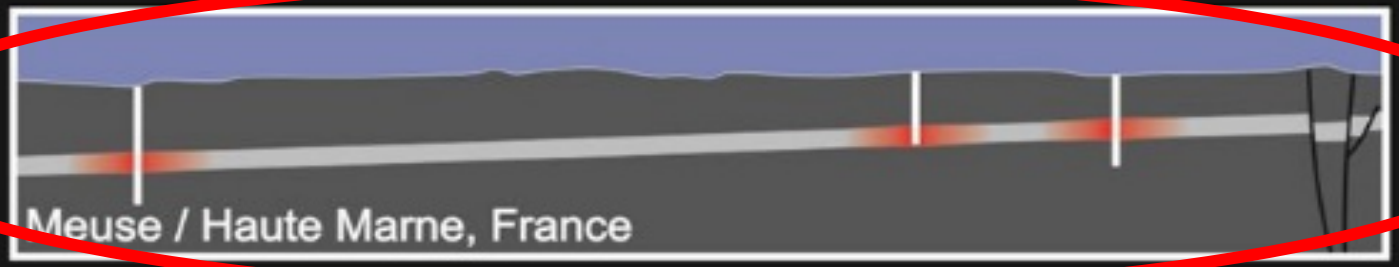
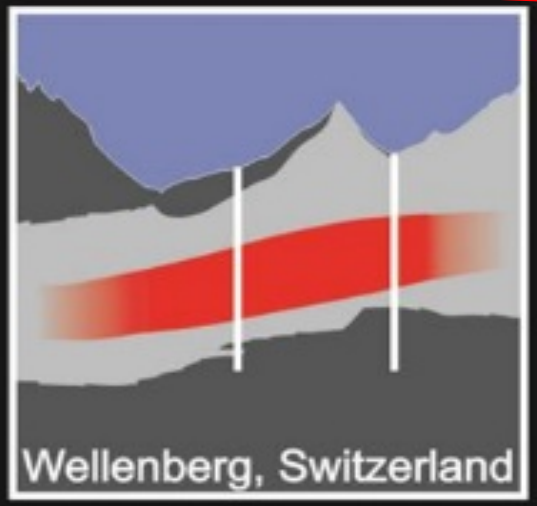
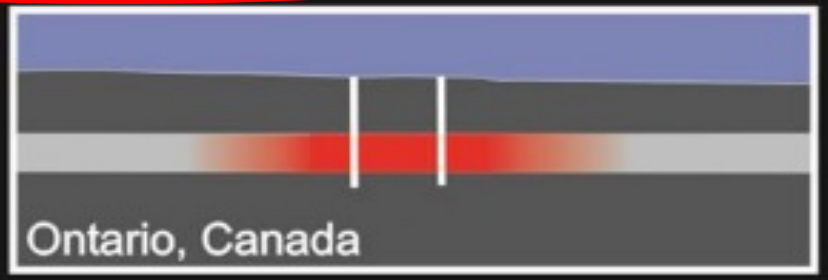
200
400
600
l, m

Neuzil (2015)

Anomalies Defined by Multiple Boreholes

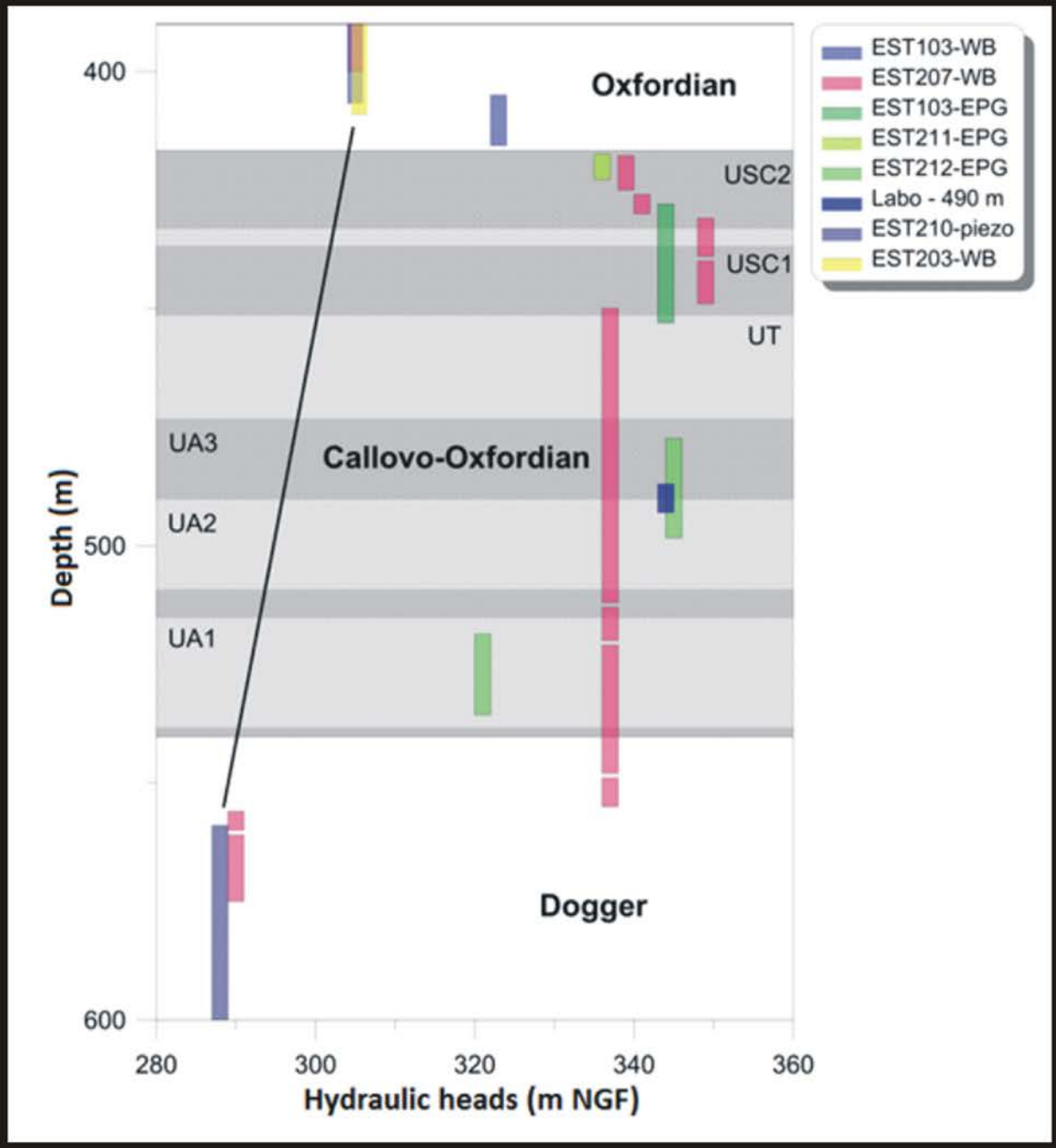






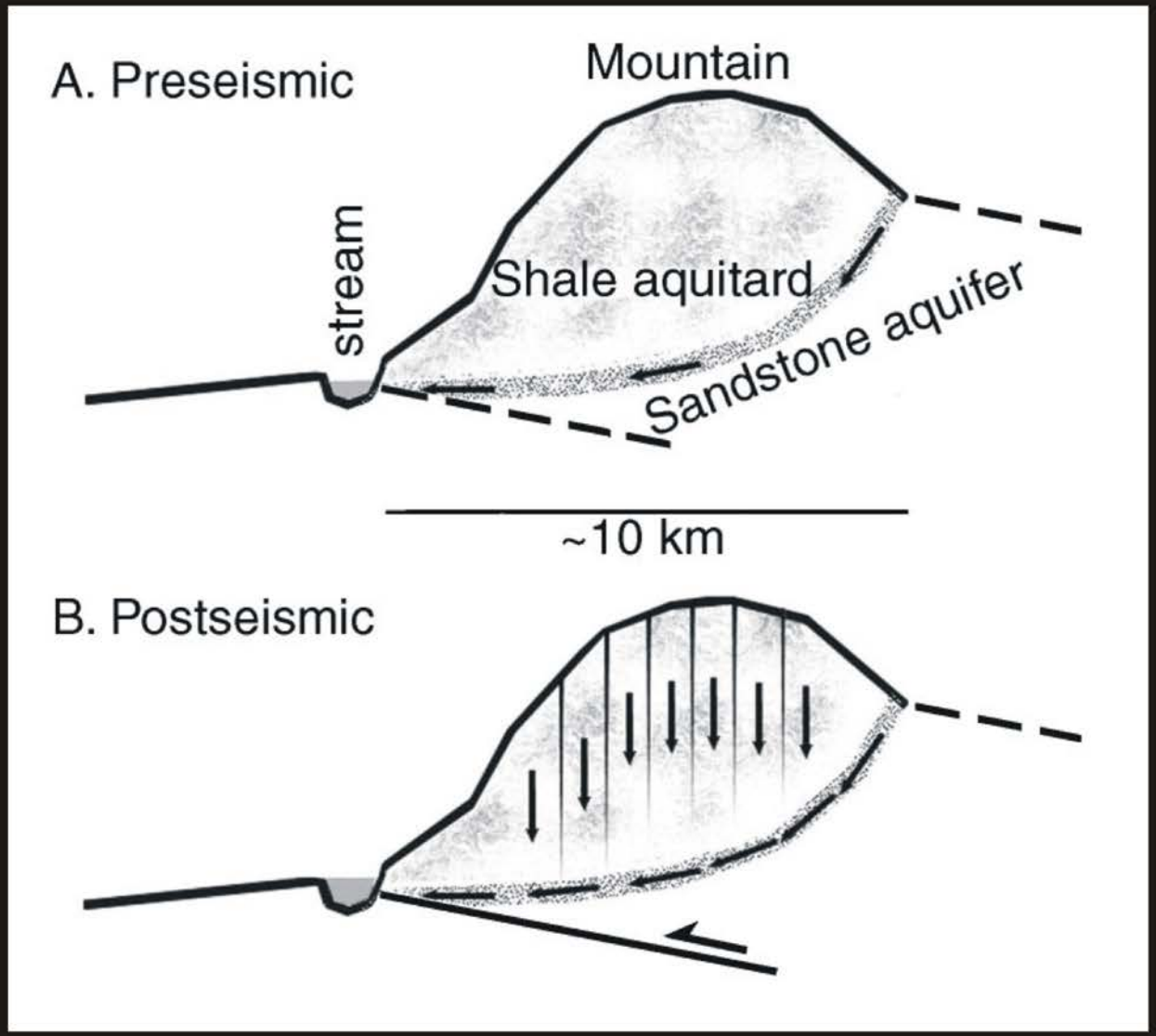
Gonçalvès et al. (2004)
NAGRA (2002)
Intera Eng. Ltd. (2011)
Neuzil (1993)

Overpressure in the Callovo-Oxfordian Bure, France



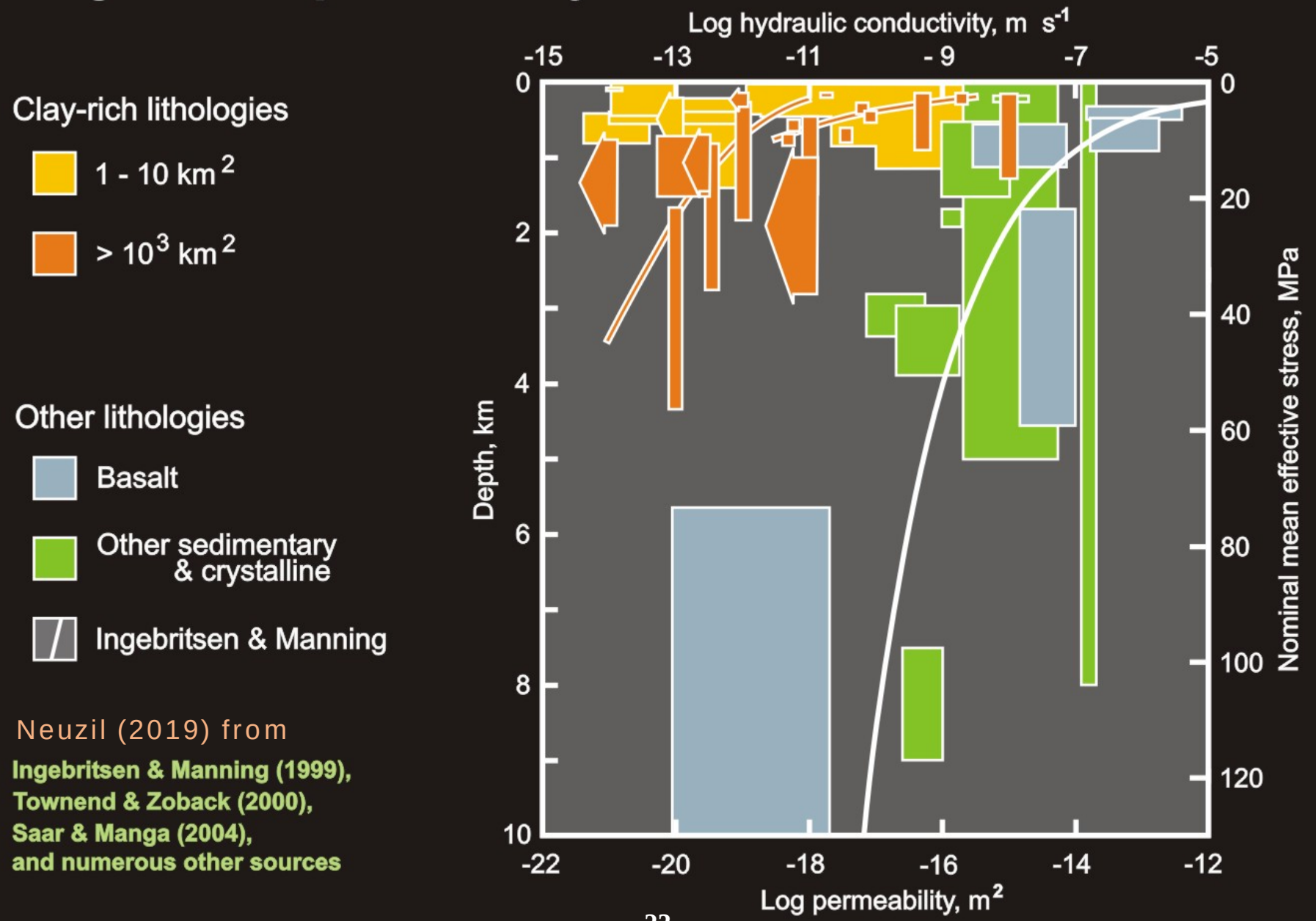
Robinet (2018)

Shale permeability enhanced by seismic shaking



Wang, Wang, and Manga (2004)

“Large-scale” permeability



Neuzil (2019) from

Ingebritsen & Manning (1999), Townend & Zoback (2000), Saar & Manga (2004), and numerous other sources

Argillaceous formations: Needs

- Data from more formations!
  - Fluid pressure
  - Lab and borehole permeability
  - Mechanical properties (long-term)
  - Fluid geochemistry
  - Identify forcings
- Constitutive flow law
  - (Molecular Dynamics simulations?)
- Multiphase physics in clays
- Dynamic permeability
- Local - regional scale permeability

Goncalves, J., S. Violette, and J. Wendling (2004), Analytical and numerical solutions for alternative overpressuring processes: Application to the Callovo-Oxfordian sedimentary sequence in the Paris basin, France, J. Geophys. Res., 109, B02110,doi:10.1029/2002JB002278

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