Depth-dependent permeability in crystalline host rock formations

BGE BUNDESGESELLSCHAFT FÜR ENDLAGERUNG

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Hydraulic conductivity and permeability in crystalline rocks

Two of the key minimum requirements for an effective containment zone, a precondition for repository type 1, in crystalline host rock are stated in Section 23 StandAG:

- The hydraulic conductivity must be less than 10^{-10} m/s
- and the surface of an effective containment zone must be at least 300 meters below the ground surface.

- Hydraulic conductivity in crystalline rock is controlled both by transmissive fracture and fault zones and by matrix permeability of crystalline rock blocks (governed by the groundwater flow through effective pore space)
- Yet fracture networks in fault zones determine most of the transmissivity and thus rock permeability in crystalline rock formations in the uppermost continental crust (Faulkner et al. 2010; Mitchell & Faulkner 2012)

An effective containment zone in crystalline rocks?

- About 60% of the permeability data values from Achtziger-Zupančič et al. (2017) show hydraulic conductivity less than 10^{-10} m/s
- The data compilation shows that in a majority of the represented crystalline rock blocks the minimum requirement of hydraulic conductivity (§ 23 para. 5 StandAG) could be fulfilled

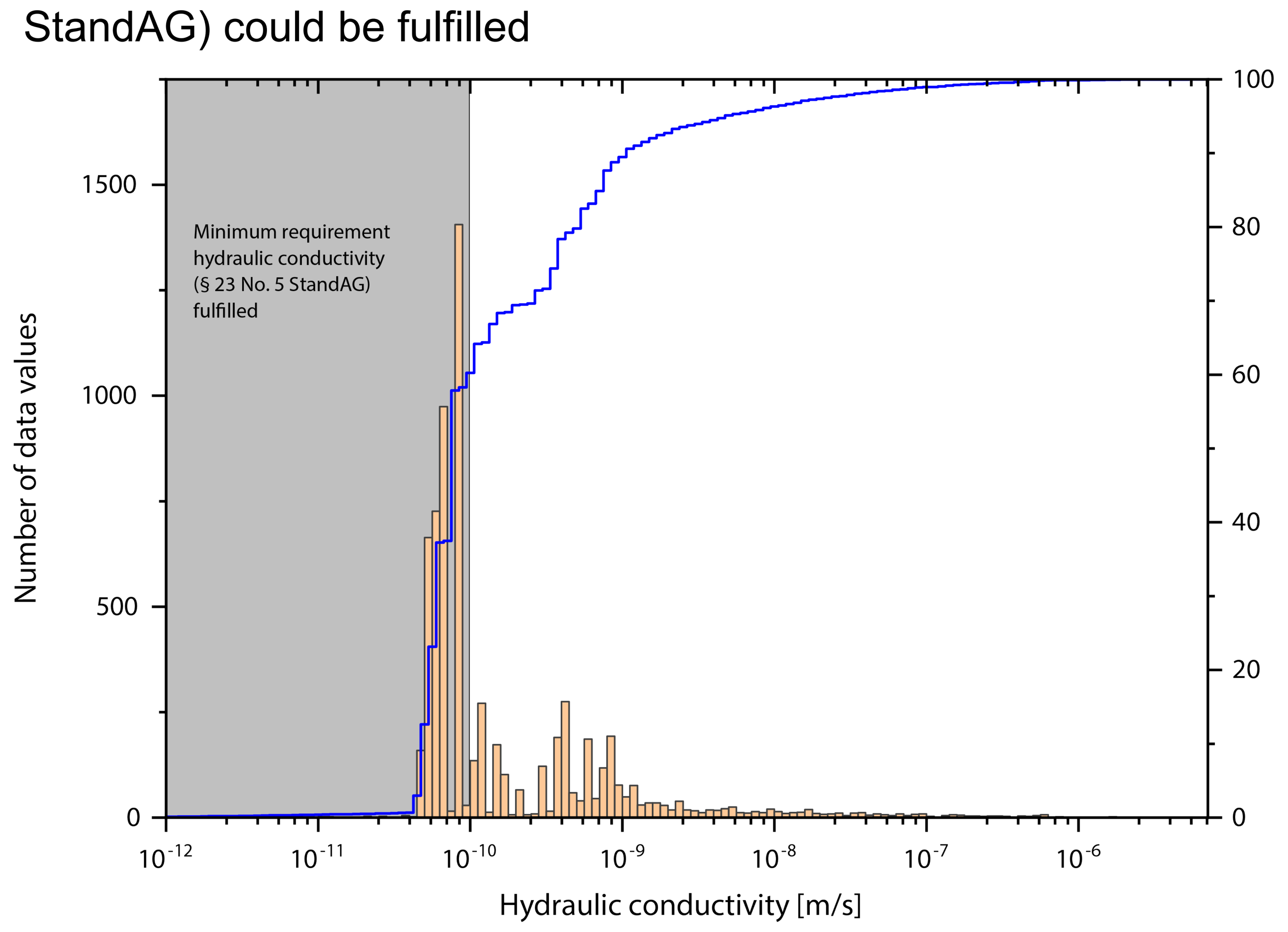

Fig. 1: Histogram showing permeability in crystalline rock formations of the German Ore Mountains [log scale of x-axis]. Cumulative percentage of rock permeability shown as blue curve; data taken from Achtziger-Zupančič et al. (2017).

Permeability data for crystalline rocks

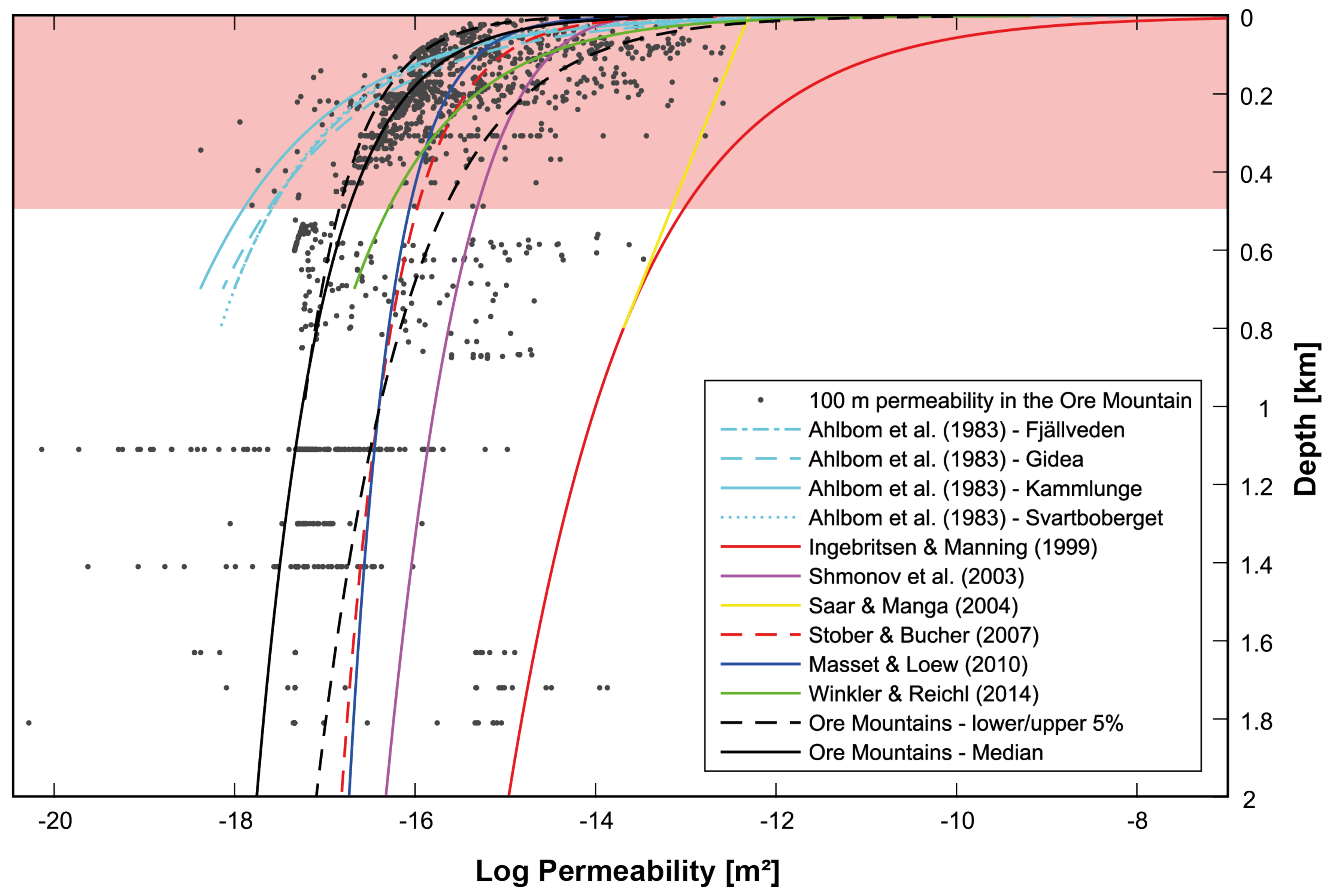

Fig. 2: Comparison of the Ore Mountains (German Erzgebirge) permeability data set (Achtziger-Zupančič et al. 2017) in comparison with other depth regression curves (log median) of permeability values from literature (Ahlbom et al. 1983a; Ahlbom et al. 1983b; Ahlbom et al. 1983c; Ahlbom et al. 1983d; Ingebritsen & Manning 1999; Masset & Loew 2010; Saar & Manga 2004; Shmonov et al. 2003; Stober & Bucher 2007; Winkler & Reichl 2014);
Data from Achtziger-Zupančič et al. 2017 plotted as regression through the log median, the 5% and 95% quantiles of the galleries and mine levels, or 100m depth intervals of ore fields/mines; Red colouring outlines the higher hydraulic conductivity in the upper 500 m in crystalline host rock formations (greater than 10^{-10} m/s);
Figure modified after Achtziger-Zupančič et al. (2017).

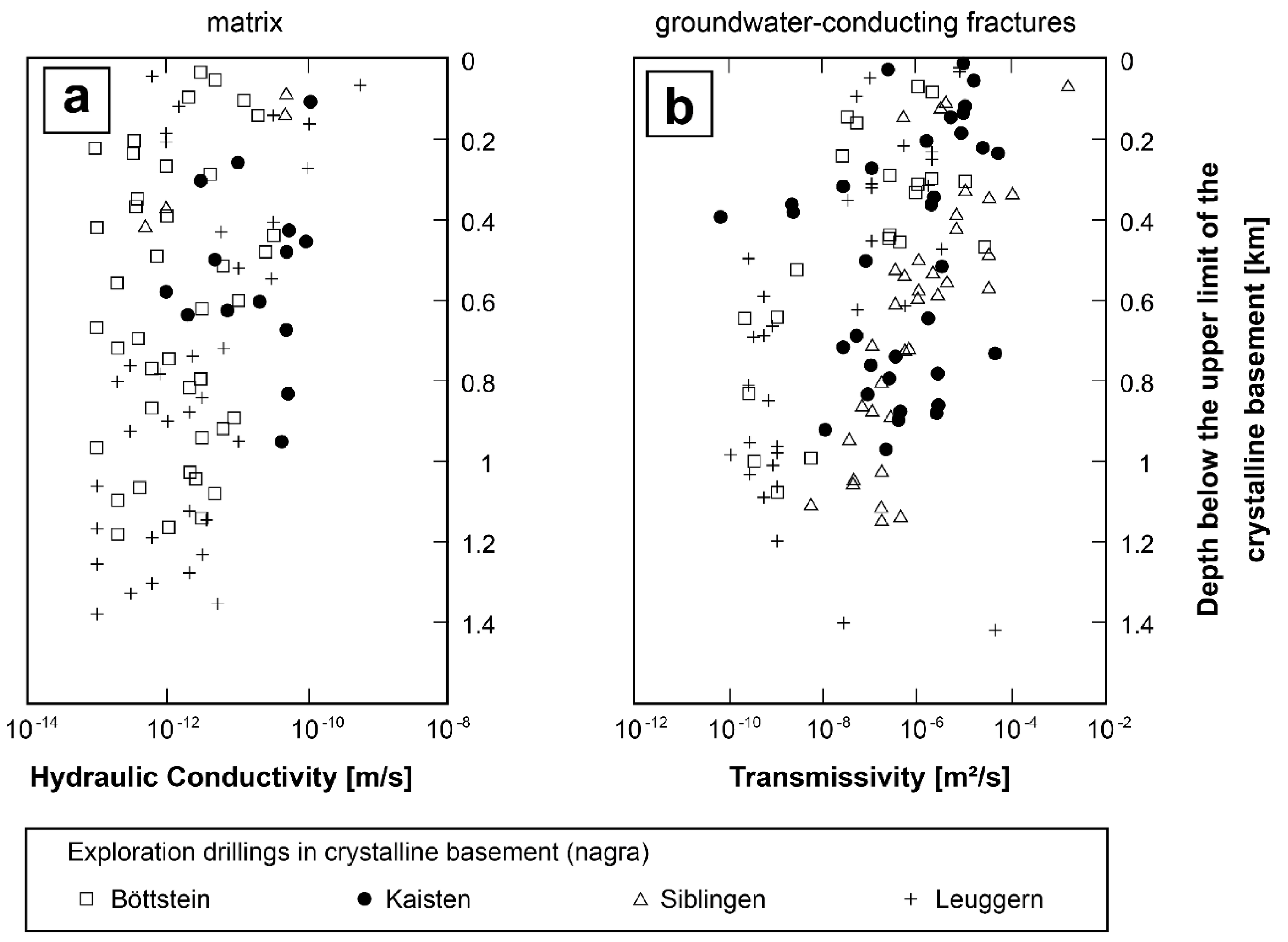

Fig. 3: Hydraulic data set from northern Switzerland (crystalline rock exploration by nagra); Hydraulic properties vs. Depth; a) log hydraulic conductivity of crystalline rock blocks, b) log transmissivity of water-conducting fractures; Figure modified after Nagra (1994)

Optimum repository depth in crystalline host rocks at greater depths?

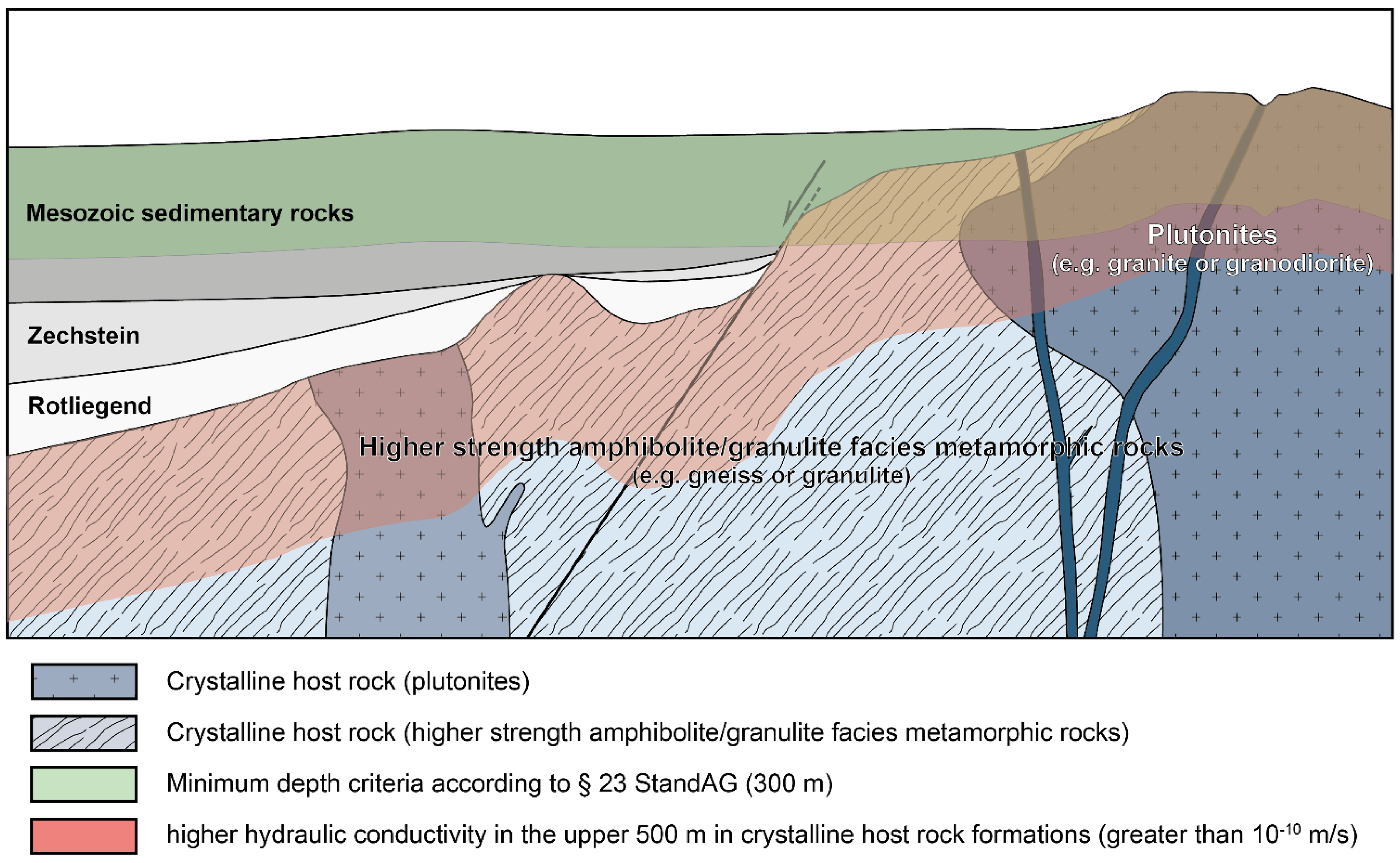

Fig. 4: Generic geological model of hydraulic conductivity in crystalline host rocks in Germany.
Red colouring outlines the higher hydraulic conductivity in the upper 500 m in crystalline host rock formations (greater than 10^{-10} m/s).

- Although a large horizontal variation of permeability values (by orders-of-magnitude due to fracture networks around fault zones) can be observed for different depth levels, the mean vertical permeability values decrease with depth
- The presented hydrogeological data sets (Fig. 2 and 3) show that the minimum requirement of hydraulic conductivity (less than 10^{-10} m/s) is, on median, only achieved at depths of at least 500 metres within crystalline host rock formations
- With increasing depth, matrix permeability in crystalline rock blocks should become more important (Fig. 3)
- Yet, even at greater depth than a few hundred metres, steep dipping conductive fractures in major regional fracture zones control groundwater flow (Faulkner et al. 2010; Mitchell & Faulkner 2012)
- Based on the existing hydrogeological data, we discuss an optimum repository depth for repository type 1 systems within crystalline host rock formations (Fig. 4)

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