Why do triangle zones exist? - Insights from numerical models

Betti Hegyi[1], Zoltán Erdős[1,2], Ritske S. Huismans[3], Christoph von Hagke[4]

[1]Department of Geophysics and Space Science, Eötvös Loránd University, Budapest, Hungary (hegyibetti96@gmail.com)
[2]CSFK Geological and Geophysical Institute of Hungary, Budapest, Hungary
[3]Department of Earth Sciences, University of Bergen, Bergen, Norway
[4]Lehr-und Forschungsgebiet für Geologie - Endogene Dynamik (GED) Rheinisch-Westfälische Technische Hochschule, Aachen University, Germany

1. Motivation

Foreland fold and thrust belts are well-studied parts of the orogenic systems as they have essential role in hydrocarbon exploration. Triangle zones are enigmatic structures in fold and thrust belts worldwide, and the geometry as well as the kinematic evolution of these structures has been the subject of wide range of studies in the last few decades. The understanding of triangle zone mechanics is incomplete despite the fact that different driving mechanisms for triangle zone formation have been proposed. The goal is to test the previously identified factors which have a first order control in the formation of triangle zone formation, with an aim of getting a better understanding about triangle zone mechanics.

2. Theoretical background

Multiple concepts exist to describe triangle zones, and the definition was modified several times in the last few decades. The term triangle zone has often been used in literature to define structures with a triangular shape, which only explains their geometrical setup. However, this has lead to a multitude of structures termed triangle zones, lacking kinematic or mechanic concepts.
To clarify the situation of the term triangle zone, a new definition was suggested (von Hagke & Malz, 2018): „Triangle zones are structures with a trinagular shape in section view accomodating shortening by coeval activity of a basal thrust and an associated back-thrust of opposite vergence". The definition highlights that not every object that looks triangular should be called triangle zone. Instead, triangle zones are structural features, defined through their kinematics. Based on a global compilation of triangle zones, two different types can be distinguished: detachment (Figure 1/A) and ramp dominated (Figure 1/B).

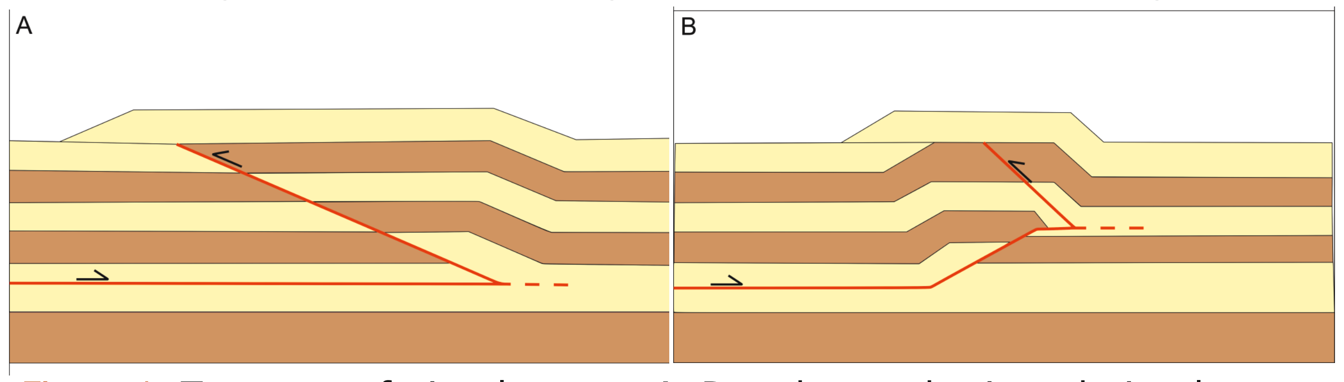

Figure 1: Two types of triangle zones. A: Detachment dominated triangle zone. This requires a weak detachment and low strain rates. B: ramp dominated triangle zone. High friction of the ramp causes backthrust formation. (Modified after von Hagke & Malz 2018)

3. Model setup

We use a 2D arbitrary Lagrangian-Eularian (ALE) finite-element technique FANTOM (Thieulot, 2011), to model triangle zone development.
The model consists of frictional plastic materials: (I) a strong, strain-weakening material representing the upper crust; (II) a weak layer located at the base of the model, representing the basal detachment; (III) a very weak internal detachment layer between these two, representing evaporites.
A velocity boundary condition is imposed on the right side and at the base of the model.

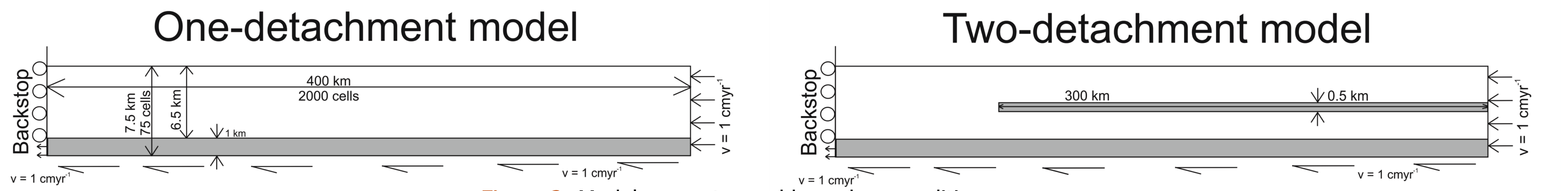

Figure 2: Model geometry and boundary conditions

4. First model results

The aim of the first models was to figure out which parameter setups are the most efficient to produce backthrusts, since backthrusts are indispensable part of triangle zones.
Another goal was to observe how an additional secondary detachment affects the geometry of the structures and the outward propagating sequence. One of our observations was that a relatively big contrast in the angle of internal friction is needed to produce backthrusts.

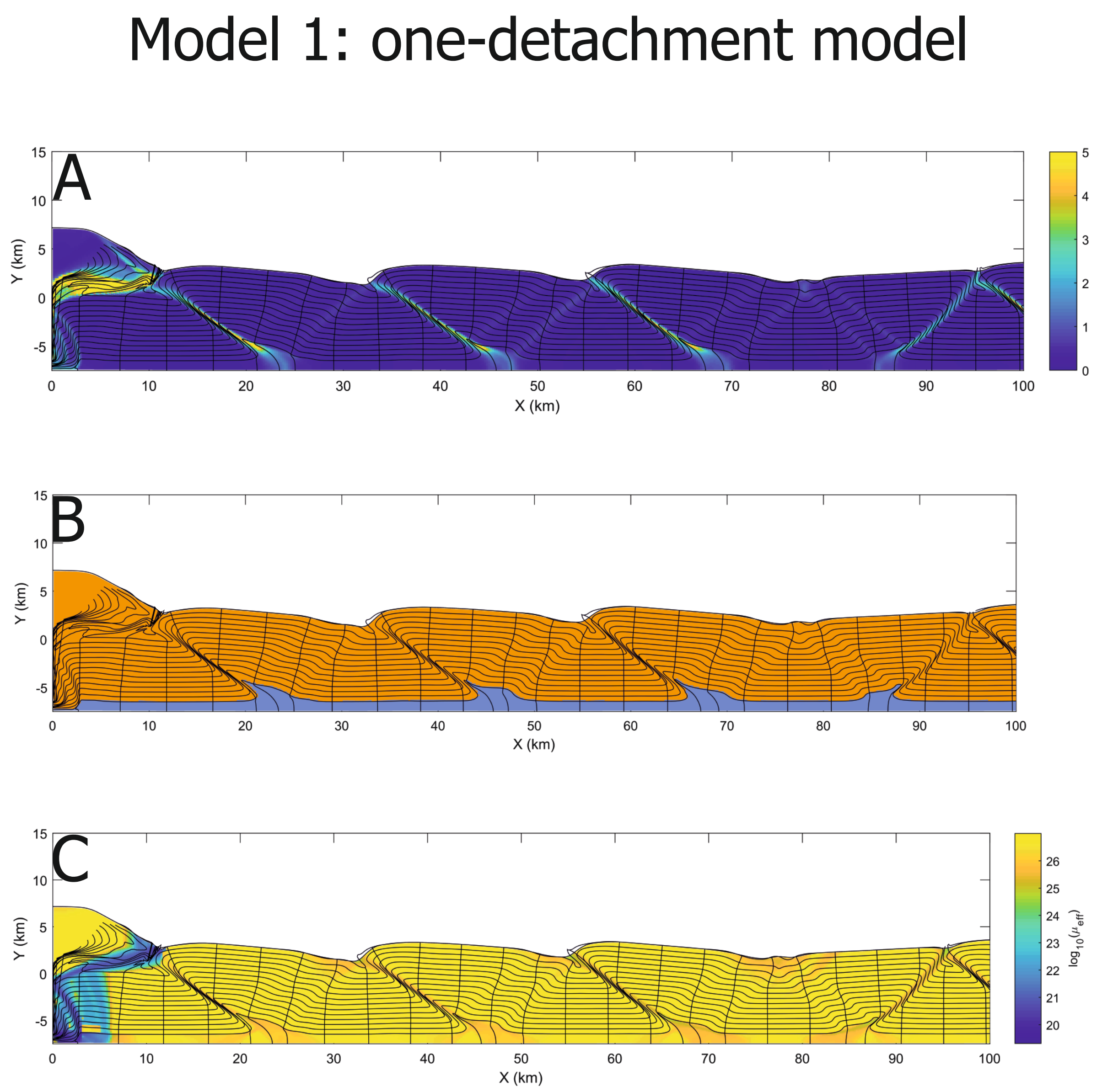

Figure 3: Model 1 results at 12 Myr (one-detachment model with frictional plastic materials). A: strain values; B: material colors; C: viscosity values.

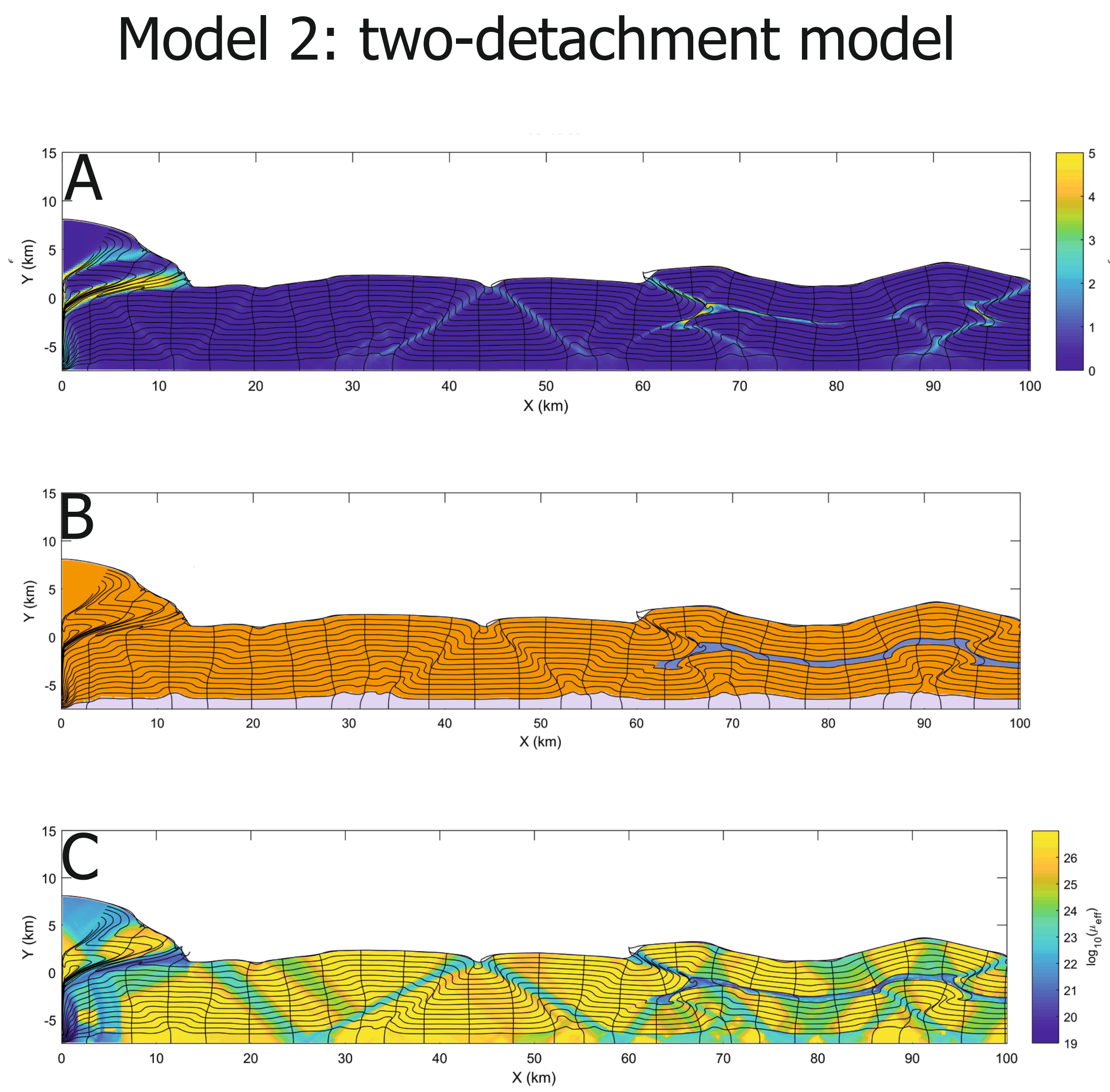

Figure 4: Model 2 results at 12 Myr (two-detachment model with frictional plastic materials). A: strain values; B: material colors; C: viscosity values.

Material description \ Physical properties	Φ [°]	C_0 [MPa]	ε range	ρ [kgm^{-3}]
Strong with strain softening	30 25	2	0.5 1	2300
Weak basal detachment	8	2	n/a	2300
Very weak internal detachment	1	2	n/a	2300

Table 1: Physical properties of the models

References

Thieulot, C., 2011. FANTOM: Two- and three-dimensional numerical modelling of creeping flows for the solution of geological problems. Physics of the Earth and Planetary Interiors 188, 47-68.
von Hagke, C., Malz, A., 2018. Triangle zones - Geometry, kinematics, mechanics, and the need for appreciation of uncertainties. Earth-Science Reviews 177, 24-42.