Sinah Kilian[1], Hugo Ortner[1], Barbara Schneider-Muntau[2]

[1]Institute of Geology
[2]Unit of Geotechnic and Tunnel Engineering

Numeric modelling of thrust sheet geometries: an example from the Northern Calcarous Alps

GEOLOGIE INNSBRUCK

RESEARCH INTEREST

BACKGROUND

This research investigates the behavior of thrust sheets using an example from the western Northern Calcareous Alps (NCA) fold- and -thrust belt. The structures above the major thrust (Karwendel thrust Fig.1) in the Karwendel mountains gave the initial motive. The Karwendel thrust runs for kilometres along a flat décollement horizon (Reichenhall Fm. or Haselgebirge). The thrust plane is very similar to a upper footwall flat nevertheless the large scale structures (Kilian&Ortner, 2019) in the Karwendel thrust sheet show buckle fold geometries.

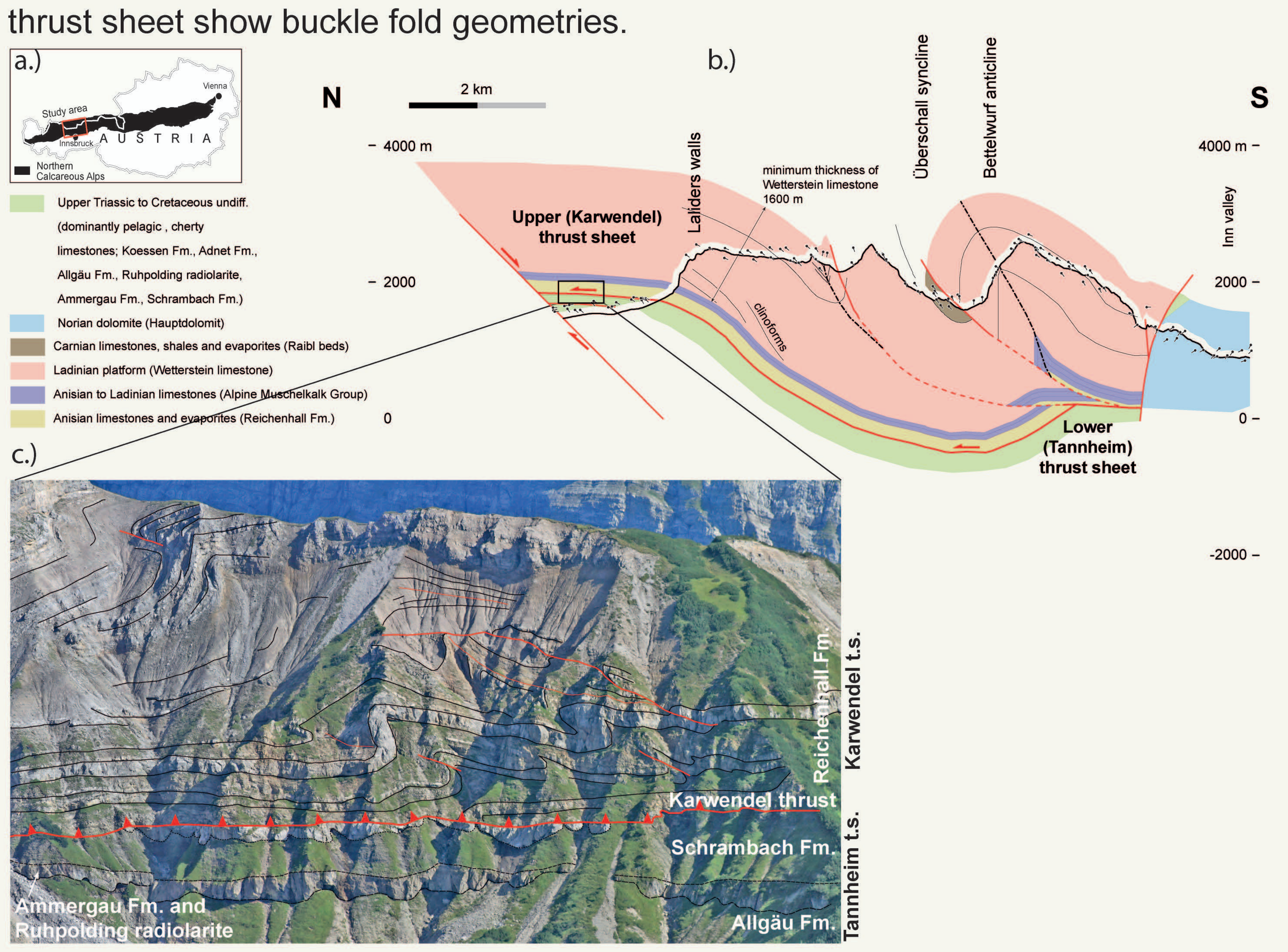

Fig. 1: a.) Study area b) Large scale buckle folds in the Laliders section across the Karwendel mountains.The main thrust is parallel to bedding in both hanging wall and footwall. c.) Medium scale buckle folds in the hanging wall. Image section approx. 246 m, t.s.=thrust sheet.

NUMERIC MODEL SETUP

Buckle fold geometries above a hanging wall flat do not fit the common geometric models for fold and thrust belts. In a numeric simulation, folding of the NCA is tested under varying boundary conditions to understand field observations.

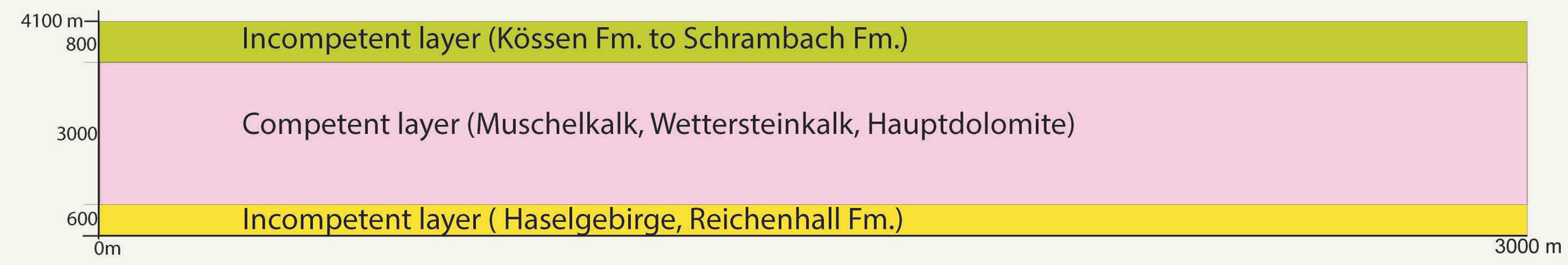

Fig. 2: Simple 3-layer model for the numeric simulation based on the stratigraphic knowledge of the NCA.

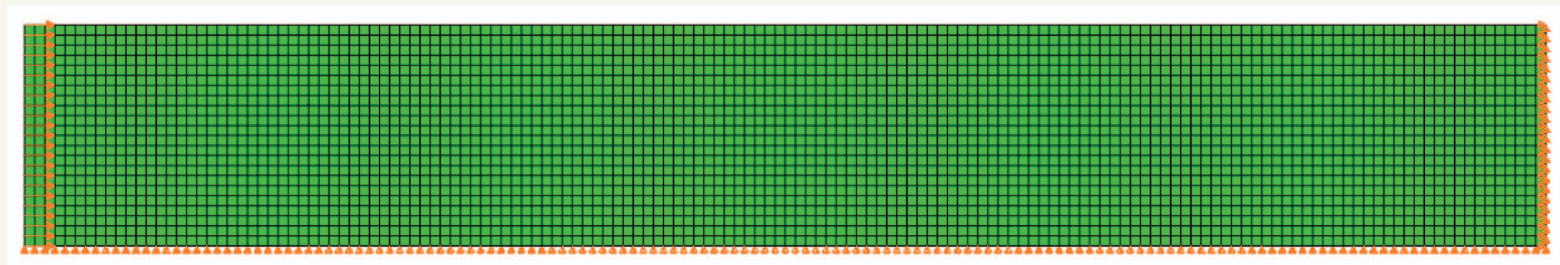

Fig. 3: Undeformed finite element model realised in Abaqus. Orange arrows indicate the boundary conditions.

For the NCA it is known that as a consequence of initial stacking at the end of the Early Cretaceous, the thrust sheets were uplifted and eroded down to the Ladinian platform carbonates (Krois & Stingl, 1994; Ortner, 2003), removing roughly half of the sediment column. Syntectonic sediments on top of the thrust sheets transgress in the Late Cretaceous and record folding into the Paleogene, and 20% of the folding postdates preserved syntectonic deposits, as documented in the Muttekopf Gosau outcrop (Ortner, 2001, 2016; Ortner et al., 2016). We expected that the erosion after the initial stacking and the sedimentation of syntectonic sediments is controlling for the structural evolution of buckle folds in the study area. Erosion, sedimentation and material parameters were tested during the numeric simulation (Figs. 4 and 5).

RESULTS

MODELLING EROSION

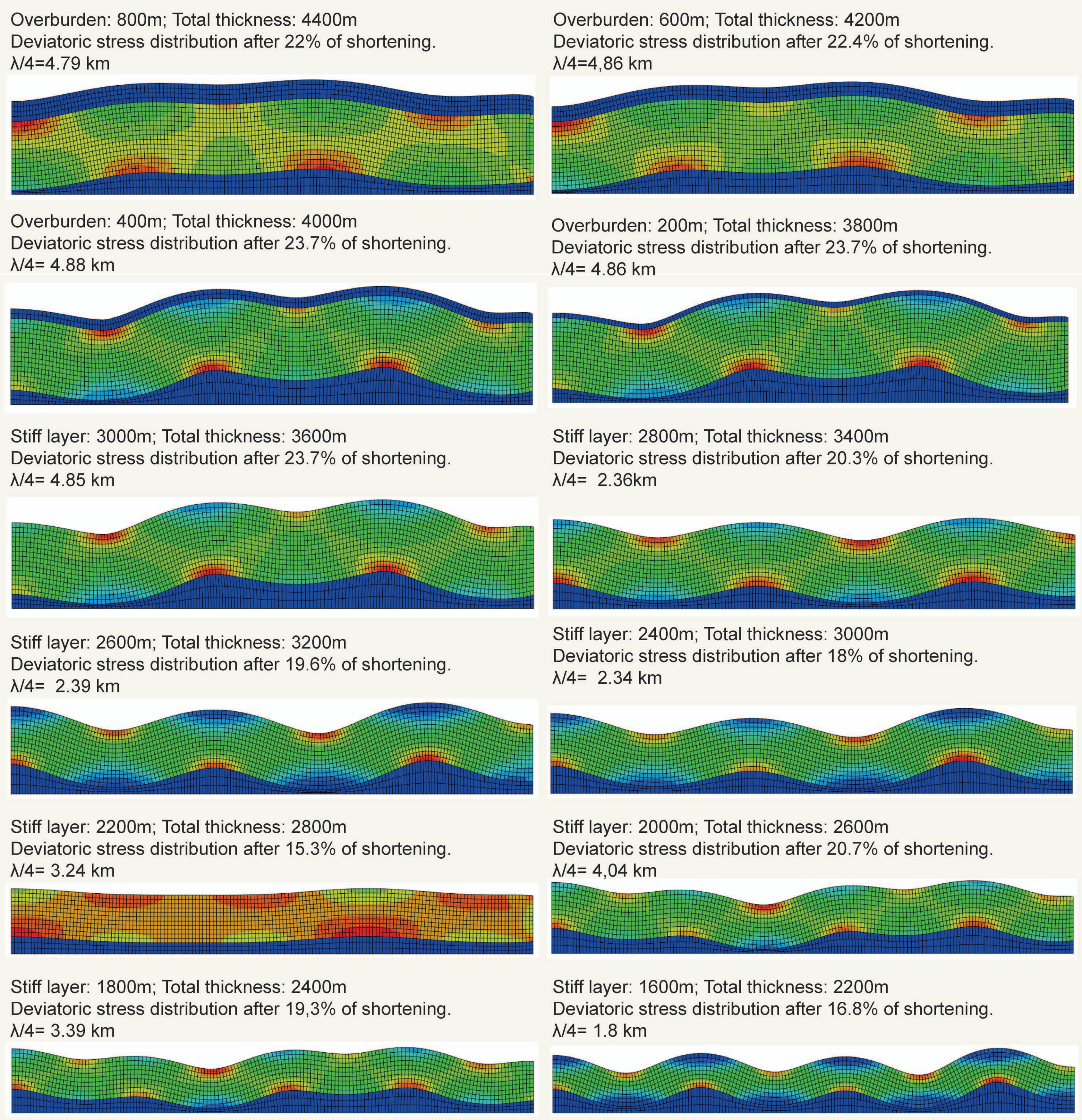

Fig. 4: Results of the erosion modelling. The material model is linear elasticity. Coloration represents the relative deviatoric stress distribution. The base layer is constant while the incompetent layer on top and the middle stiff layer is eroded. Following material characteristics were assumed: Layer 1 (bottom): E-Module 2 000 000 kN/m², Poisson ratio 0.25; Layer 2 (middle): E-Module 80 000 000 kN/m², Poisson ratio 0.2 ;Layer 3 (top) : E-Module 10 000 000 kN/m²; Poisson ratio 0.25.

MODELLING SEDIMENTATION

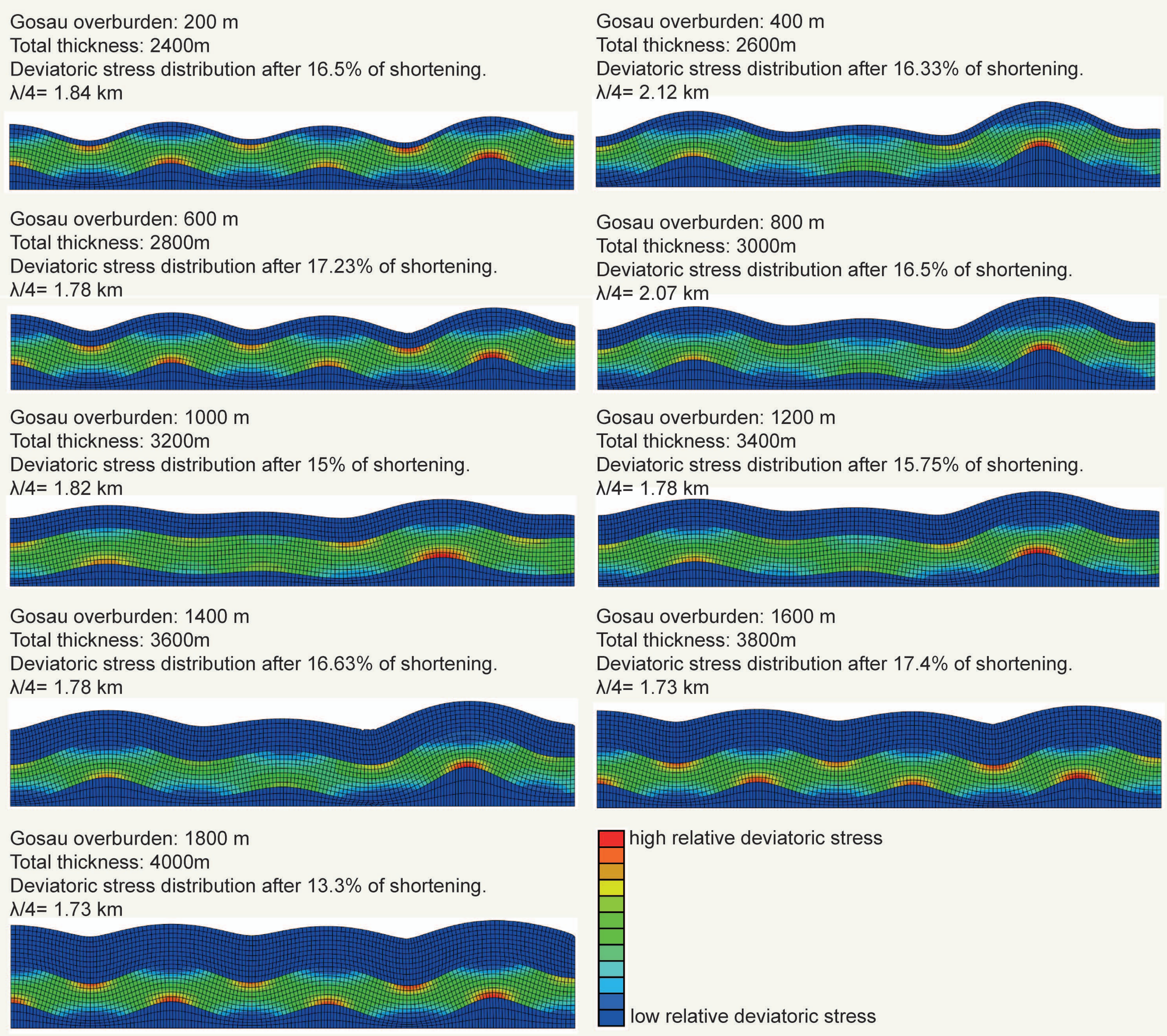

Fig. 5: Results from modelling with changing overburden. The model is linear elasticity. Coloration represents the relative deviatoric stress distribution. The competent intermediate unit and the basal incompetent unit have constant thickness in the models, while the top incompetent unit ("Gosau overburden") increases in thickness in the model runs to test the influence of the thickness of syntectonic sediments in the model. Material characteristics: Layer 1 (bottom): E-Module 2 000 000 kN/m2, Poisson ratio 0.25; Layer 2 (middle): E-Module 80 000 000 kN/m², Poisson ratio 0.2; Layer 3 (top) : E-Module 10 000 000 kN/m²; Poisson ratio 0.25.

References:

Jestl, S., 2016: Pseudo-3D-Modellierung Karwendel, im Bereich zwischen Eng und Inntal. Bachelor thesis at the Institute of Geology, University of Innsbruck, unpublished.

Kilian, S.; Ortner, H., 2019: Structural evidence of in-sequence and out-of-sequence thrusting in the Karwendel mountains and the tectonic subdivision of the western Northern Calcareous Alps. In press Austrian Journal of Earth Science.

Krois, R., and Stingl, V., 1994, Kretazische „Augensteine“: Notiz zu einem fraglichen Gosauvorkommen im Karwendel (Tirol, Österreich).-J b. Geol. Bundesanst, v. 137, p. 289-293.

Ortner, H., 2001: Growing folds and sedimentation of the Gosau Group, Muttekopf, Northern Calcareous Alps, Austria: Int. J. Earth Sci. (Geol. Rundsch.), v. 90, p. 727-739.

-, 2003: Cretaceous thrusting in the western part of the Northern Calcareous Alps (Austria) - evidences from synorogenic sedimentation and structural data: Mitteilungen der Österreichischen Geologischen Gesellschaft, v. 94, p. 63-77.

Ortner, H., and Kilian, S., 2016: Sediment creep on slopes in pelagic limestones: Upper Jurassic of Northern Calcareous Alps, Austria, Sedimentary Geology, p. 350-363.

Ortner, H., Kositz, A., Willingshofer, E., and Sokoutis, D., 2016: Geometry of growth strata in a transpressive fold belt in field and analogue model: Gosau Group at Muttekopf, Northern Calcareous Alps, Austria, Basin Research, Volume 28, p. 731–751.

Stückler, G., 2015: Pseudo-3D-Modellierung im Karwendel zwischen Karwendelbach und Nordkette. Bachelor thesis at the Institute of Geology, University of Innsbruck, unpublished.

Acknowledgements:
supported by Land Tirol (Tiroler Wissenschaftsfond) and the Doctoral programm of the University of Innsbruck

CONCLUSIONS

The modelling showed that the thickness of the stiff layer and the competence contrast between the layers is a control on the development of buckle folds. Additionelly, a very weak décollement horizon is nescessary to allow folding. Testing the influence of erosion showed that the sediment thickness of the stiff layer controls the initial wavelength of the folds. The produced wavelengths of the folds fit field observations (e.g., Stückler, 2015; Jestl, 2015).

We assume that folds developed after the initial stacking in the late Early Cretaceous and after a decrease in lithostatic pressure due to Upper Cretaceous erosion. Further, this research showed that rheologic differences need to be considered in geometric models. Further research aims to simulate the process from folding to faulting to finally develop a geometric-rheological model for the construction of cross sections in fold and thrust belts. Precise geological models in fold and thrust belts are a prerequisite for earthquake hazard management.