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Mineral stability, brine development and rock-fluid reaction at repository-relevant temperatures ($T < 200\,°C$) in the potential host rock rock salt

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Mineral stability, brine development and rock-fluid reaction at repository-relevant temperatures (T<200°C) in the potential host rock rock salt

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Indroduction

For a repository of heat generating, radioactive waste, the thermal behaviour of the host rock and the impact of temperature increase on rock properties is of general importance. In the German Site Selection Act (2017), the maximum temperature of the container surface is precautionary limited to 100°C, but this limit might change in future, based on scientific and technological findings.
Rock salt, as one of the possible host rocks, consists predominantly of halite with varying amounts of accessory minerals (e.g. Hudec & Jackson, 2007). However, some lithological units within a salt deposit, e.g. potash seams, show a different mineralogical composition with high amounts of potash minerals. Most of them are not very stable regarding temperature resistance and stress. They contain water in the crystal lattice, and therefore react sensitive on changes in their environment.

Examples

The melting point of most evaporite minerals is higher than the expected temperatures in a repository, but dehydration and partial melting might occur at relevant temperatures (Fig. 1).

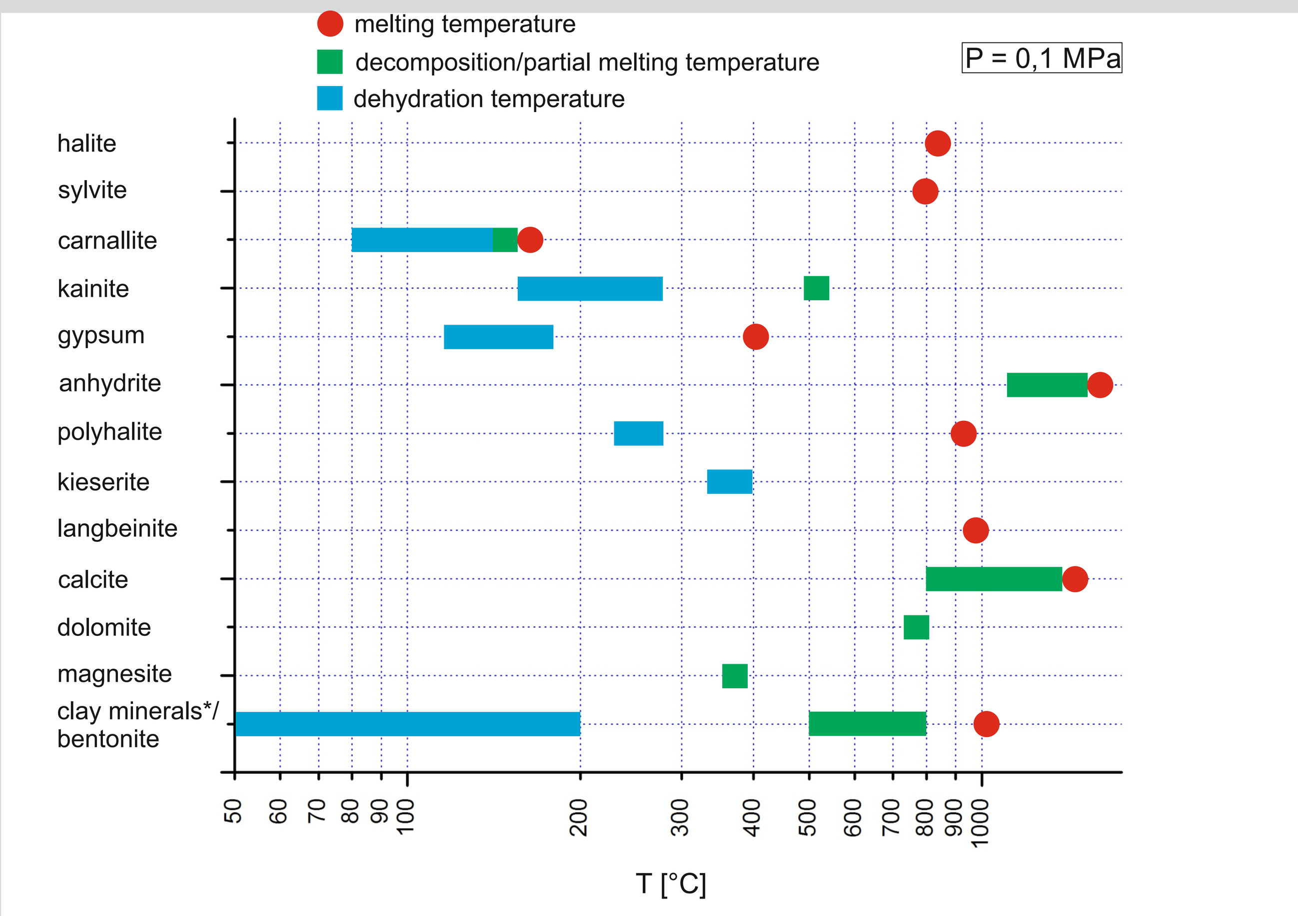

Fig. 1: Melting-, decomposition/partial melting- and dehydration temperatures of evaporate and accessory minerals at atmospheric pressure. *clay minerals are generalized and refer to the properties of the smectite and illite groups. From BGR (2016), extended and modified.

Further, the influence of confining pressure plays a significant role for the thermal properties of minerals and rocks. For example, the dehydration temperature of carnallite is ca. 80°C at 0.1 MPa confining pressure, but increases to ca. 145°C at 10 MPa confining pressure (Kern & Franke, 1986). The melting point of carnallite increases from ca. 145°C/8 MPa to ca. 167°C/24 MPa (Fig. 2), which corresponds to a depth of ca. 1000 m.

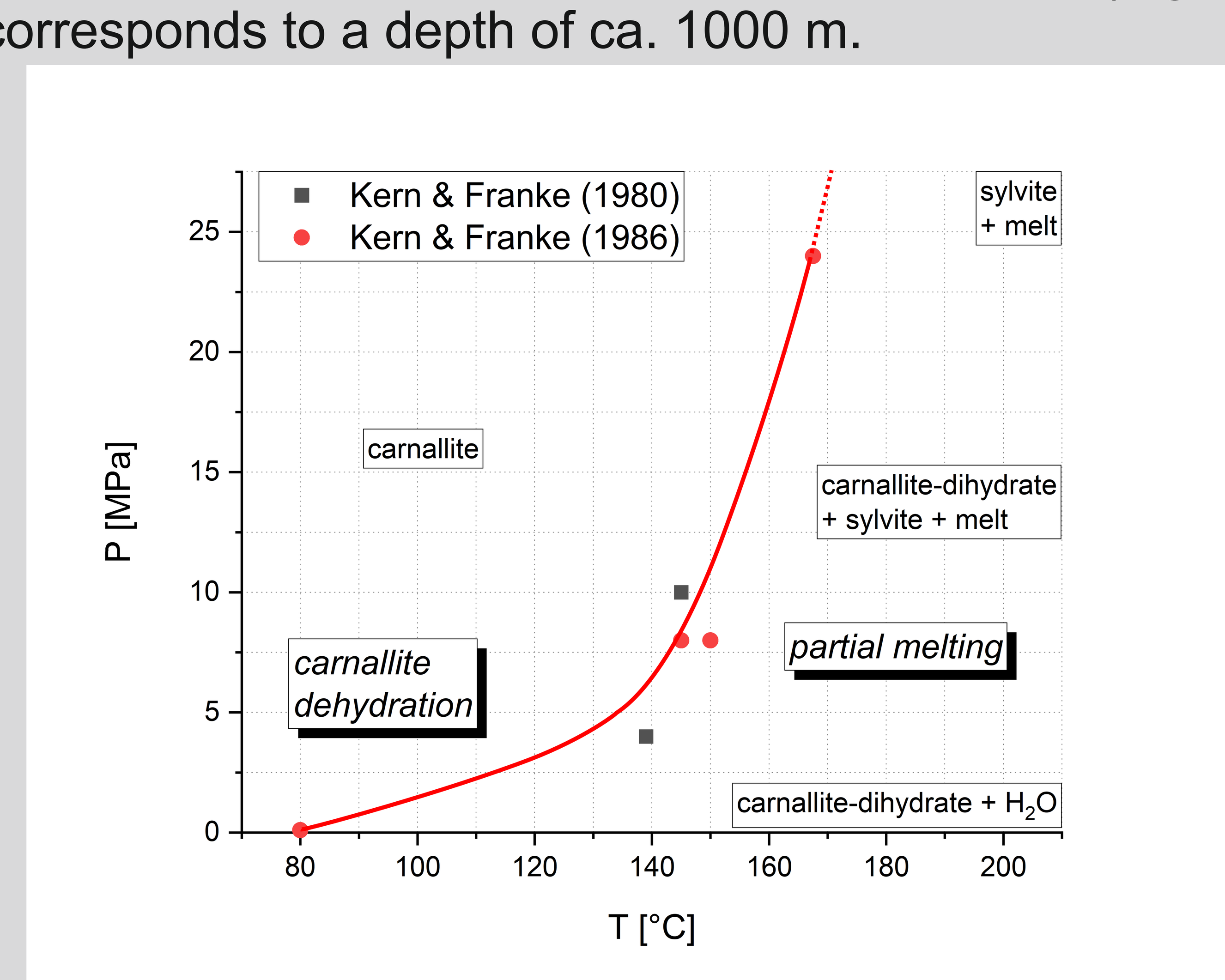

Fig. 2: P-T-diagram of carnallite. From Kern & Franke (1980, 1984, 1986), modified.

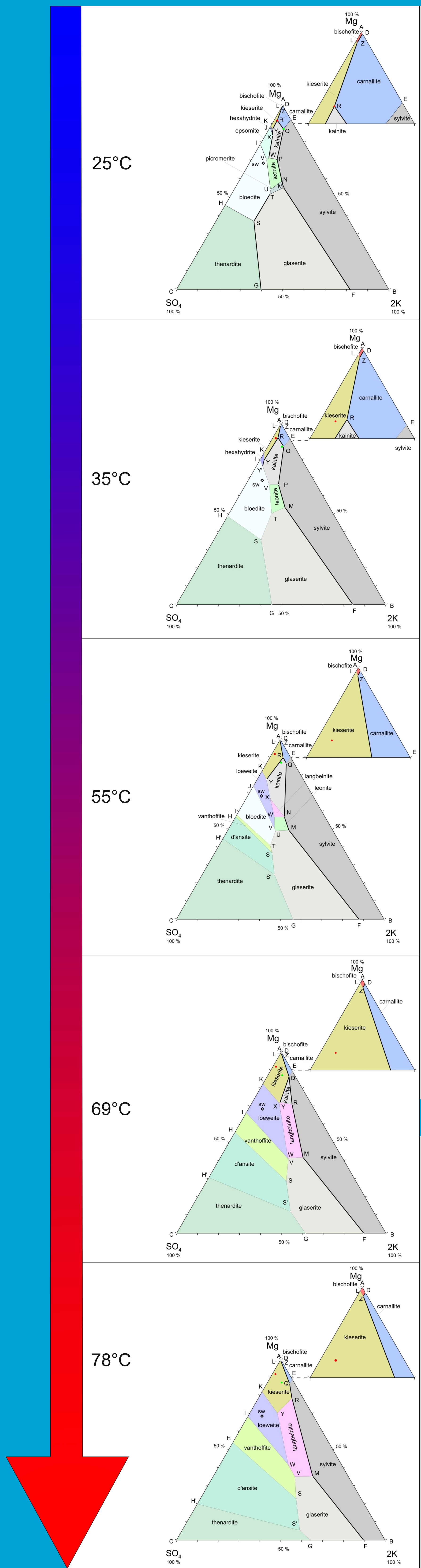

Fig. 3: Jänecke-diagram at 25°C, 35°C, 55°C, 69°C and 78°C. The upper part (90-100% Mg, 0-10% 2K, 0-10% SO_4) is enlarged. SW = Seawater. Points A to Z see Usdowski & Dietzel (1998). From Usdowski & Dietzel (1998), modified.

Dependent on the mineral paragenesis and composition of saline solutions, different minerals develop with increasing temperature (Fig. 3; Usdowski & Dietzel, 1998). For instance, a salt rock with an initial composition of

kieserite + kainite + carnallite + solution $R_{25°C}$ (91.9% Mg; 1.5% 2K; 6.6% SO_4)

reacts solely to

kieserite + solution,

when the temperature increases from 25°C to 78°C, symbolized by the red point (Fig. 3).

A rock with a composition of

kainite + carnallite + sylvite + solution $Q_{25°C}$ (87.2% Mg; 6.8% 2K; 6.0% SO_4)

reacts between 35°C and 55°C to

kainite + solution,

from 55°C to 78°C

kieserite + solution

is stable, symbolized by the green point (Fig. 3).

Conclusions

For the site selection, design and construction of an underground repository, the mineralogical composition of the host rocks and fluids and their spatial distribution have to be evaluated carefully. Some minerals (e.g. carnallite) react sensitively to elevated temperature and pressure due to dehydration, decomposition or melting. Brines in salt rocks can change their mineral saturation status when temperature increases. This can cause dissolution or precipitaion of minerals.

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