Deformation of Accretionary Wedges based on 2D Discrete Element Simulations

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Abstract

We use 2-D numerical simulation to examine the evolution of accretionary wedges and fold-and-thrust belts. From the previous studies (Chapple, 1978, Dahlen, 1990, and Davis et al., 1983), we know that the major factor of controlling the evolution of accretionary wedge is the basal friction of décollement. Therefore, the primary objective of this study is to characterize localization of the deformation in different basal frictions in accretionary prism. We have exploited a series of experiments which are done with a range of frictional coefficients of element-wall friction (μ_b) and interparticles. From our results, three modes of deformation are observed, which depend mainly on μ_b. For the weak base case (low μ_b), the frontal accretion by 'pop-up' structures at or near the toe of the wedge is dominant. The surface slope of this case is much gentle than those of high basal friction. There are obvious back thrusts near the rear part of the wedge. Lower layers are uplifted by back thrusts. For the strong base case (high μ_b), uplift is concentrated near the back of the wedge, and is accompanied by underthrusting. Back thrusts and underthrusting uplifts lower layers. For intermediate values of μ_b, the wedge's deformation oscillates between the two modes of the weak base case and the strong base case (Figure 2).

Introduction

Accretionary wedges are mechanically analogous to a wedge of sand in front of a moving bulldozer. The magnitude of the critical taper is governed by the relative magnitudes of the frictional resistance along the base and the compressive strength of the wedge material(Chapple, 1978; Dahlen, 1990; Davis et al., 1983).

The sandbox experiments have been a good way used to understand the mechanics of collisional orogeny (Konstantinovskaia and Malavieille, 2005). However, analogue models are often limited in the range of problems that they can examine. For example, it is often difficult to find a range of granular materials with different coefficients of internal friction. The other method of simulations uses the finite-element method (FEM) (e.g. Beaumont et al., 1994; Fuller et al., 2006).

However, the FEM has some difficulties in modelling large amounts of deformation accurately, owing to excessive mesh deformation (or interpolation) in the regions of localization. For example, they can have difficulty in modeling the succession of faults in intricate fans observed in analogue models and the upper crust. In our studying, we use a numerical method that models each element as being discrete and separable from its initial neighbors. This method can solve the difficulties which met in analogue models and FEM. Therefore, we are going to implement 2-D particle-flow code (PFC^{2D} 3.1, (Itasca, 2002) of the distinct-element method (DEM) which was first developed by Cundall & Strack (1979). Then widely applied to many scientific domain such as chemistry, physics, soil mechanics, geology and geophysics (Allen and Tildesley, 1987; Bardet and Proubet, 1992; Burbidge and Braun, 2002; Finch et al., 2003; Finch et al., 2004; Scott, 1996; Strayer and Suppe, 2002).

The initial model geometry is consisted of an open box with three side walls (Figure 1). The starting model for the experiments on collisional orogens is constructed by filling 13,101 particles into a rectangular area surrounded by wall elements (250m ×15m). Particle-to-particle friction is 0.5. The friction between particles and bottom wall are 0.1, 0.15, 0.2, 0.25, and 0.3, defining the horizontal décollement. The walls and base are elastic and frictional. The left-hand side wall advances at a controlled, uniform velocity toward the right-hand side wall. The upper surface of the model is free and the whole model is gravitationally loaded by 1g.

Figure 2 shows the final step for a range of models with μ=0.5 but a variety of basal frictions, μ_b. From this figure, we can see three main modes of deformation, which depend mainly on μ_b. The low basal friction (LF) wedge grows by frontal accretion. On the other hand, underthrusting is the primary structure of high basal friction (HF) wedge. For intermediate values of μ_b, the wedge's deformation oscillates between the two modes of the LF case and the HF case.

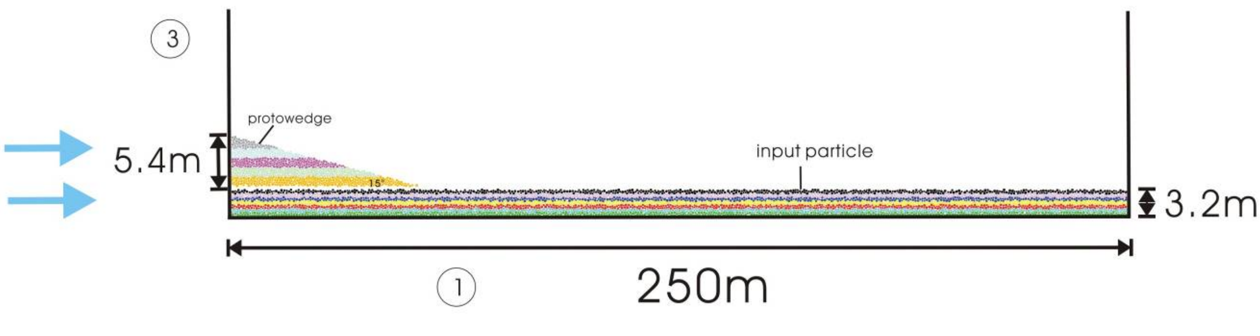

Figure 1. Simulation setup of particle configuration. The initial thickness of input particle layer is 3.2m. The wall 3 moves at a controlled, uniform velocity toward the right-hand side.

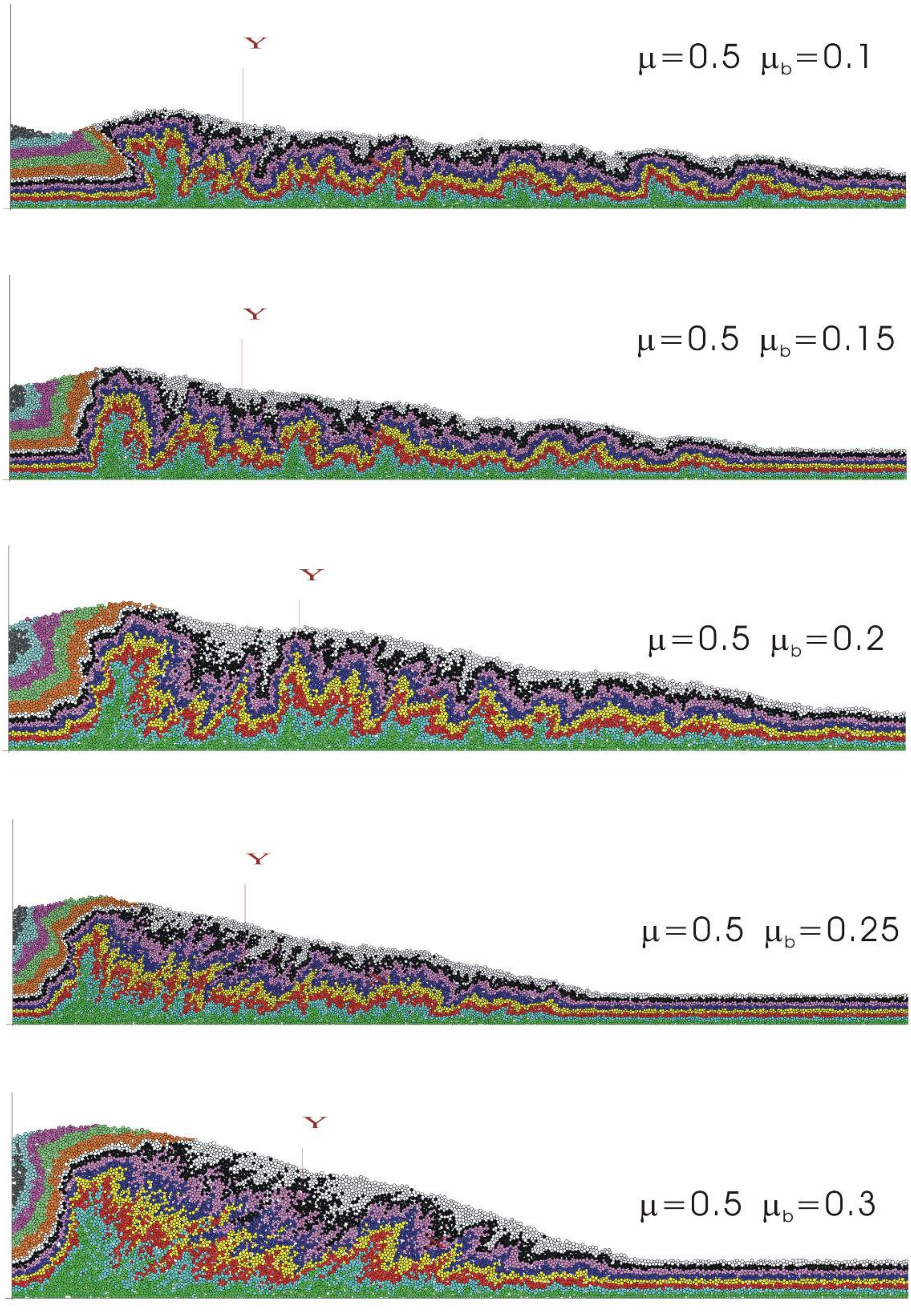

Figure 2. Model experiments in steps of shortening 100m with μ=0.5 but different μ_b.

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