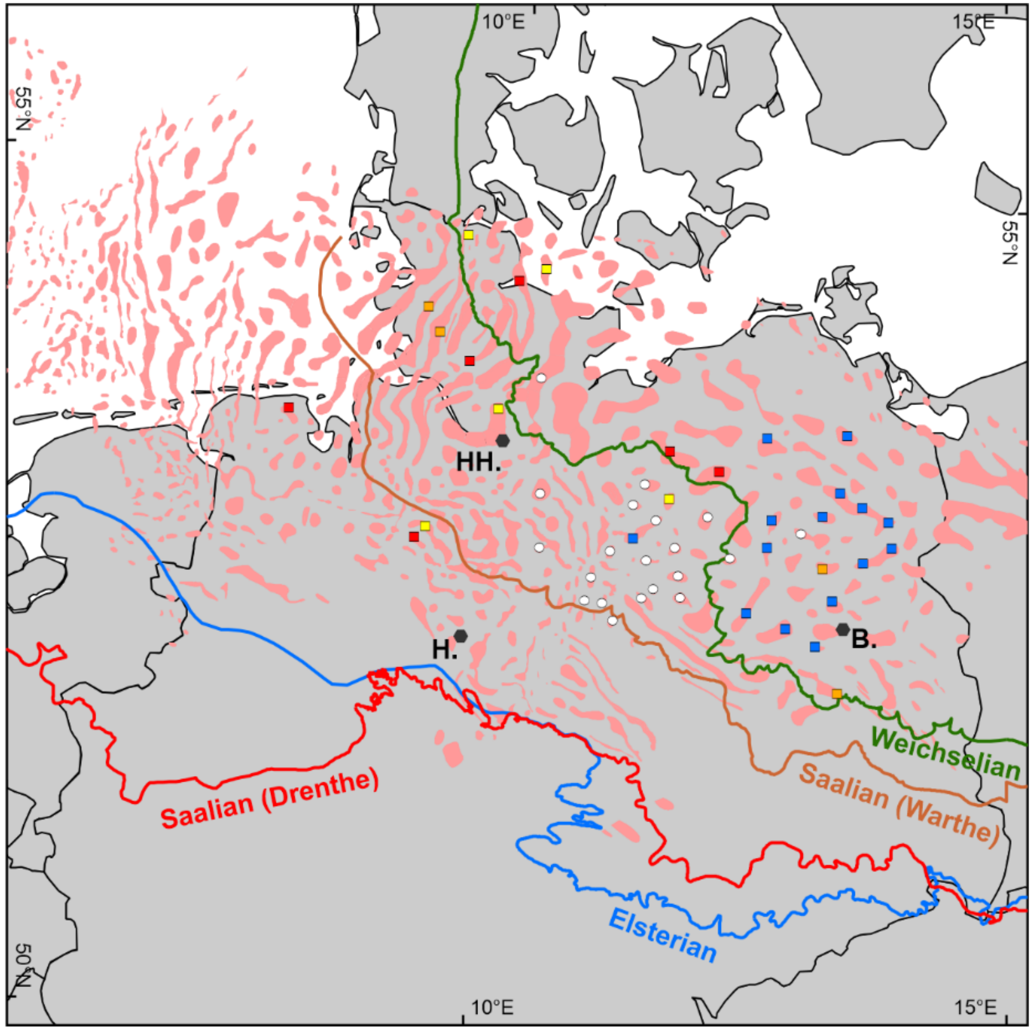
Ice-load induced salt movement – Insights into the controlling parameters from numerical modelling

Jörg Lang[1)] & Andrea Hampel[2)]

1) Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Germany (Joerg.Lang@bgr.de)

2) Institut für Geologie, Leibniz Universität Hannover, Germany



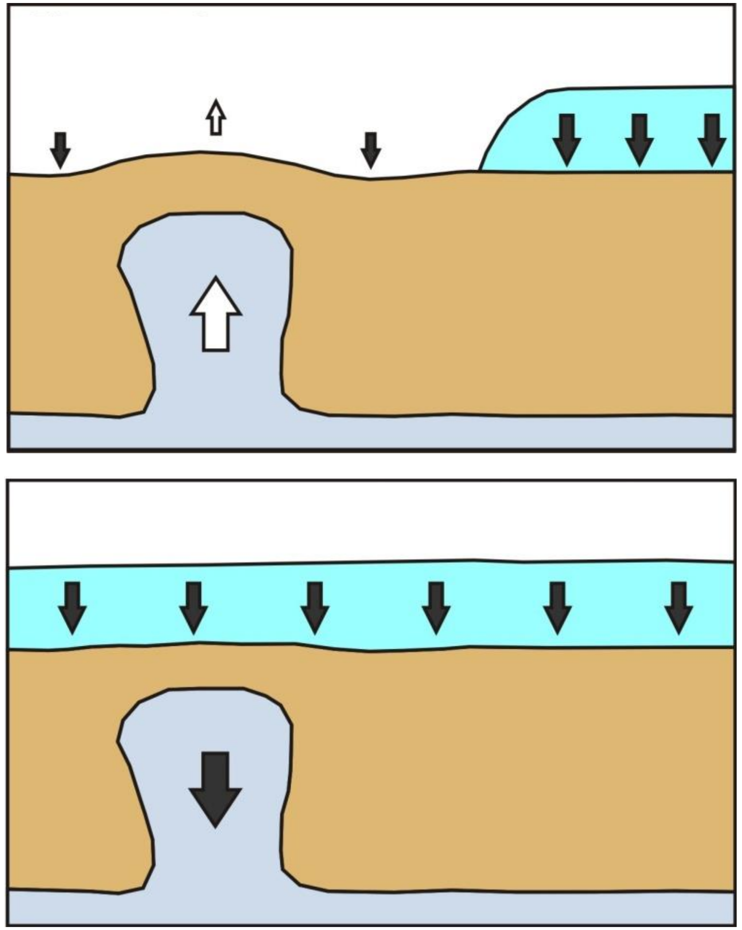
(Ice margins: Ehlers et al. 2011; Winsemann et al. 2020; salt structures: Warsitzka et al. 2019; active salt structures: Illies 1955; Hurtig 1965; Sirocko et al. 2008; Al Hseinat et al. 2016; Hardt et al. 2021)

Introduction

- All salt structures in northern Germany have been at least once covered by Pleistocene ice sheets
- Many salt structures display indicators for Pleistocene to Holocene activity, like faulting or topographic expressions

➢ Is young salt movement related to ice loading during the Pleistocene?

Conceptual model:

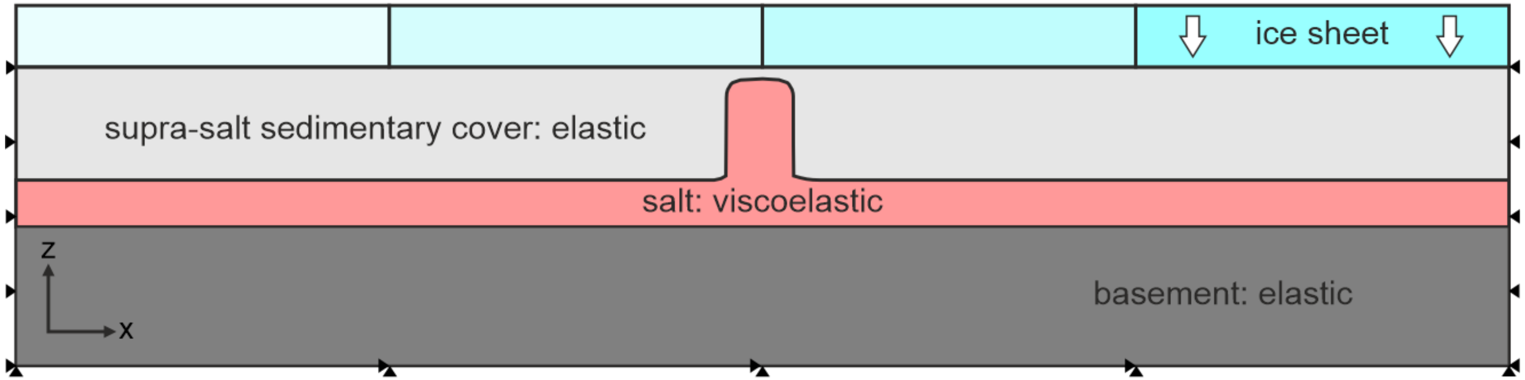


(modified after Liszkowski 1993; Sirocko et al. 2008; Lang et al. 2014)

Do salt structures respond to ice-sheet loading?

- Conceptual models are supported by numerical modelling (cf., Lang et al. 2014)
- Controlling parameters need to be better explored!

Model set-up (simplified):



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Behaviour of salt rocks

Salt rocks may deform by linear solution-precipitation creep and non-linear dislocation creep

Linear viscosity (most geologist's models)

$$\dot{\varepsilon} = \frac{\sigma}{\eta}$$

ε: strain rate

σ: stress

η: viscosity

Power-law creep (most engineer's models)

$$\dot{\varepsilon} = A * \sigma^n = A_0 \exp\left(-\frac{Q}{R * T}\right) * \sigma^n$$

A: pre-exponential factor

n: exponent (e.g., BGRa: n=5)

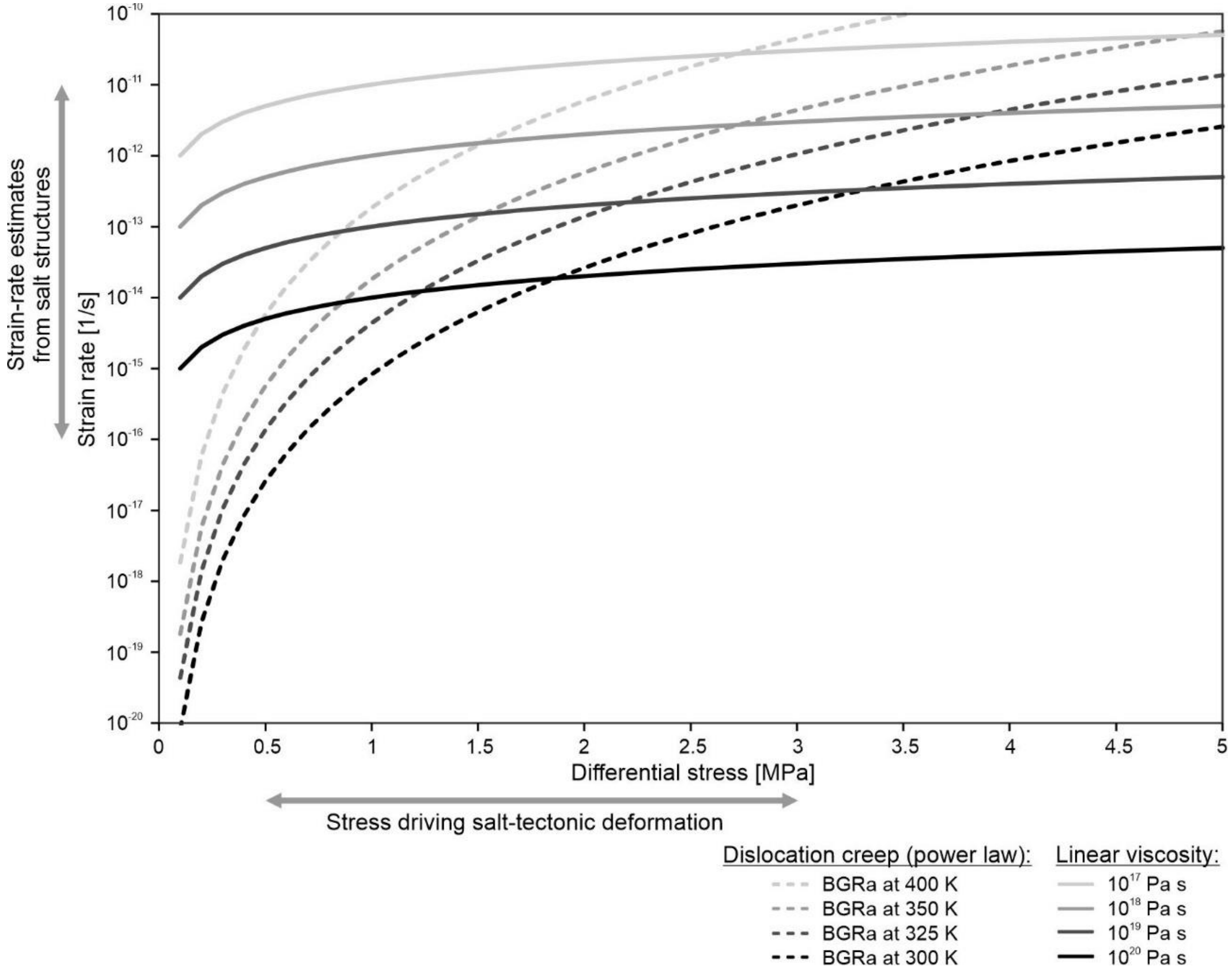
Q: activation energy

R: universal gas constant

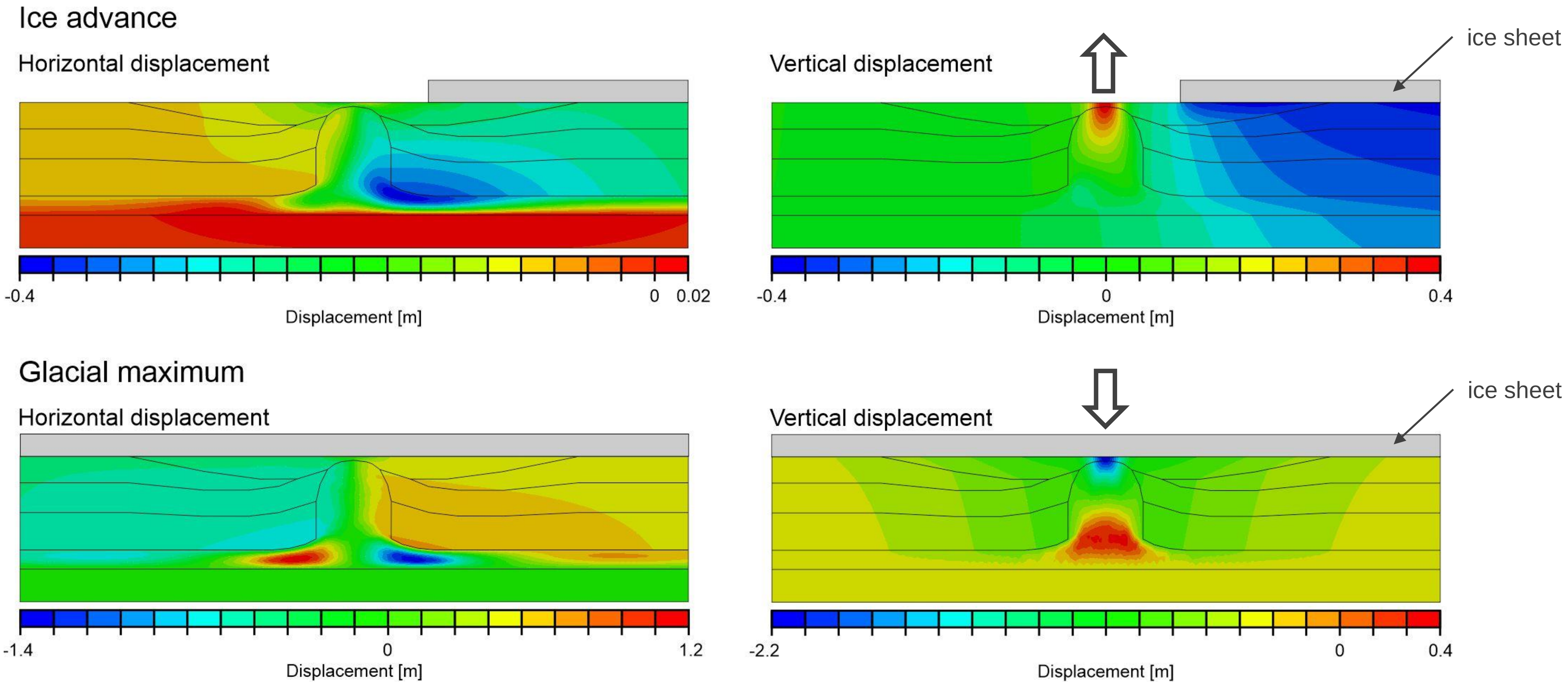
T: temperature

A_0: material-dependent parameter

(e.g., BGRa: A_0=0,18 1/d = 2,08*10^{-6} 1/s)

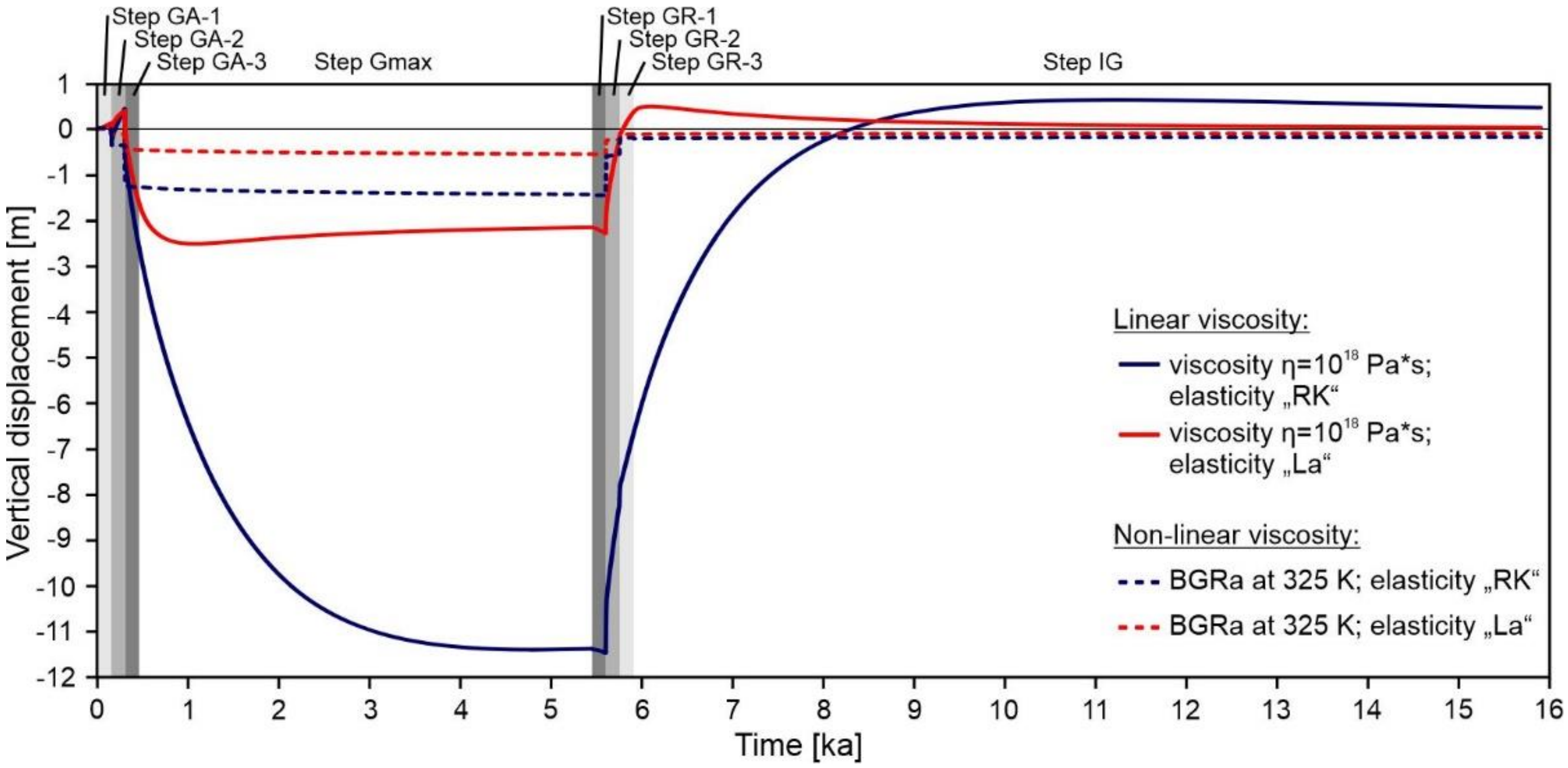


Deformation of the model section by ice loading



Ice loading triggers salt flow: the salt structure rises in front of the ice sheet and falls below the ice sheet

Parameter study – main results



- Linear vs power-law viscosity
- Two different sets of elastic parameters

Linear viscosity always allows for larger displacements => appropriate due to low stress and long time-scale

Elasticity may have a larger impact than viscosity => careful parameter choice required

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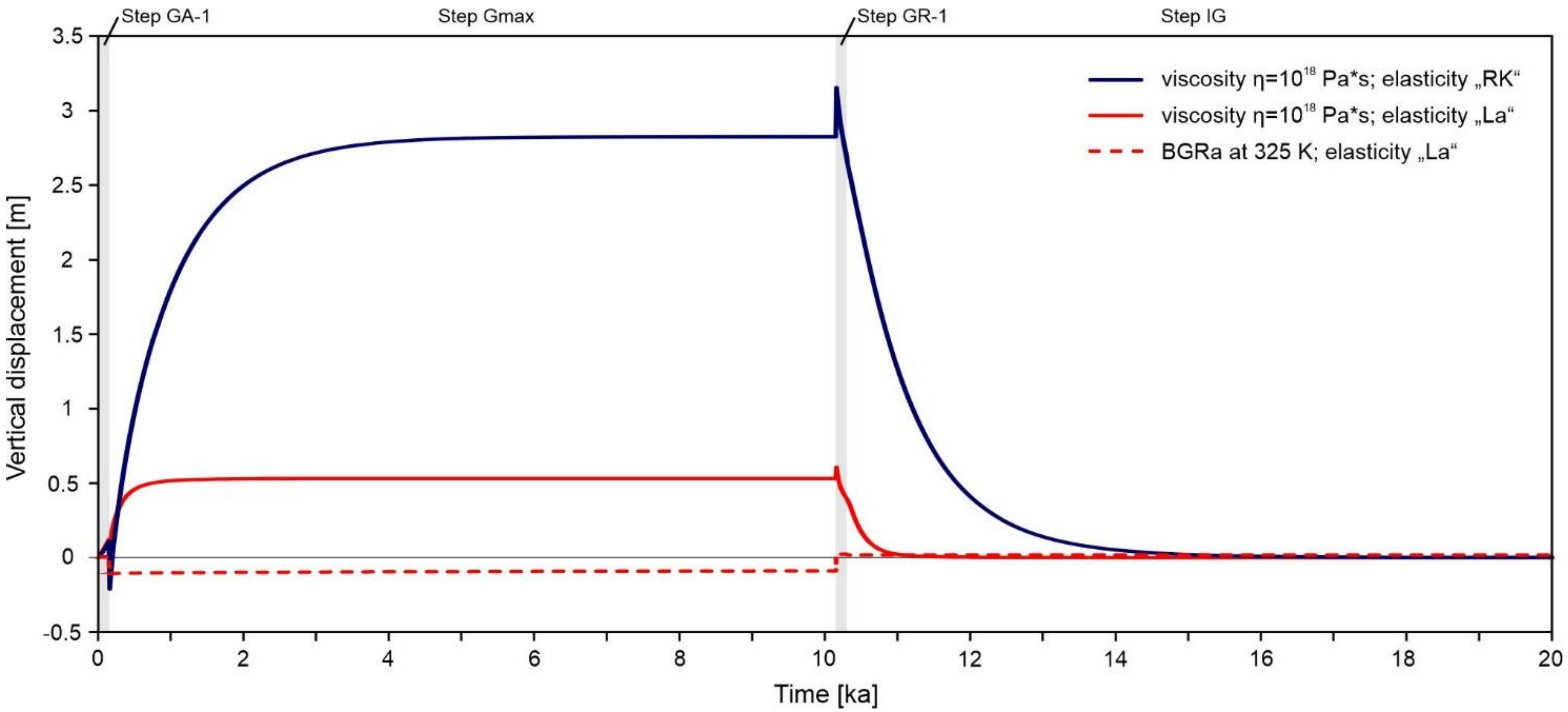
Further tested parameters



- **Ice-margin configuration**
- Internal architecture of the salt structure
- Duration of loading and unloading phases
- Rheology of the salt rocks
- Thickness of the overburden

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Summary & Outlook

- Salt structures respond to ice loading: an ice advance towards the salt structure causes lateral salt flow and rise of the salt structure; complete ice coverage leads to downward displacement of the salt structure
- Linear viscosity allows for larger displacements than power-law viscosity; at the considered stress levels and time scales, linear viscosity seems appropriate
- Elasticity may have a larger impact than viscosity and thus needs to be considered
- Future models will use more realistic geometries; results will be compared to field examples