DRG Final Meeting

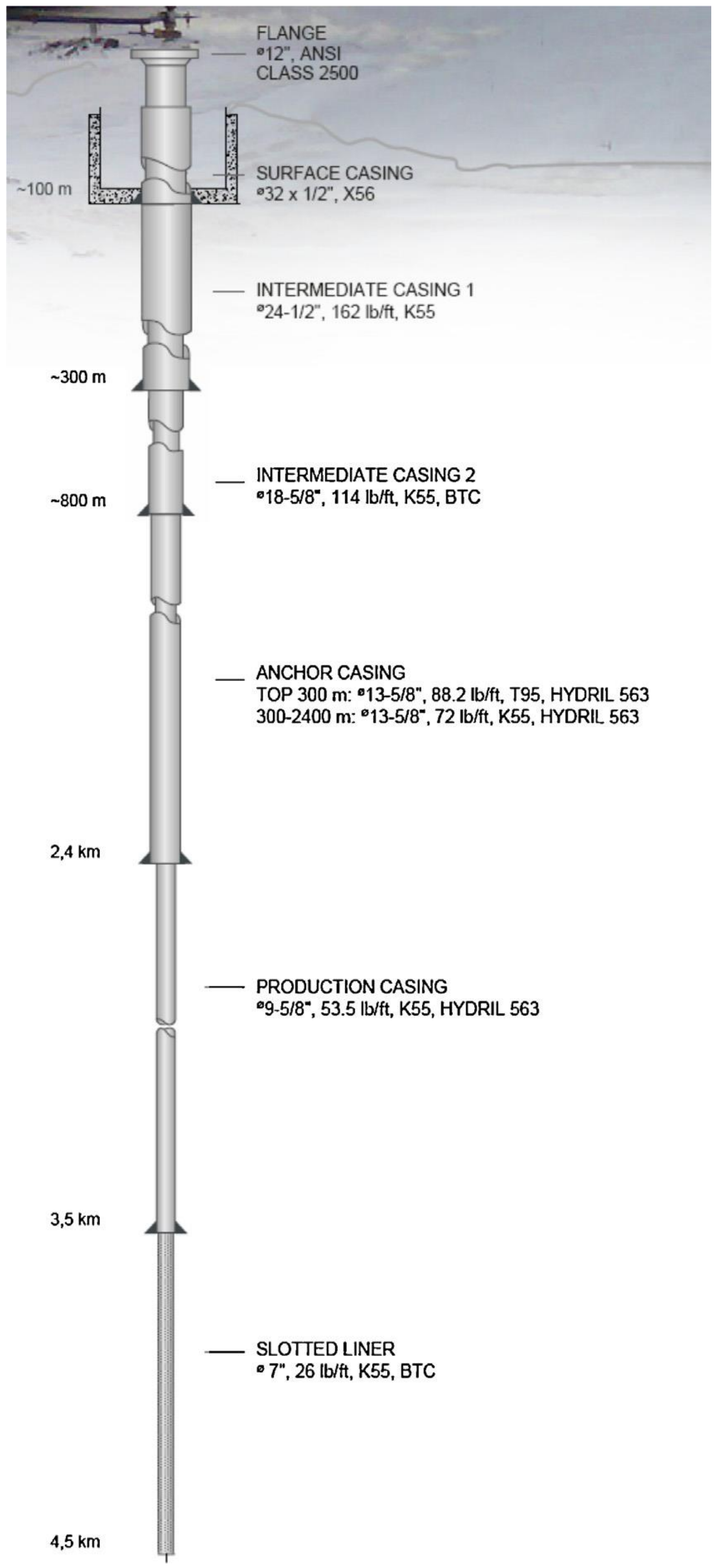
December 14, 2017

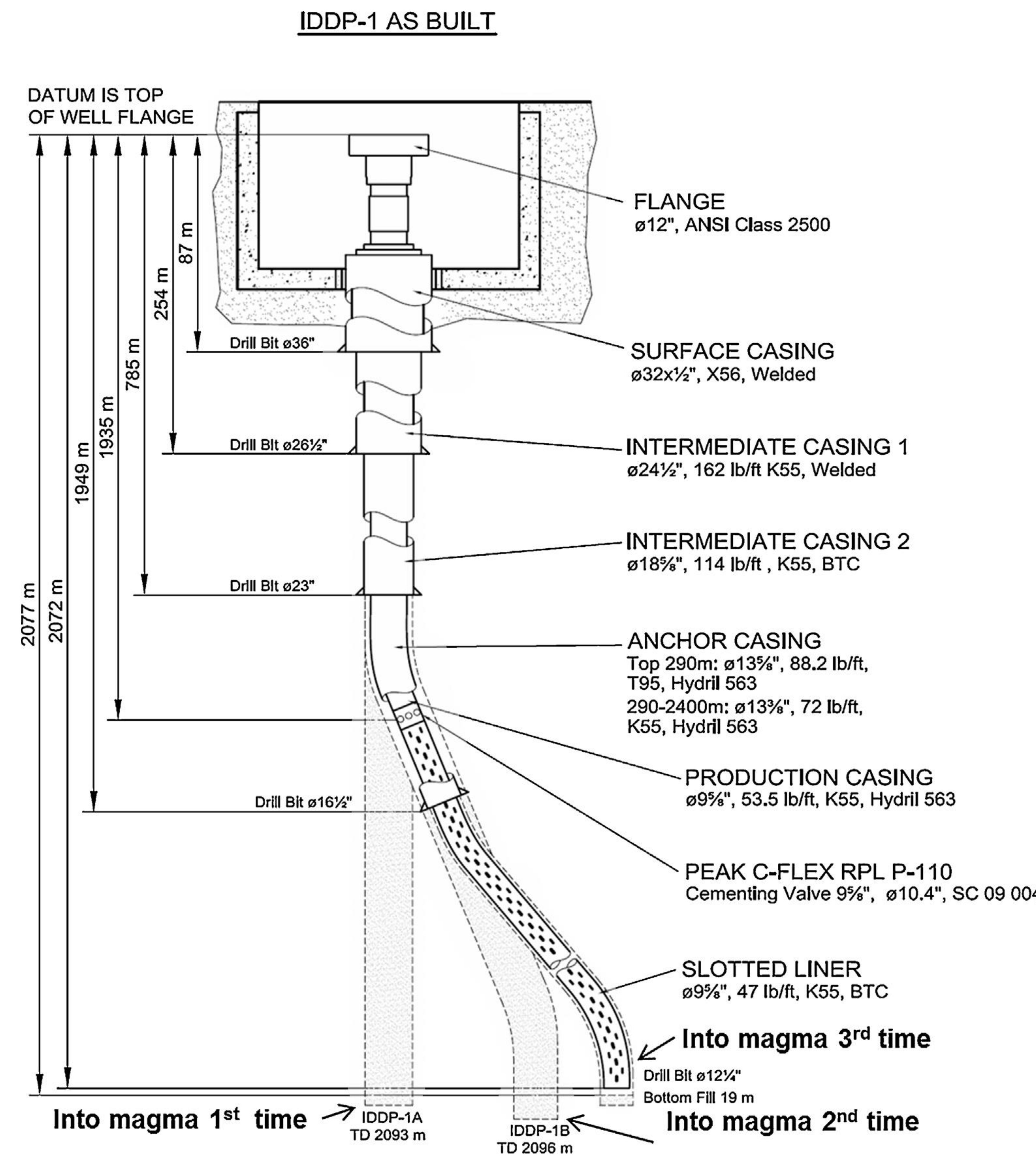
Jean-Claude Berthet

2-D and 3-D simulations using CSMP++ and iTOUGH2

- 2-D Modelling of IDDP-1 and Krafla
  - CSMP++
  - iTOUGH2-EOS1sc
- 3-D Modelling
  - iTOUGH2-EOS1sc
  - Simulation of random intrusions

Well IDDP-1 in Krafla

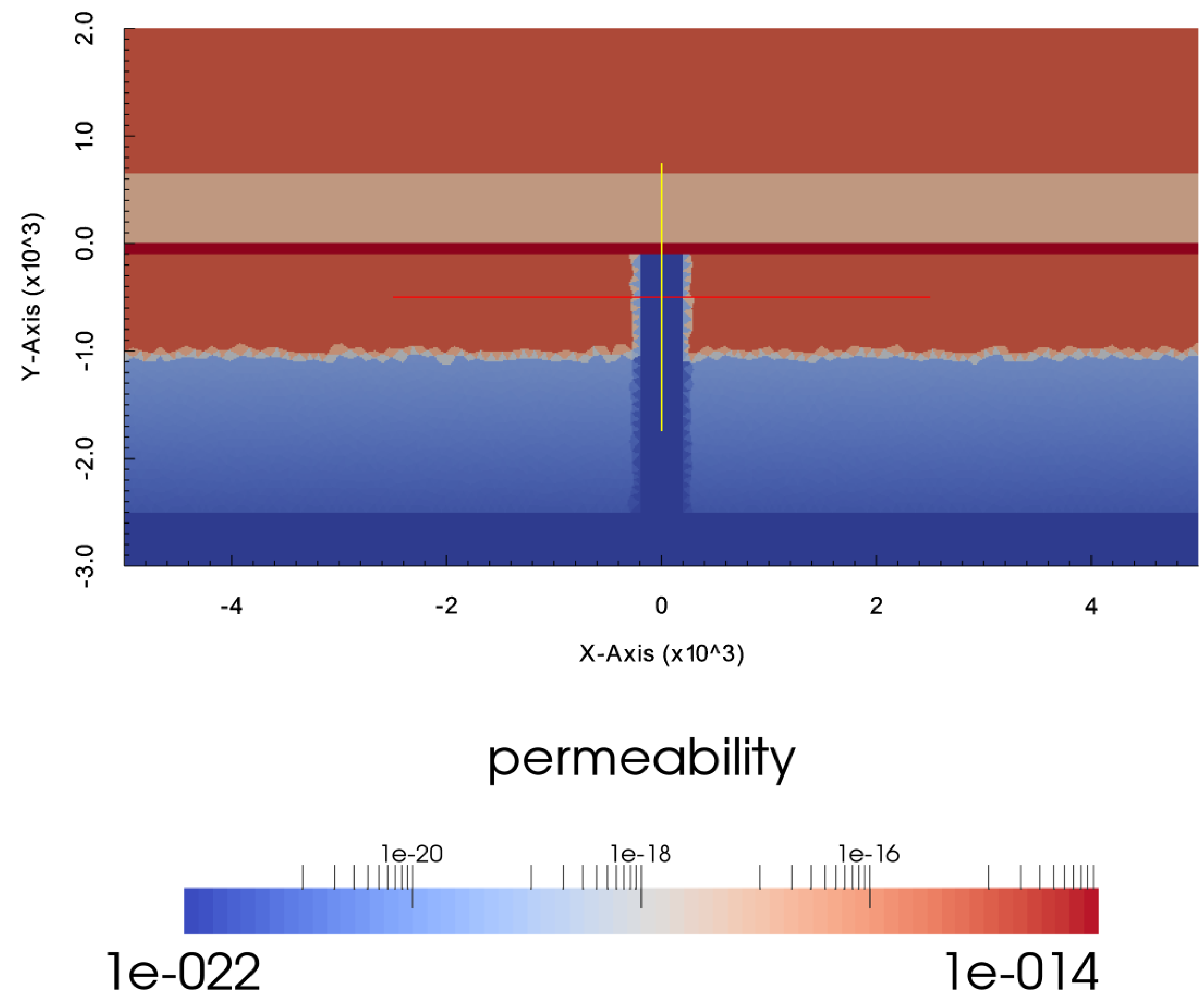




Drilling of the well IDDP-1, B. Pálsson, et al. Geothermics 49 (2014) 23-30

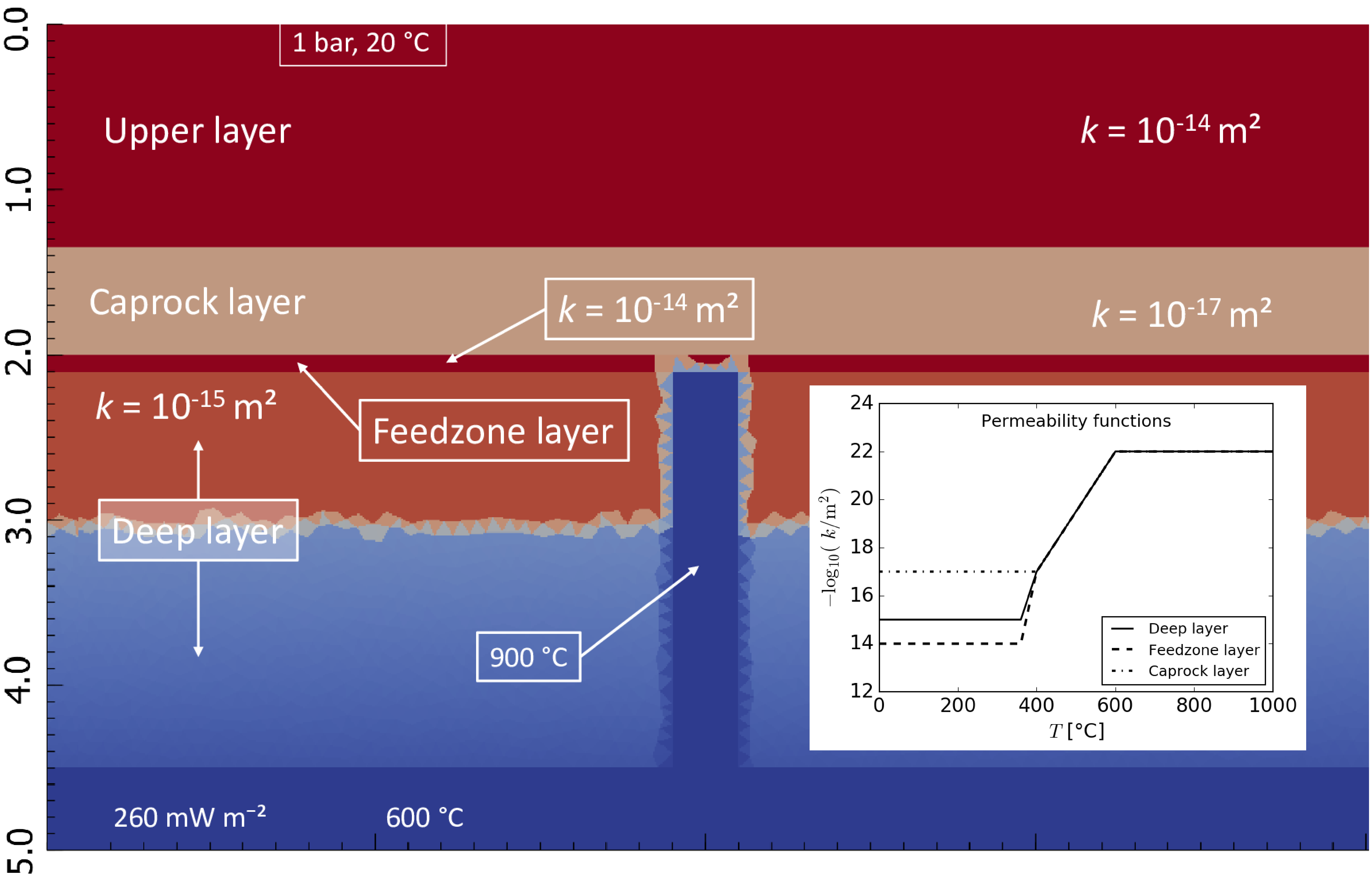
Stratigraphy

- “The upper 1362 m of the well consists of basaltic lavas and hyaloclastite formations […]”
- “Below 1350 m depth, the well enters a dyke complex which extends to the bottom of the well at 2104 m depth, where the well encountered rhyolitic magma.”
- “The upper reservoir is isothermal at 170°C.”
- “The largest feed-zones […] were encountered below 2000 m depth […]”
- “All these wells [in the vicinity of IDDP-1] encountered large feed zones at or below 2000 m.”
- “[…] in the upper 1300 m of well IDDP1, few smaller feed zones were intersected […]”
- “[…] feed zones are scarce at 1350-2000 m depth. […] this interval may be characterized as representing a tight cap rock to the lower reservoir.”
- “[…] the estimated temperature of the magma encountered in IDDP-1 is ~900 °C.”
- “Temperature recovery indicates that the reservoir temperatures approach 500 °C near the well bottom, […]”

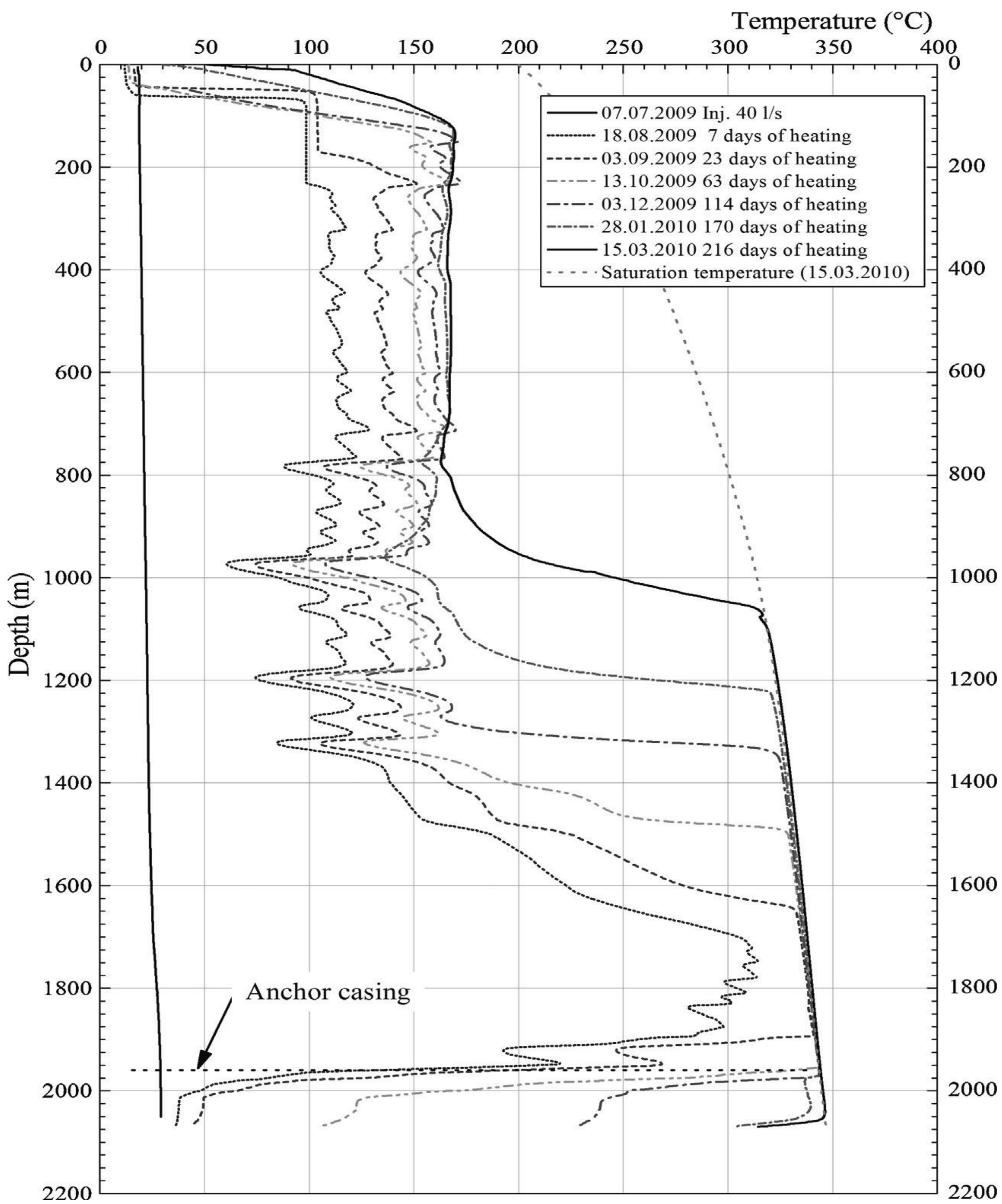


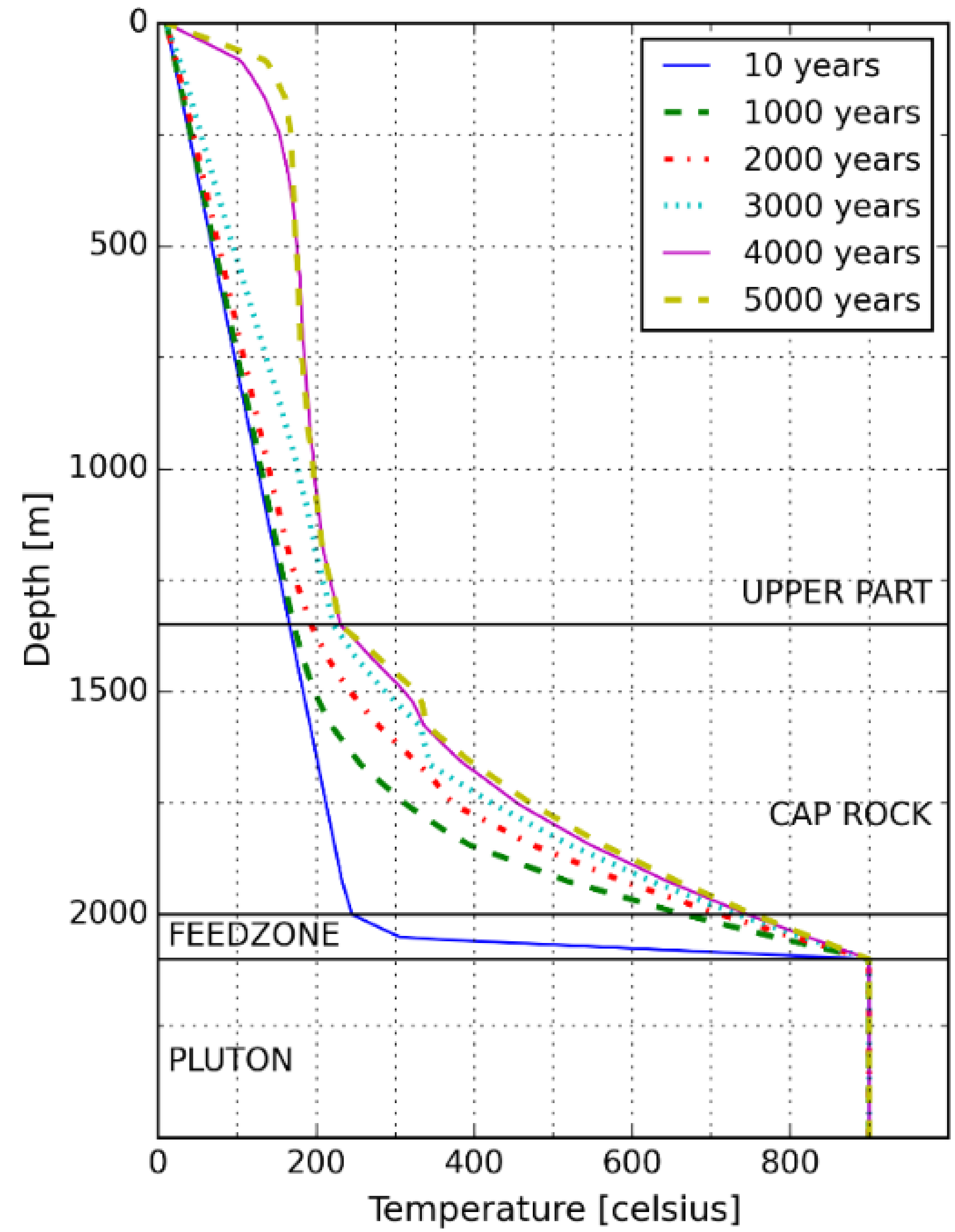
Stratigraphy, alteration mineralogy, permeability and temperature conditions of well IDDP-1, Krafla, NE-Iceland. A.K. Mortensen, Geothermics 49 (2014) 31-41

First IDDP-1 CSMP++ model



Temperature profile





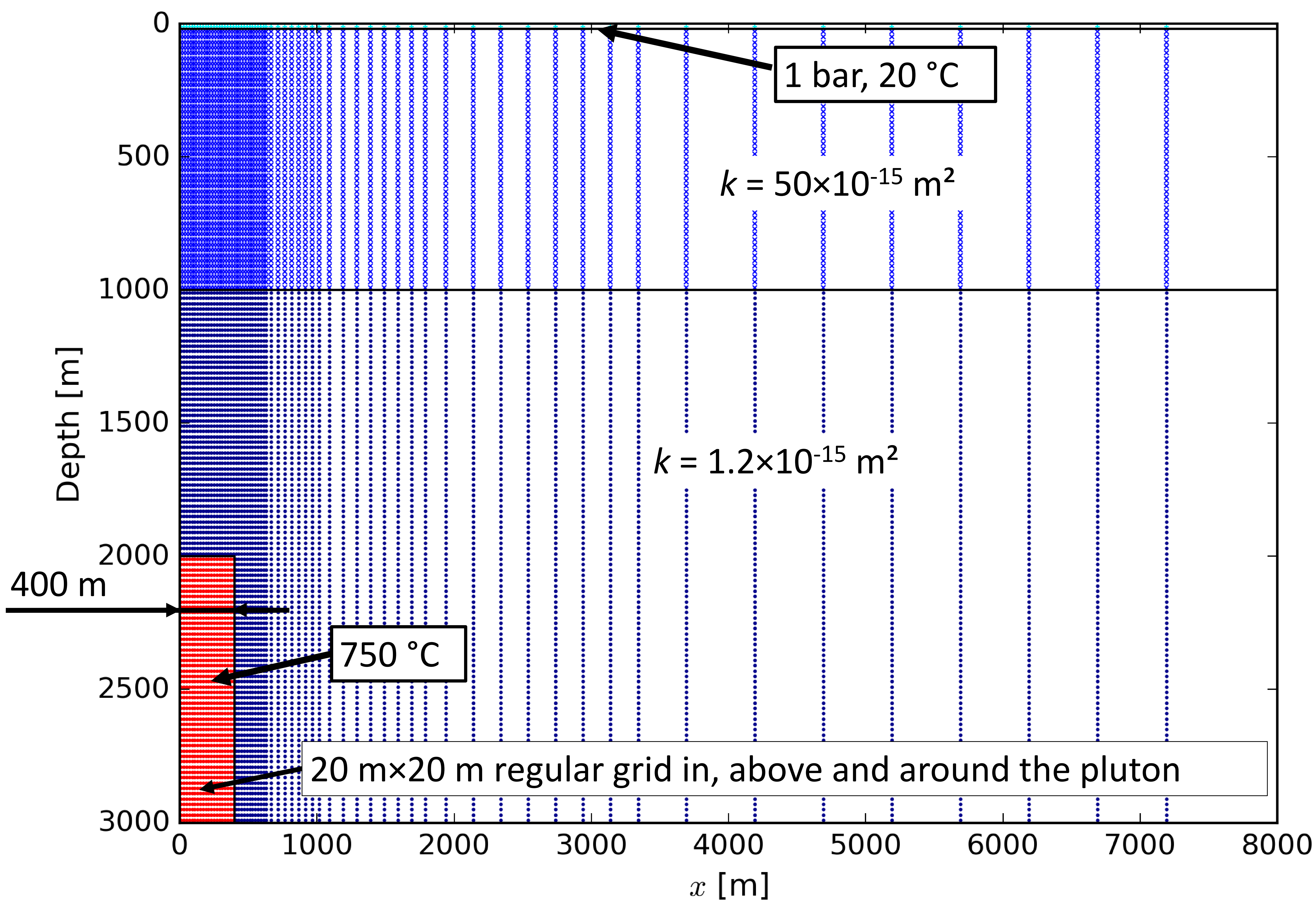
- "Horner plot for the six recovery logs in IDDP-1 indicates a bottom hole temperature of ~500 °C"

Mortensen et al., Geothermics 49 (2014) 31-41

2015

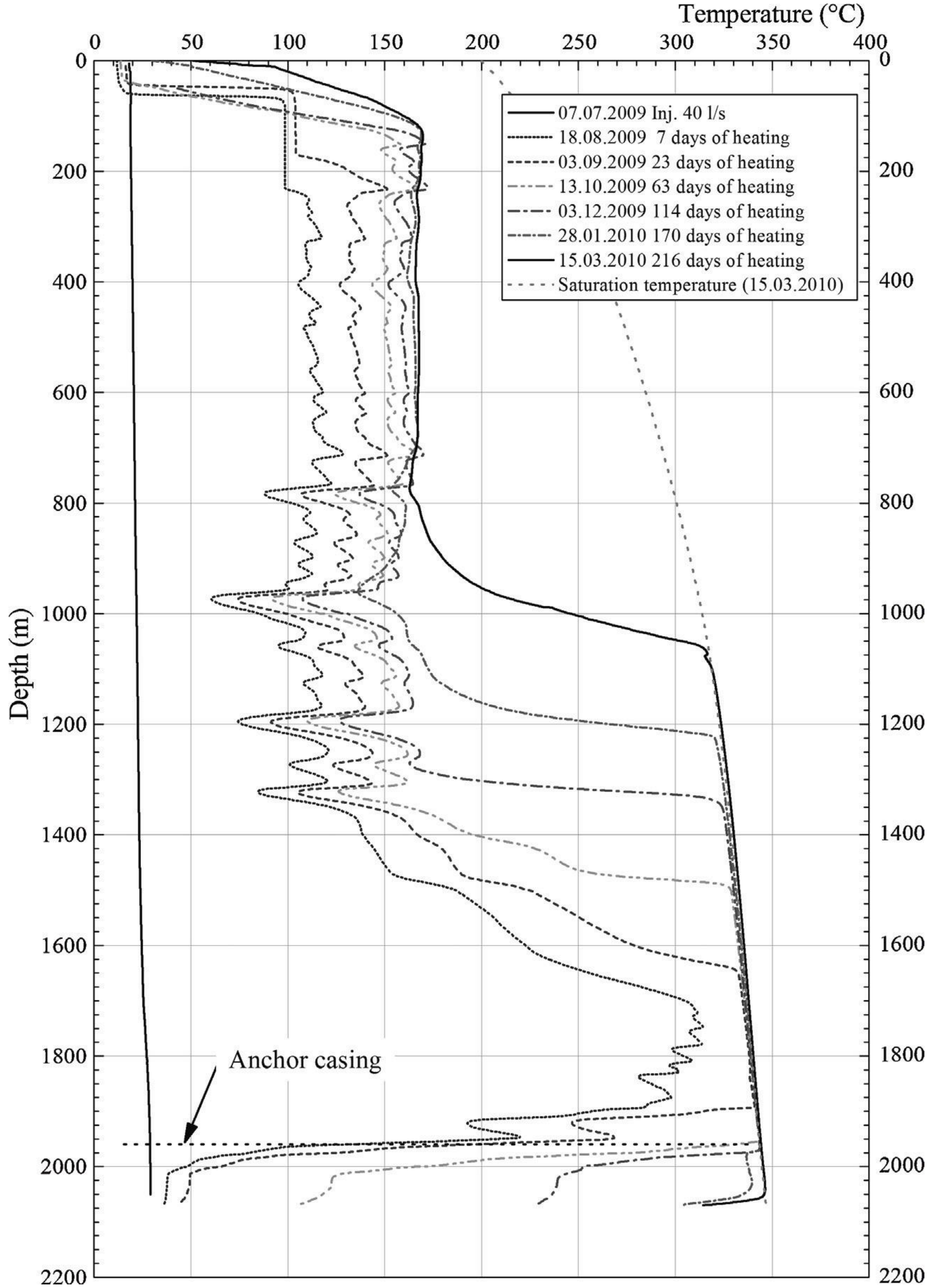
- *Revision of the Conceptual Model of the Krafla Geothermal System*, Tobias Björn Weisenberg, et al.
  - “[…] rock of permeability 1 mD [10^{-15} m²] extending up to 1 km depth”
  - “The permeability in the uppermost 1 km is much higher (50 mD [50×10^{-15} m²] […]).”
  - “It seems clear from this modelling that the reason for the “two systems” in this part of the system is due to a large difference in permeability.”
- iTOUGH2 becomes super-critical EOS1sc

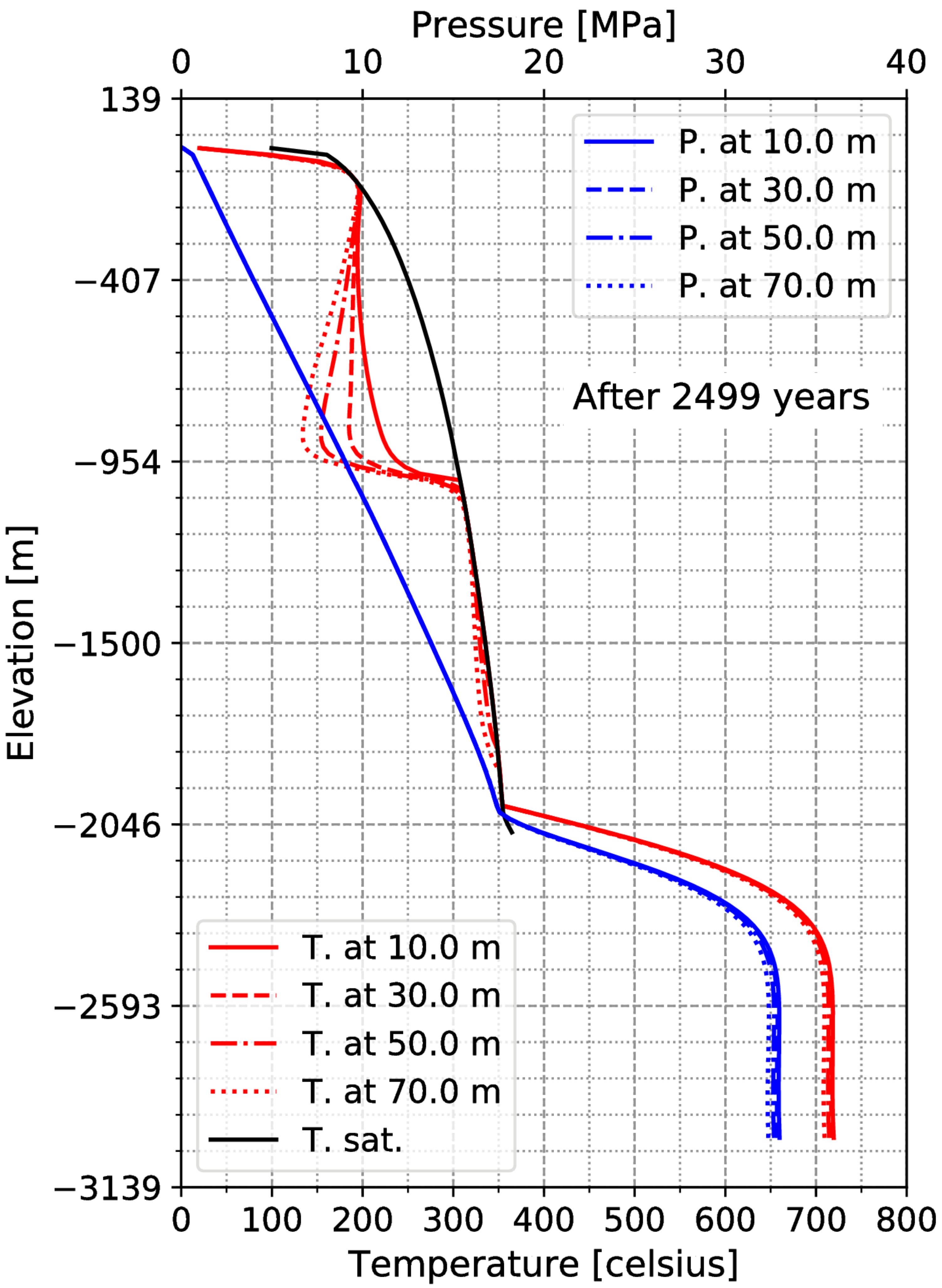
iTOUGH2



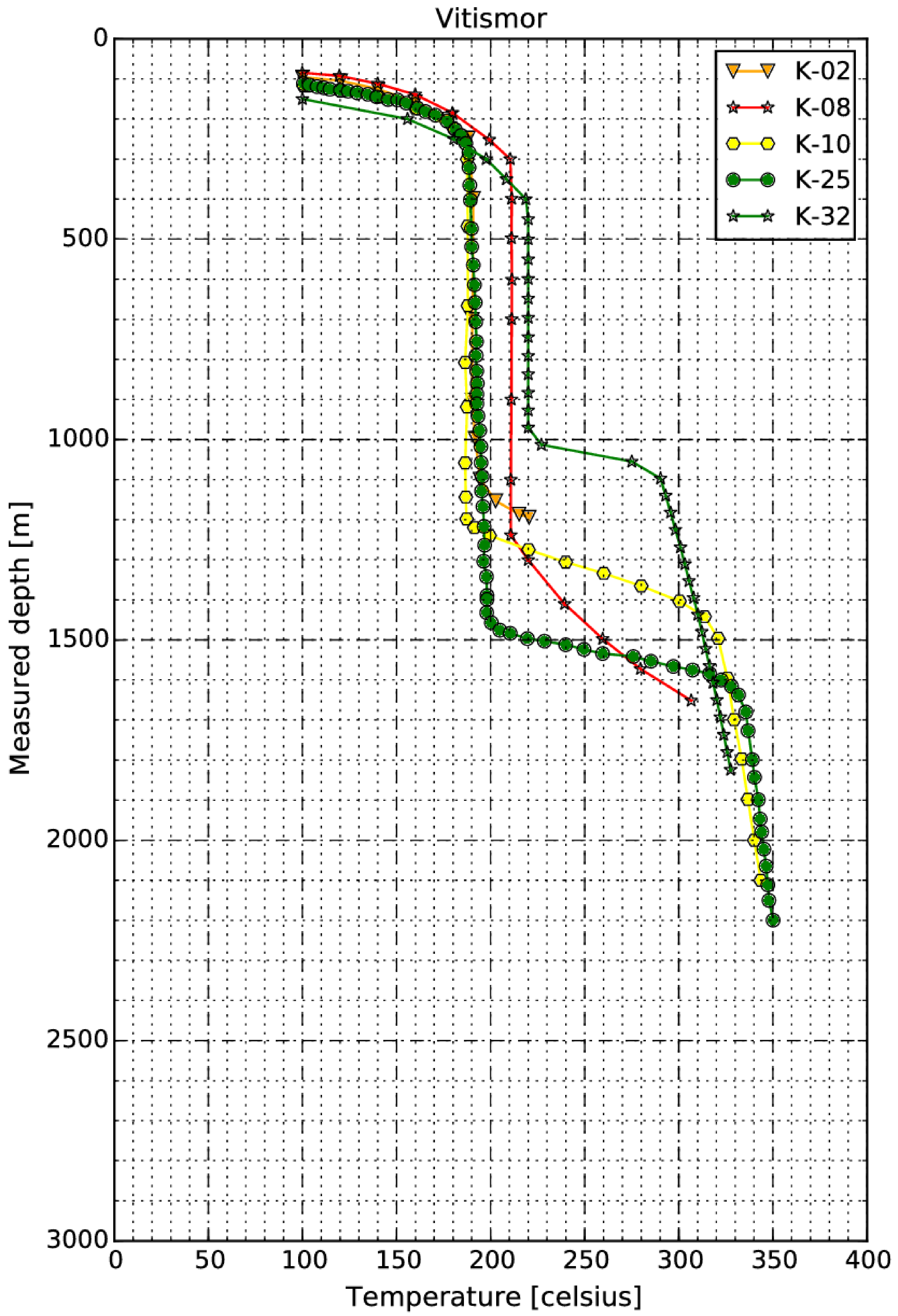
1 bar, 20 °C
k = 50×10^-15 m²
k = 1.2×10^-15 m²
400 m
750 °C
20 m×20 m regular grid in, above and around the pluton
Depth [m]
x [m]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000

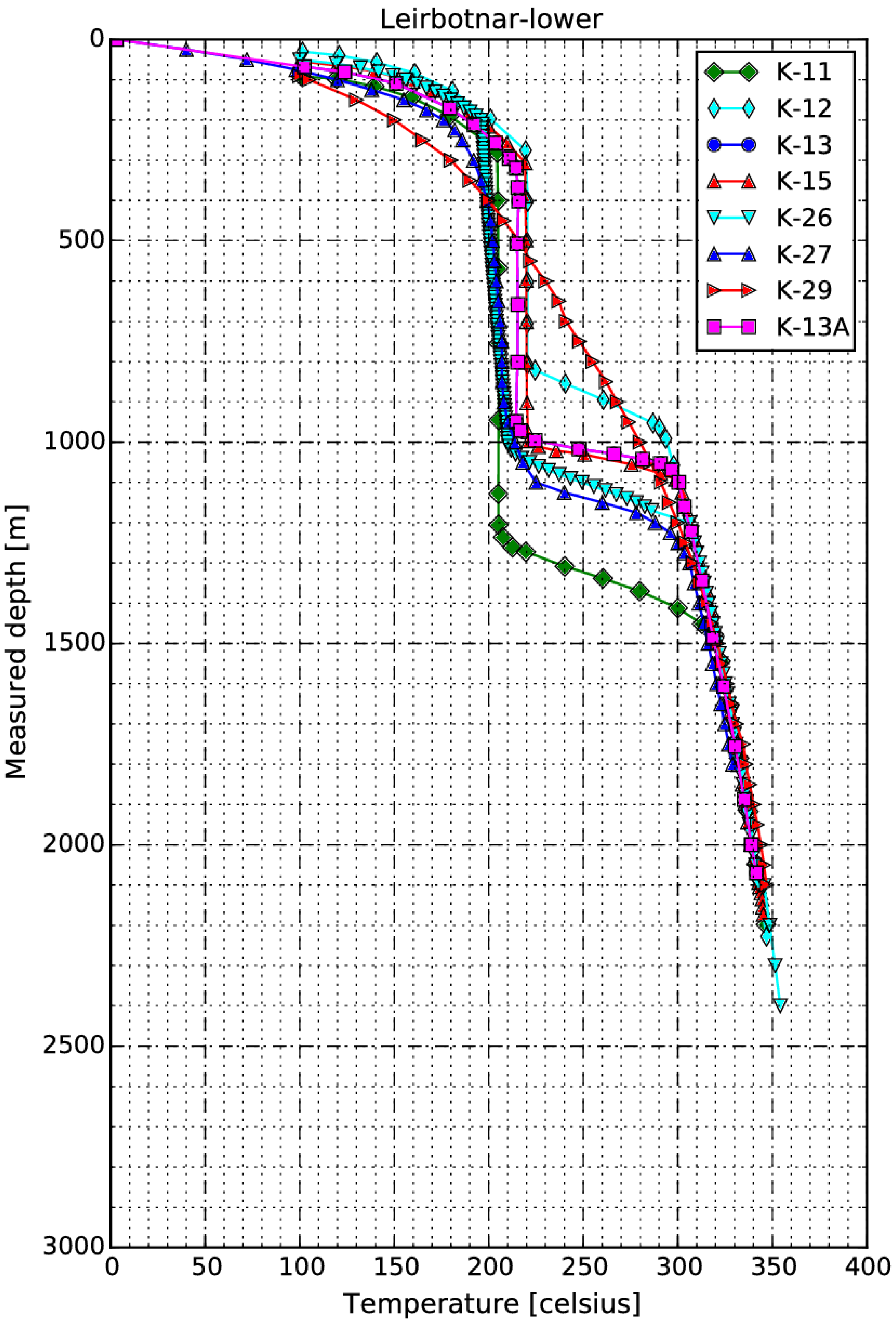
Temperature profile



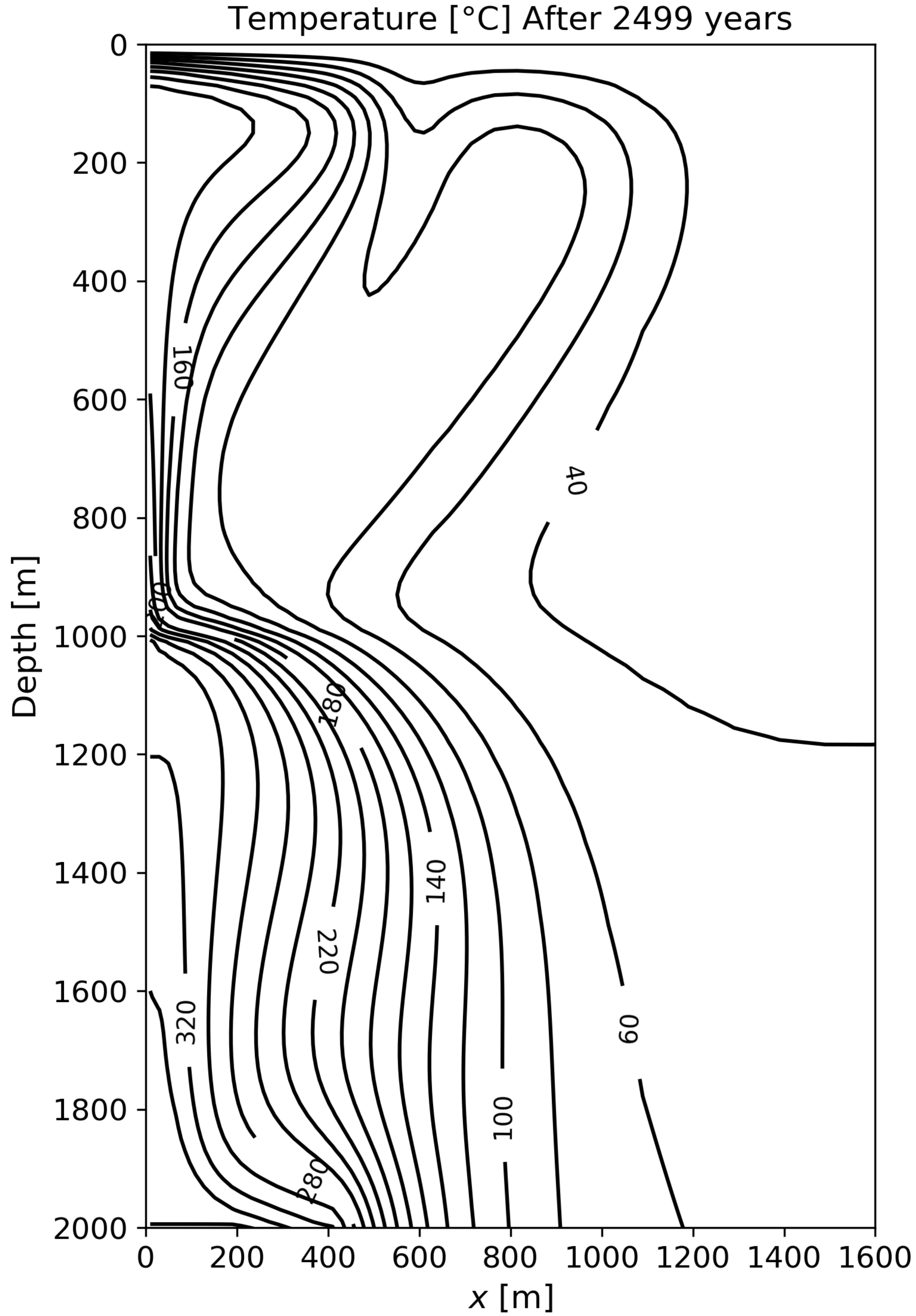


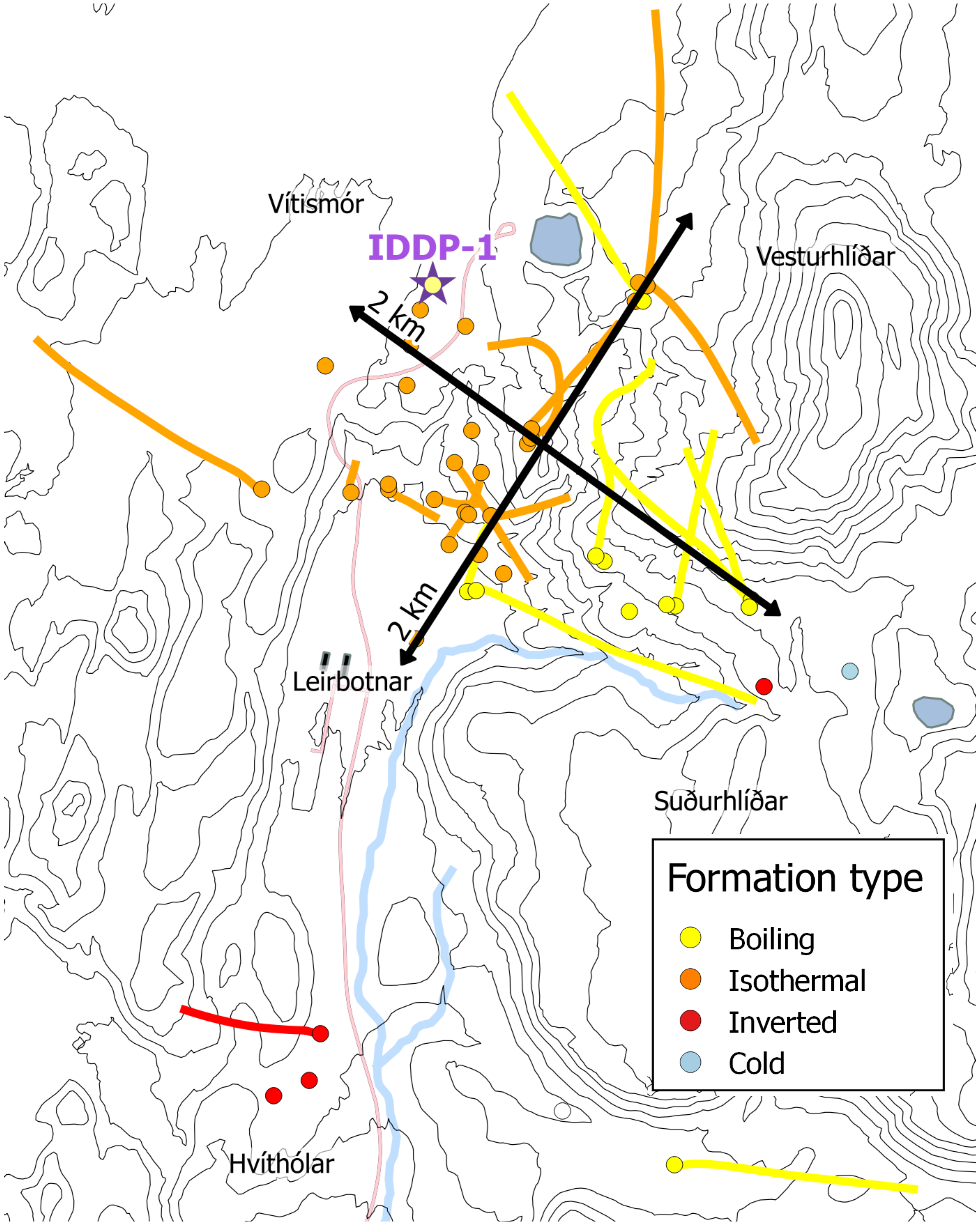
Formation temperature





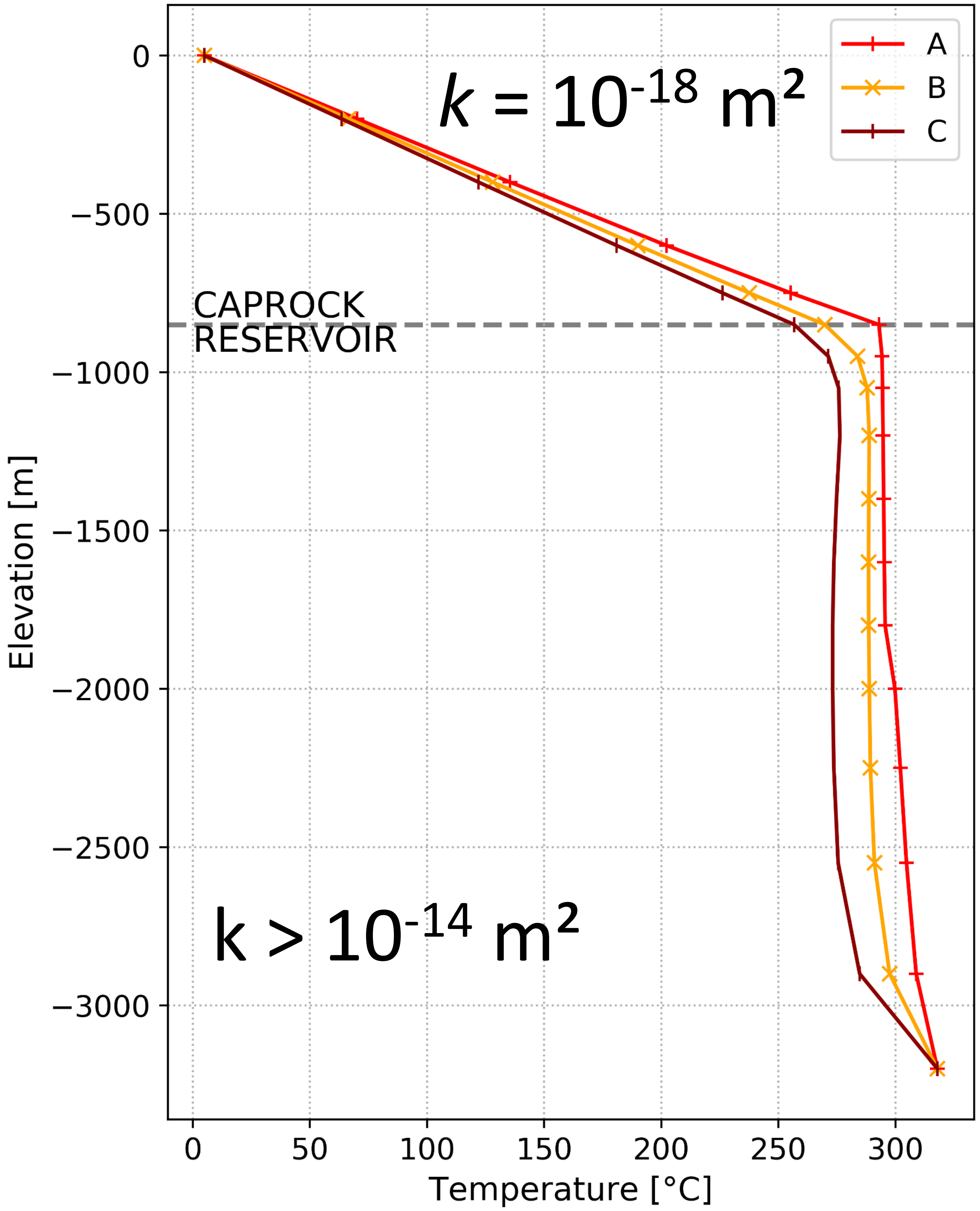
Temperature inversion





3-D Models

- Caprock
  - above 800 m
- Reservoir
  - Below 800 m
  - Uniform temperature
  - Around 290 °C
- Traditional method
  - Heat sources
  - Run to a steady state
- Simulate random intrusions



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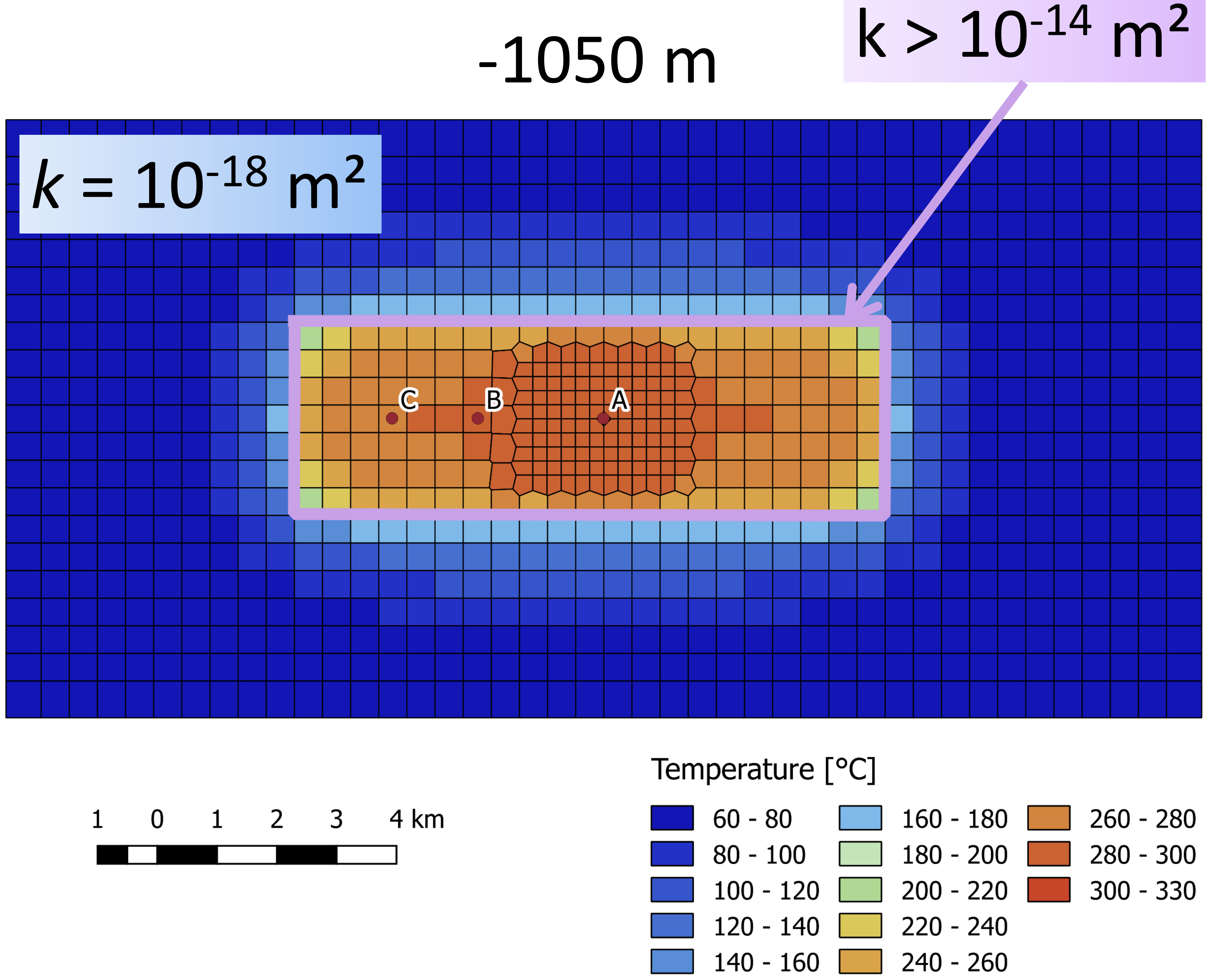
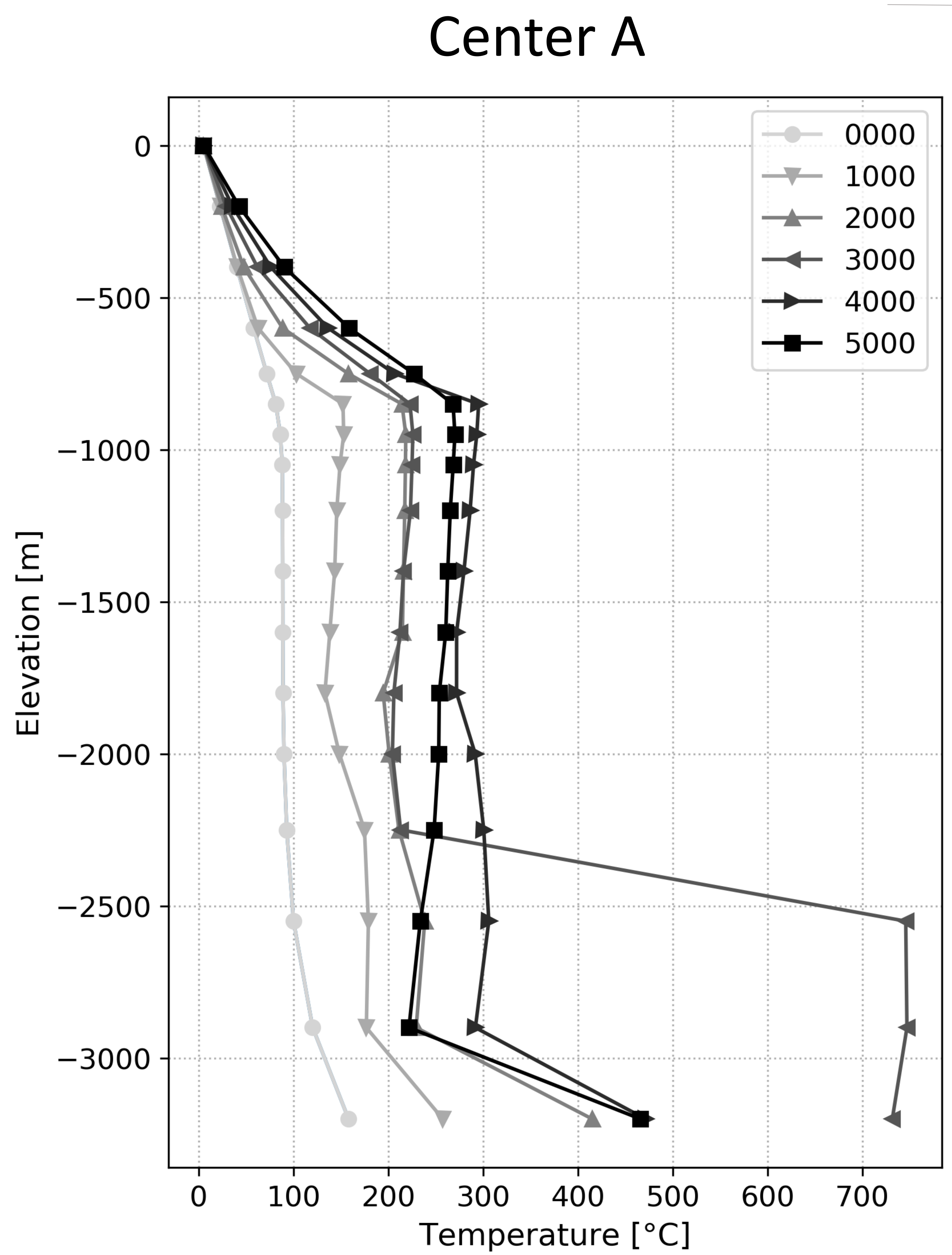


3-D Models

- Simulate random intrusions
  - 3 intrusions per 100 years
  - iTOUGH2 command RESTART

```
>> RESTART TIME: 1 YEAR
   ...
   00519
   OB378 1   75.0e6
   OB378 2  800.0
   PB378 1   75.0e6
   PB378 2  800.0
   QB378 1   75.0e6
   QB378 2  800.0
   ...
```

- 2000 years
  - An intrusion appears below the center of the reservoir.
- 4000 years
  - The intrusion has heated up the center to around 300 °C.



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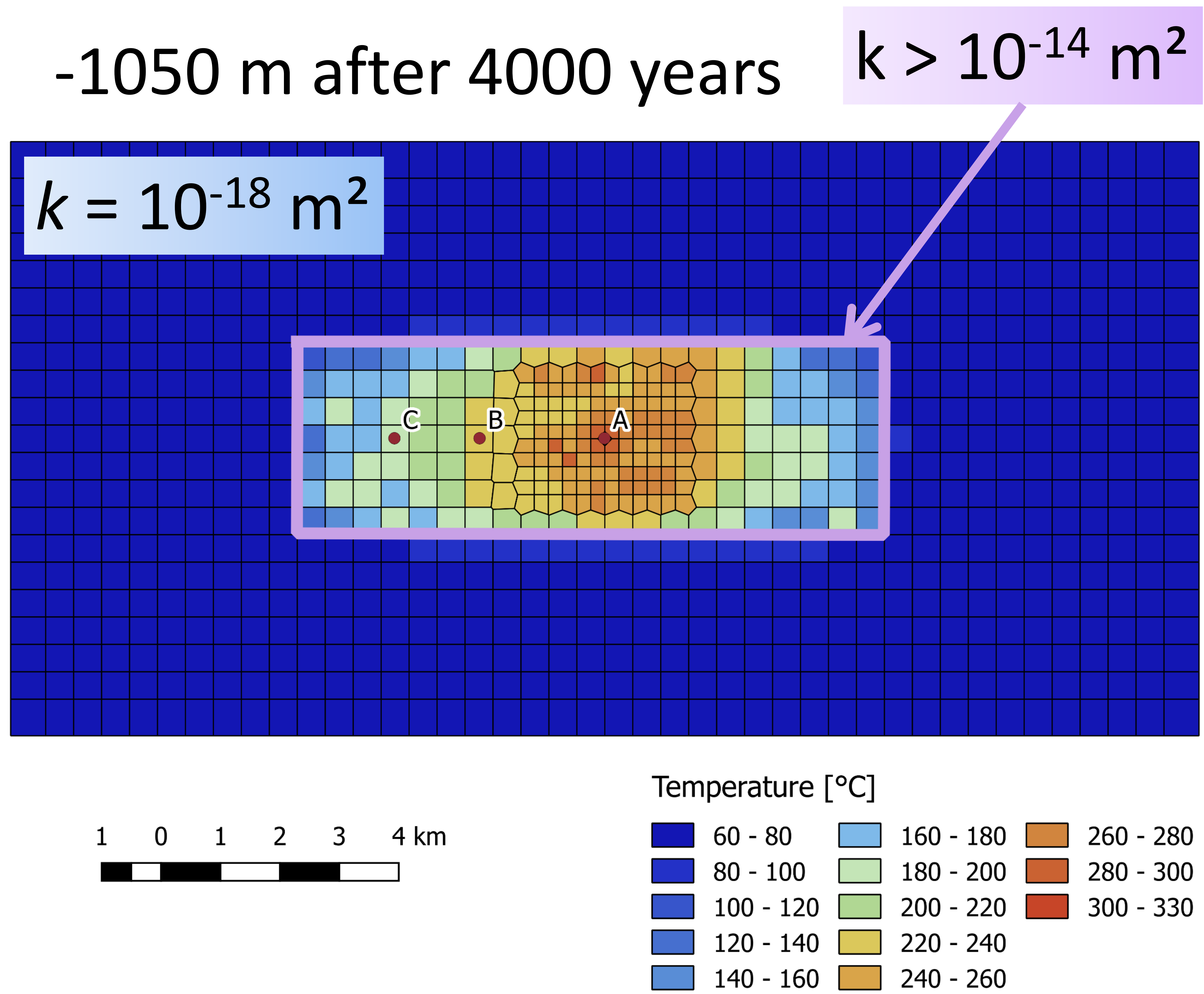
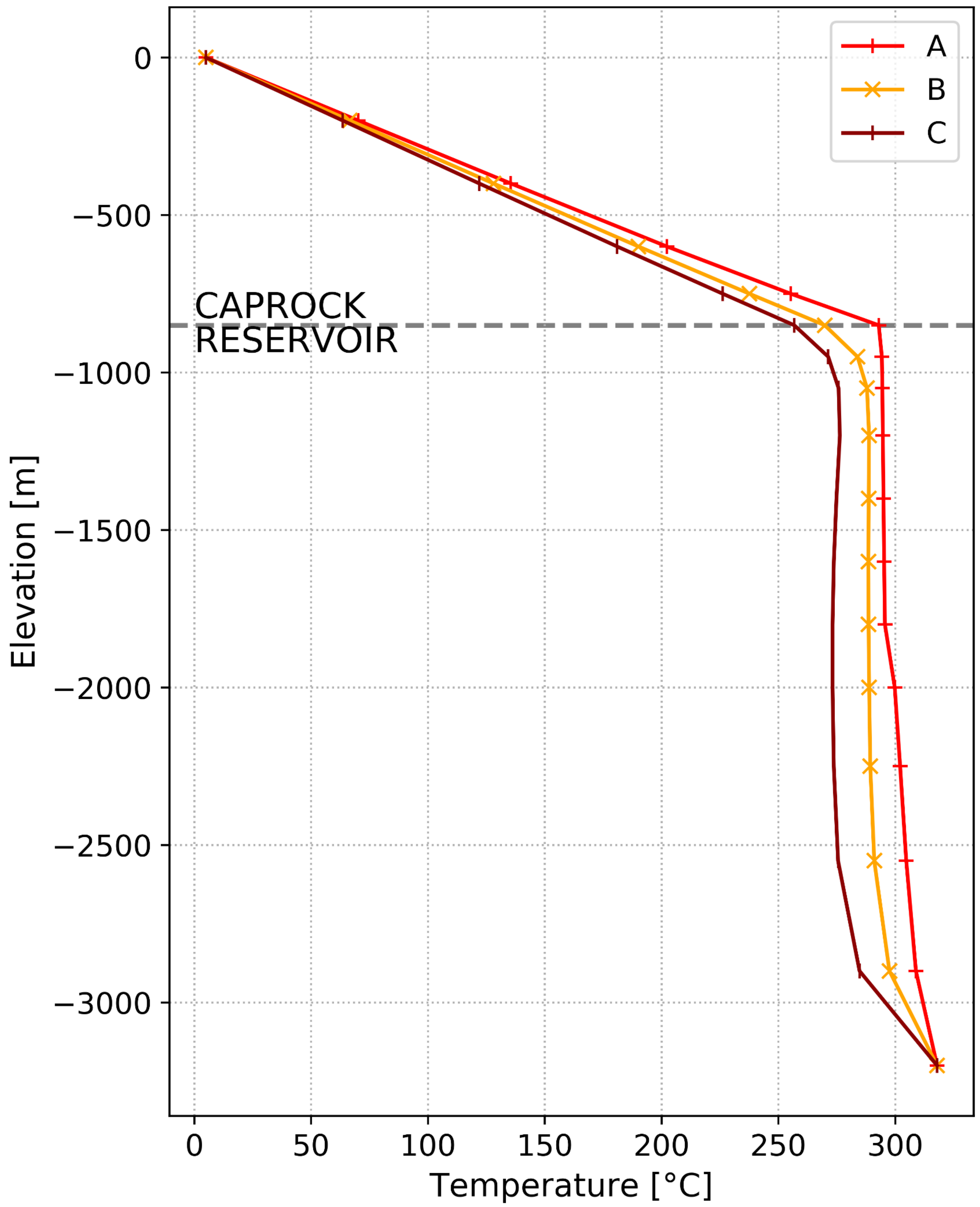
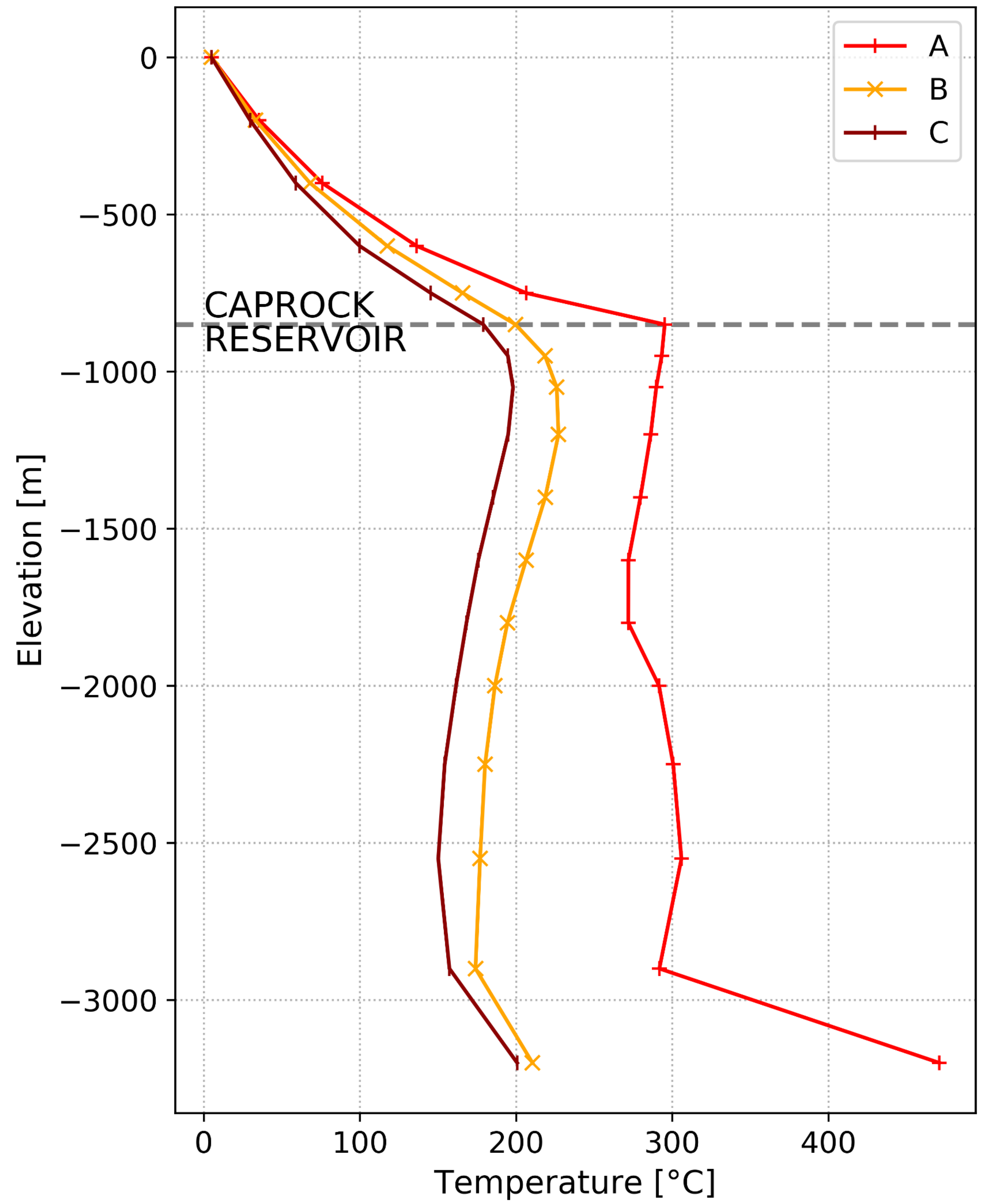


3-D Models

Steady state model



Random intrusion model



Conclusion

- Permeability of the caprock from 1300 m to 2000 m
  - Tight caprock: $k = 10^{-17}$ m²
    - Heat transported by conduction
    - Temperature gradient: 300 °C/km
  - Semi-permeable caprock: $k = 1.2\times10^{-15}$ m²
    - Heat transported by convection
    - Temperature follows the boiling curve
    - Plume too narrow: isothermal within 100 m versus 2 km
  - Solution maybe $k \approx 10^{-16}$ m²
- 3-D simulations