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Benchmarking analogue models of brittle thrust wedges

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ABSTRACT

We performed a quantitative comparison of brittle thrust wedge experiments to evaluate the variability among analogue models and to appraise the reproducibility and limits of model interpretation. Fifteen analogue modeling laboratories participated in this benchmark initiative. Each laboratory received a shipment of the same type of quartz and corundum sand and all laboratories adhered to a stringent model building protocol and used the same type of foil to cover base and sidewalls of the sandbox. Sieve structure, sifting height, filling rate, and details on off-scraping of excess sand followed prescribed procedures.

Our analogue benchmark shows that even for simple plane-strain experiments with prescribed stringent model construction techniques, quantitative model results show variability, most notably for surface slope, thrust spacing and number of forward and backthrusts. One of the sources of the variability in model results is related to slight variations in how sand is deposited in the sandbox. Small changes in sifting height, sifting rate, and scraping will result in slightly heterogeneous material bulk densities, which will affect the mechanical properties of the sand, and will result in lateral and vertical differences in peak and boundary friction angles, as well as cohesion values once the model is constructed. Initial variations in basal friction are inferred to play the most important role in causing model variability.

Our comparison shows that the human factor plays a decisive role, and even when one modeler repeats the same experiment, quantitative model results still show variability. Our observations highlight the limits of up-scaling quantitative analogue model results to nature or for making comparisons with numerical models. The frictional behavior of sand is highly sensitive to small variations in material state or experimental set-up, and hence, it will remain difficult to scale quantitative results such as number of thrusts, thrust spacing, and pop-up width from model to nature.

1. Introduction

Scaled analogue experiments have a long history of modeling geological processes. Analogue models built of materials such as sand, silicone or clay have helped geoscientists to gain insights into the kinematic and dynamic evolution of a wide variety of geological structures. However, as for all models, their results reflect the initial boundary conditions, the choice of materials, the modeling apparatus and the technique of building the model. Unfortunately, many publications on analogue modeling do not adequately record experimental details and material properties, making a detailed comparison of model results among different laboratories simulating similar geological processes difficult. Additionally, experiments are rarely re-run to test the reproducibility and to determine the intrinsic variability of model results.

Schreurs et al. (2006) were the first to report a direct comparison of scaled analogue experiments to test the reproducibility of model results amongst ten analogue modeling laboratories. One of the two experimental set-ups chosen in their comparison was a brittle thrust wedge experiment (Fig. 1). The experimental set-up, the model-building technique, and the material covering walls and base were all prescribed. However, each laboratory used its own granular material to simulate brittle deformation. Consequently, in the comparison of Schreurs et al. (2006) the material properties can be considered as extrinsic and were a major source of model variability.

The qualitative evolution of all models was broadly similar (Fig. 2) with the development of a thrust wedge characterized by in-sequence forward thrusting and by minor back thrusting. However, significant quantitative variations existed between models in parameters such as the spacing between thrusts, their dip angles, number of forward and back thrusts and surface slopes.

In the analogue modeling comparison by Schreurs et al. (2006), each laboratory used its own granular material and differences existed in terms of material properties such as grain size, grain shape and grain size distribution. Hence, we suspect that the

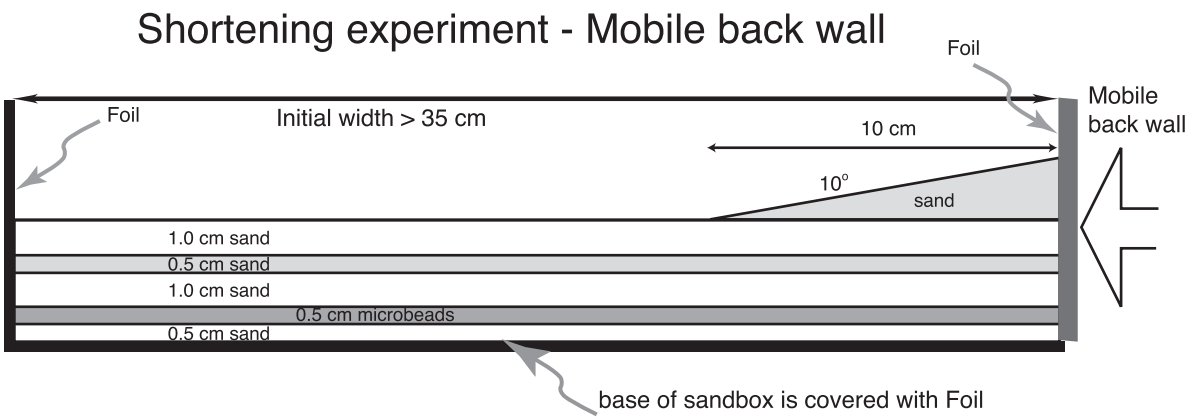

Fig. 1. Experimental set-up used in model comparison experiments by Schreurs et al. (2006). Model consists of a 3.5 cm-thick sand layer with an embedded microbeads layer and an overlying sand wedge with a surface slope of 10° adjacent to the mobile wall. All walls are covered by Alkor foil. Figure reproduced from Schreurs et al. (2006) with permission from the Geological Society of London.

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