IDENTIFICATION OF CONTROLLING PARAMETERS OF THE ACCRETIVE SOUTH CHILEAN MARGIN (38°-40°S) WITH ANALOGUE MODELS

Jo Lohrmann, Nina Kukowski, Jürgen Adam, Helmut Echtler & Onno Oncken

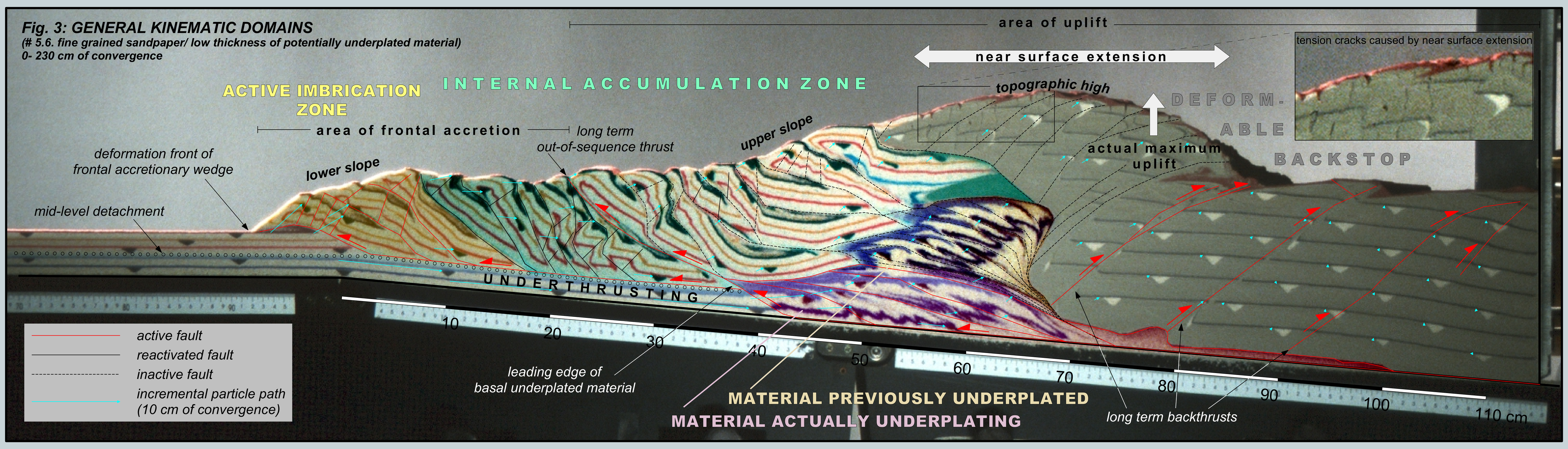
GeoForschungsZentrum Potsdam, Telegrafenberg C, D-14473 Potsdam, jo@gfz-potsdam.de

INTRODUCTION

To investigate the relationship between mass-transfer patterns at active convergent margins and related deformation processes, we apply scaled analogue experiments with geometrical and mechanical parameters obtained from geophysical and geological data. In this study, we focus on the Neogene geodynamic evolution (Miocene to recent) of the accretive South Chilean forearc region (38°-40°S).

We expect the following parameters to be the most important in controlling the observed deformation processes:

- ***Variation of sediment supply* to the trench:** Variation of sediment fill along the South Chilean trench has been reported by several researchers (Bangs et al, 1997; von Huene et al., 1985; Schweller et al., 1981).
- ***Roughness of the basal subduction interface***: Plate coupling along the subduction interface controlled by basal friction has a significant impact on mass-transfer patterns. However, the additional influence of the roughness of the subduction interface on the kinematics of accretive margins is not systematically evaluated until now.
- ***Deviation of the distribution of vertical load*** from that of an ideally shaped wedge: Surficial erosion and sedimentation as well as internal deformation cause topographic lows and highs in the forearc geometry.



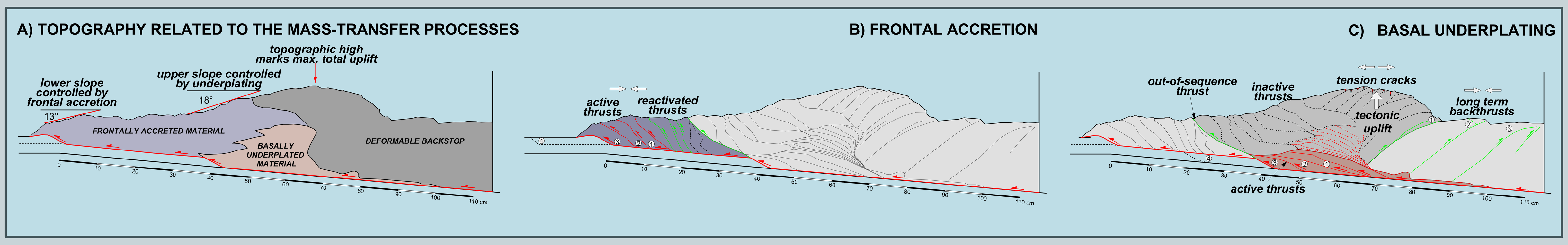
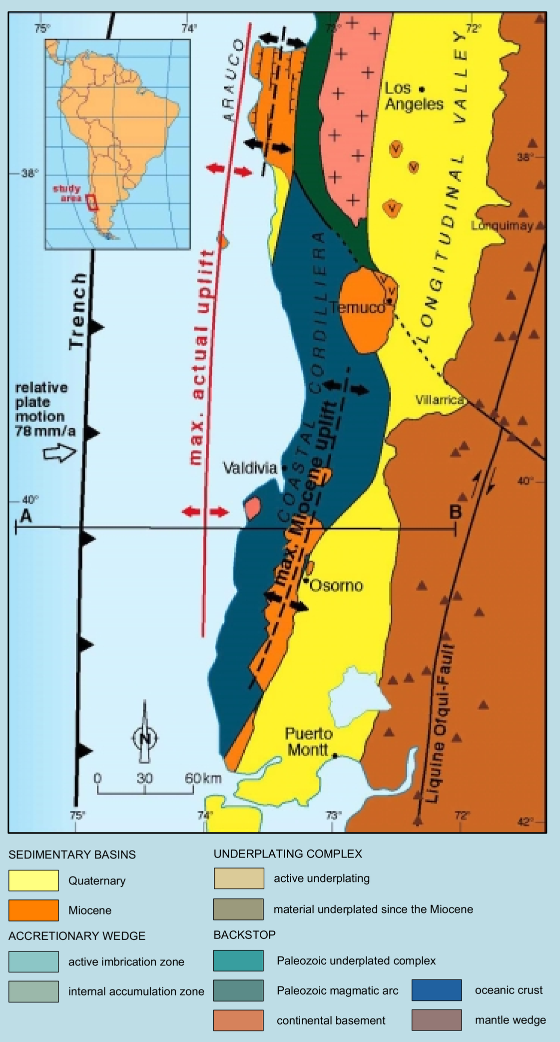


Fig. 4: KINEMATIC DOMAINS OF A BASALLY ACCRETIVE EXPERIMENT (# 5.6. fine grained sandpaper/ low thickness of potentially underplated material) 0- 230 cm of convergence

BOUNDARY CONDITIONS OBSERVED FROM SEISMIC AND GEOLOGICAL DATA



Depth migrated reflection seismic lines (RC 2901, lines 727-732) (Díaz-Naveas, 1999) image the main structural characteristics of the South Chilean forearc system: Only the upper sequence of trench sediments is off-scraped and frontally accreted, whereas the lower part of the trench sediments is underthrust beneath the frontal accretionary wedge. The underthrust, internally undeformed sediment pile can be identified only up to 30 km landward of the trench. However, its fate is not resolved further landward.

A zone of trench parallel uplift and trench normal extension in the inner forearc region can be derived from neotectonic and seismic data (Fig.1) (Boettcher, 1999, Díaz-Naveas, 1999). Since the Miocene onset of the recent accretive phase, the uplift centre can be identified. However, its position varies between the Arauco area and the Valdivia area. In the Valdivia area, the actual centre of extension is shifted 50 km trenchward since the Miocene, whereas in Arauco, the actual and Miocene axes of maximum uplift are located at the same position.

Fig. 1: GEOLOGICAL MAP OF SOUTHERN CHILE

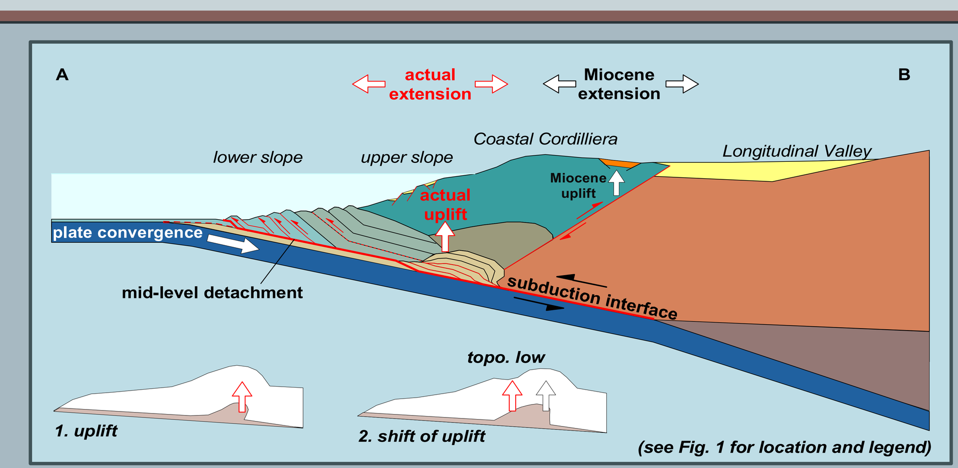


Fig. 8: RESULTING CONCEPTUAL MODEL

The sandbox experiments reported here (Fig.3-6) show that underplating causes strong uplift and localized near surface extension in the overall convergent system. These features are identified at the South Chilean margin (Fig.1). Therefore it is most probable that the underthrust sediments will be (partly) underplated beneath the forearc in the mode here discussed (Fig.8). This concept is supported by the Paleozoic evolution of the South Chilean margin (Gräfe et al., 2000). Additionally, an equivalent mass-transfer pattern has been observed at other accretive margins (e.g. Makran, Western Mediterranean Ridge).

GENERAL KINEMATIC EVOLUTION OF BASALLY ACCRETIVE EXPERIMENTS

Applying the formerly discussed boundary conditions in sandbox experiments, the lower part of the input layer is underthrust and underplated beneath the backstop by duplex formation and antiformal stacking. The upper part of the input layer is frontally accreted forming an imbricate fan on the top of an active detachment located within the glass bead layer. At the leading edge of the underplated material, the active detachment steps down to the basal sandpaper interface.

Different kinematic domains are evolving in this system (Fig.4). The plotted particle paths for the three experiments are comparable and show general characteristics for the different kinematic domains (Fig.5).

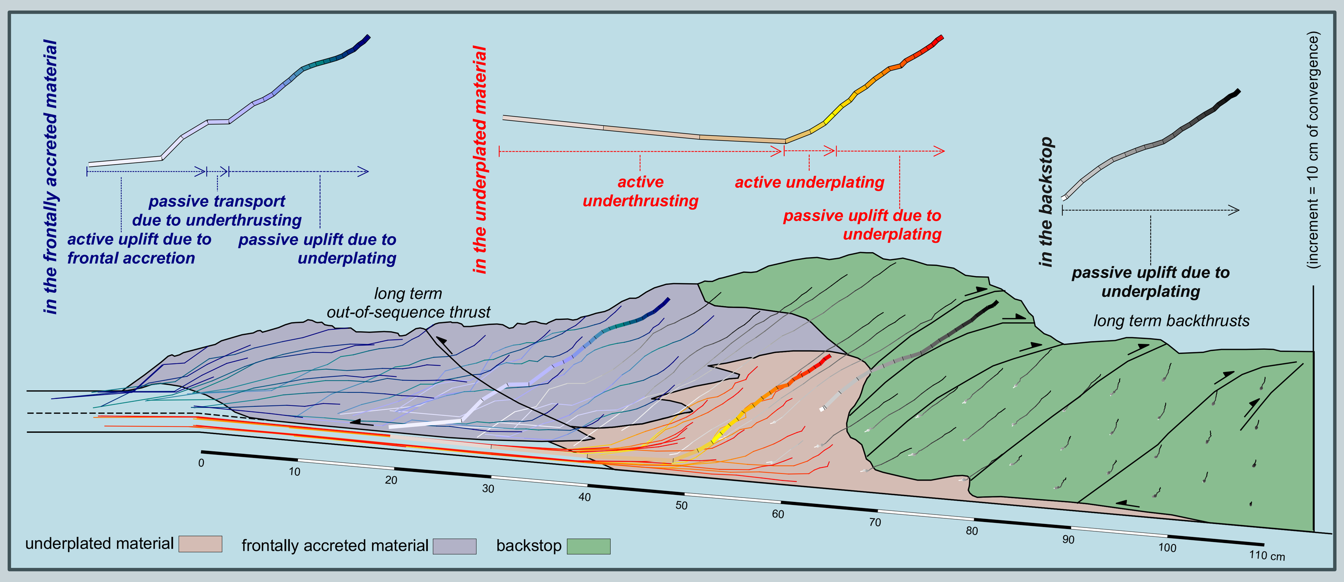
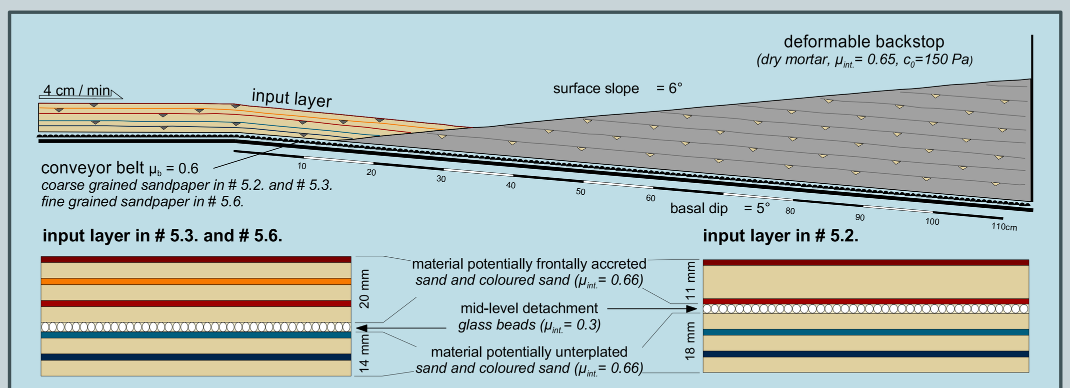


Fig. 5: PARTICLE PATHS IN A SAND WEDGE CONTROLLED BY UNDERPLATING (# 5.6. fine grained sandpaper/ low thickness of potentially underplated material) 0- 230 cm of convergence



We discuss our results by means of three key sandbox experiments. These were performed in a systematical manner to evaluate the specific role of the controlling parameters in changing only a single parameter from one experiment to the next (Fig.2). Two essential mechanical constraints are required for underthrusting and underplating :

- A thin weak layer (glass beads) in the input layer, which acts as potential mid-level detachment and mechanically decouples the upper part of the input layer from the lower part of the input layer.
- A conveyor belt made of sandpaper acts as high friction subduction interface resulting in high basal coupling.

Geometrical constraints, which are observed in the natural system, are taken into account:

- The basal dip of 5° represents the subduction interface (Díaz-Naveas, 1999).
- A deformable backstop (cohesive, dry mortar) represents the forearc wedge consisting of continental crust.
- Variation in the initial geometrical setup of the input layer, which represent a different assembly of the trench sediments (Díaz-Naveas, 1999).

Fig. 2: EXPERIMENTAL SETUP

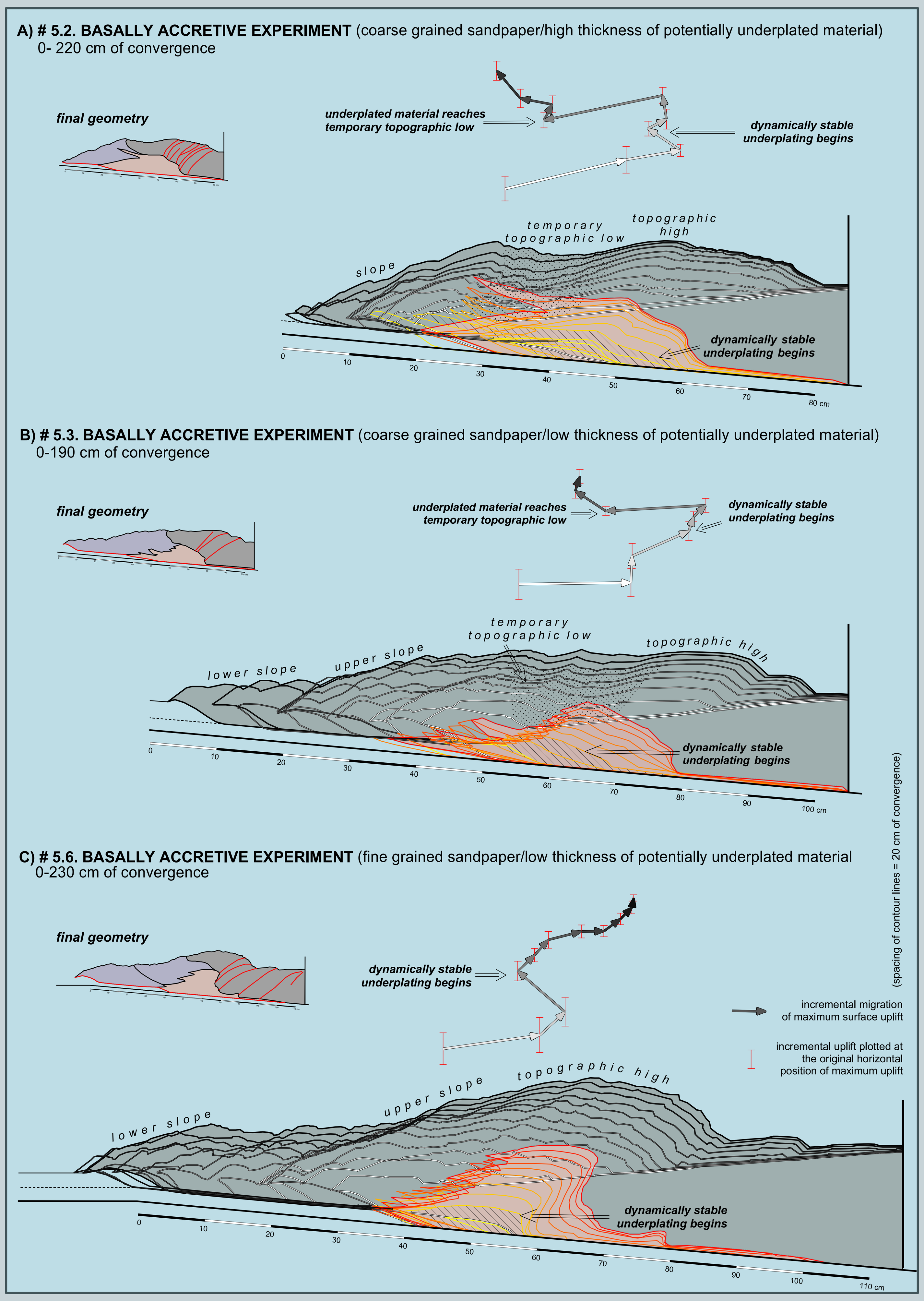


Fig. 6: THREE EXPERIMENTS WITH SYSTEMATICALLY VARIED INPUT PARAMETERS: OVERALL WEDGE GEOMETRIES OF EVOLVING WEDGES AND ANALYSES OF THE MIGRATION OF MAXIMUM SURFACE UPLIFT

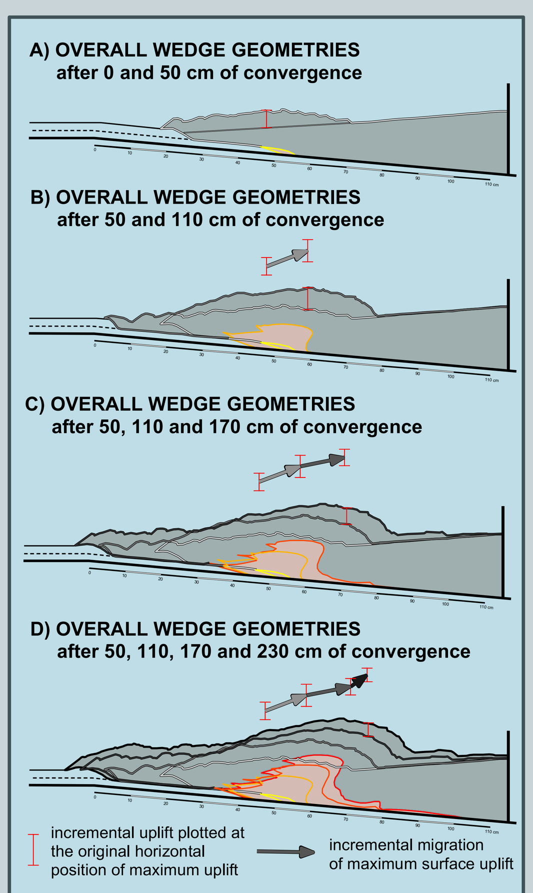


Fig. 7: MAPPING THE INCREMENTAL MIGRATION OF MAXIMUM SURFACE UPLIFT

INTERPRETATION AND CONCLUSIONS

Implications for basal underplating at accretive margins, deduced from convergent sandbox experiments are:

- The lower part of trench sediments is underthrust beneath the frontal accretionary wedge.
- The position of active underplating is marked by strong uplift, near surface extension and the possible existence of mega shear zones (long term backthrusts, out-of-sequence thrust).

The variation of boundary conditions results in:

- ***Variation of sediment supply*** (Fig.6a,b) mainly results in changing the distribution of material volumina (frontally accreted versus basally underplated) as well as rates of accretion, underplating and uplift. The general pattern of the incremental migration of surface uplift is not influenced by this parameter.
- ***The roughness of the subduction interface*** determines the position of underplating. The fine grained sandpaper (Fig.6c) is able to transport the underthrust material to a more internal position than the coarse grained sandpaper (Fig.6a,b) and the deformation style differs significantly within the underplated material. The deformation style influences the shape of underplated material and therewith the overall geometry of the wedge. In the experiment with fine grained sandpaper, a most ideal wedge shape without irregularities above the underplated material results. In contrast, in the experiments with coarse grained sandpaper, the wedge shapes show distinct topographic lows above the underplated material.
- ***The vertical load*** significantly controls the migration of the position of maximum uplift. If the wedge on top of the underplated material has an ideal wedge shape (Fig.6c), the position of maximum uplift migrates continuously to the rear of the sand wedge, and the incremental uplift rates decrease with time. If a topographic low develops above the underplated material (Fig.6a,b), the incremental migration of the maximum uplift is irregular. Due to changes in the mechanism of underplating, the position of maximum uplift is shifted towards the topographic low, and incremental uplift increases. This shift in the mechanism of underplating results in a compensation of the topographic low as long until an ideal wedge shape is re-established (Fig. 6b).

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