

Erosion influence on the evolution of compressive system constrained by analogue modelling

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KEYWORDS: compressive system, erosion, analogue modelling

Introduction

In the last decade, the relations between mass transfer, climate and deformation have been studied at orogenic scale (Molnar y England, 1990; Beaumont et al., 1992; Zeitler et al., 1991; Avouac y Burov, 1996; Willett, 1999; Montgomery, 2001; Lamb y Davis, 2003), and structures scale (Colleta et al., 1991; Cobbold et al. 1993, Mugnier et al. 1997). The effect of synkinematic mass transfer in front of compressive systems has been recently studied using experimental or numerical modelling (Storti & McClay 1995; Hardy et al. 1998; Nalpas et al. 1999; Leturmy et al. 2000; Bonini 2001, Casas et al. 2001; Barrier et al. 2002, Nalpas et al., 2003). A major outcome of these works is that high sedimentation rates in front of a compressive structure favours steepening of active thrusts.

The aim of this study is to understand the role of erosion in the evolution of compressive system at upper crustal scale using analogue modelling which present variations in the spatial repartition of erosion.

Analogue modelling – Experimental procedure

The modelling techniques used are similar to those usually applied in experiments on brittle systems at the Laboratory of Experimental Tectonics of the Geosciences department, Rennes University, and have been described in previous studies (e.g. Faugère and Brun, 1984; Vendeville et al., 1987). Dry quartz sand with an angle of internal friction close to 30° , and a density of about 1400 kg/ m^3 was used to model the brittle behaviour. The experiment was constructed on a table with a mobile wall pushed by a screw jack driven at constant velocity (2 cm/hr) by a stepper motor (Fig. 1).

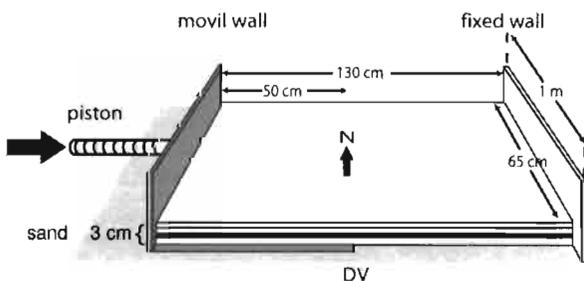


Figure 1: Experimental modelling apparatus.

The dimensions of the experiment are sufficiently large to ensure that a large part of the model escapes boundary effects. Attached to the mobile wall, was a horizontal rigid sheet, which created a linear velocity discontinuity at the limit of the sheet at the base of the experiment (cf. Malavielle, 1984; Allemand et al., 1989; Nalpas et al., 2003). The models consisted of 3 cm-thick sand layer. Experiments were carried out in the Laboratory of Analogue Deformation at the department of Geology, University of Chile. The sand pack was made of thin

alternating coloured layers, which allow the identification of faults and folds on cross-sections. The erosion of very fine layers of sand is carried out regularly using a vacuum cleaner. During experiments, photographs of the surface of models were taken at regular time intervals to study the progressive evolution of structures (Fig. 2). At the end of each experiment, the geometry of structures and their changes along strike were observed on serial cross-sections.

Results

For purposes of description deformation features are referenced by an arbitrary cardinal system, with N pointing to the top in figures 2 and 3.

Development of the experiment without erosion: the beginning of the deformation took place when completing the first centimetre of shortening, at this moment two faults of opposite sense are created forming a pop-up symmetrical with respect to the edge of the movable plate. After the formation of the pop-up, the shortening is concentrated in the antithetic main fault, of West vergency. With the development of this antithetic fault the system became asymmetric, causing a series of synthetic transitory secondary faults, of East vergency. The permanent activity of the main fault generates an important rise in the zone on the DV. The increase of the shortening forms new systems of faults of pop-up in direction of the East.

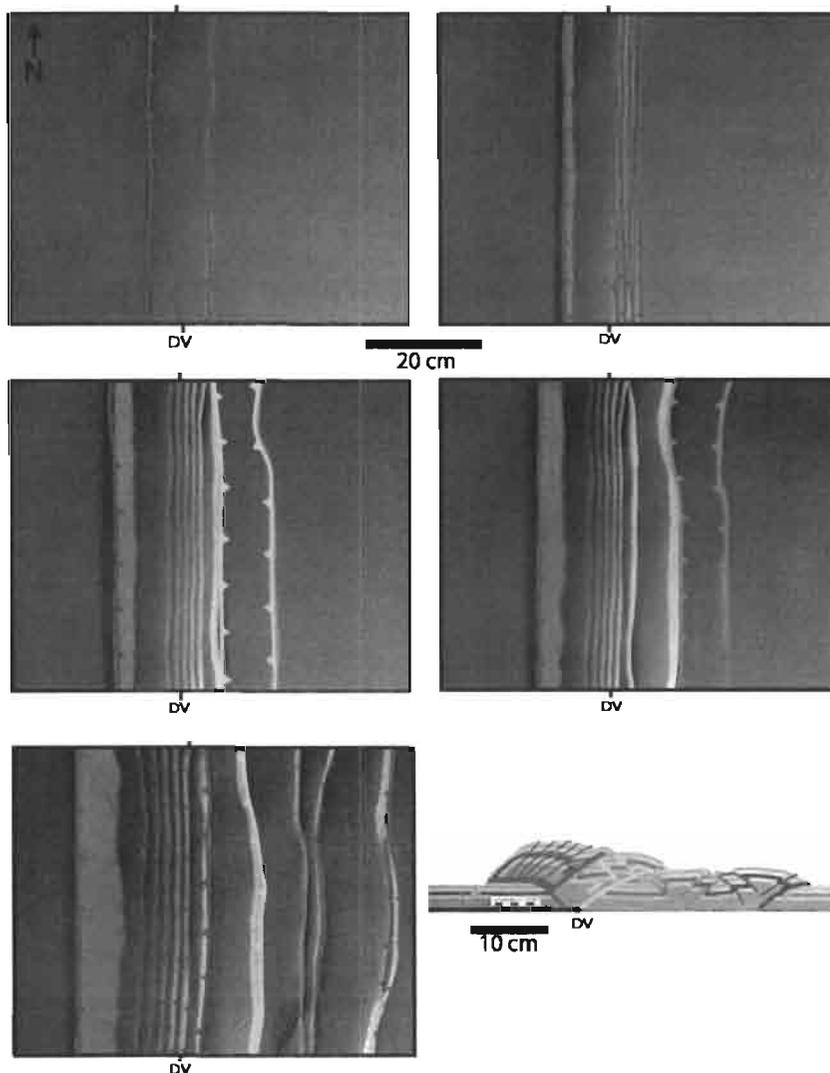


Figure 2: Surface views and cross-section of experiment without erosion.

In synthesis in the East-West profile the four systems of double vergency that formed during the development of the experience, can be appreciated with an indication of different colours. It is possible to distinguish in the Eastern slope of the raised surface the formation of two high plateaus.

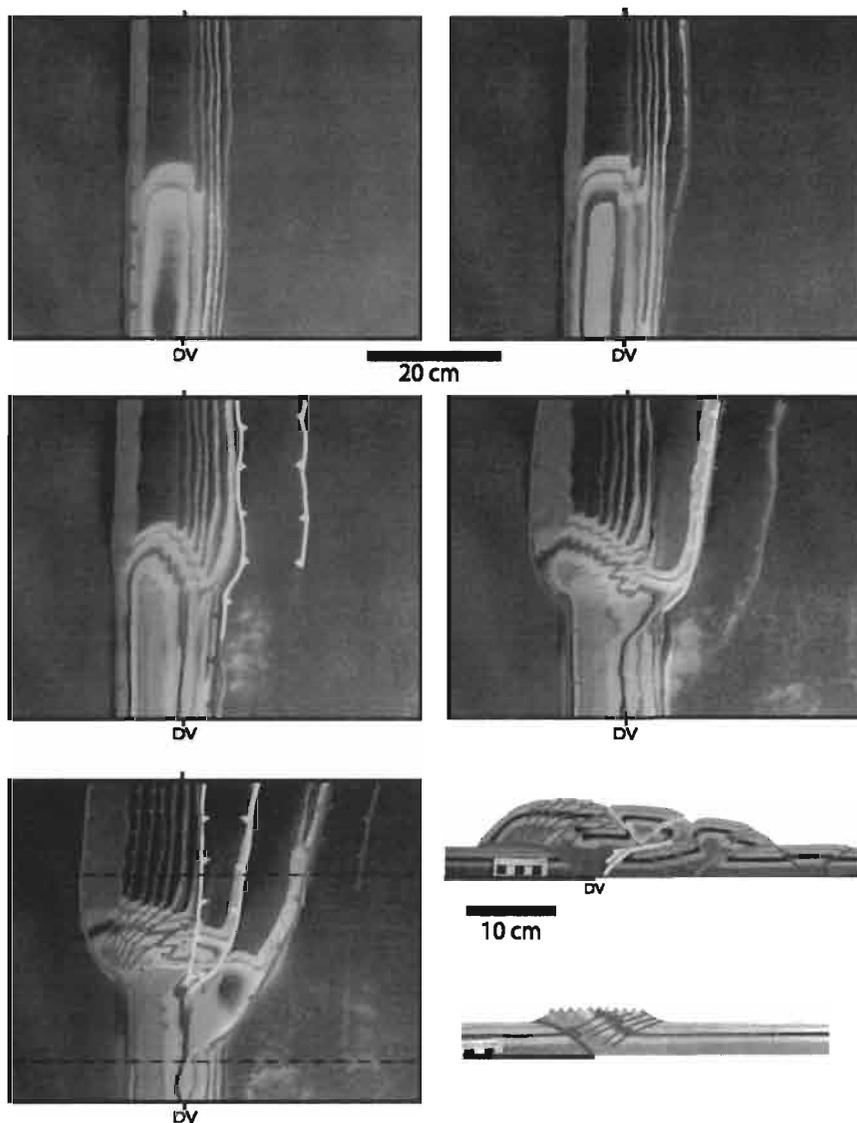


Figure 3: Surface views and cross-section of experiment with erosion only in the southern part.

In this experiment erosion was made in the Southern part of model (fig 3). This experiment had a structural evolution, of the zone without erosion, very similar to the development of the previous experiment. That is to say, over the DV was developed 4 systems of double vergency, but the last one is less developed than previously.

On the other hand, the zone eroded maintain focused the deformation in the main structure of the model (West vergency fault). If the cross-section of the zone where erosion was made, it is clear that the deformation did not propagate towards the flanks (E-W) of the model, but is still concentrated in the same place above the DV.

Conclusions

- Experiments at crustal scale show that erosion is a fundamental parameter that can influence the evolution of a compressive system.
- Without erosion the deformation show a progradation of pop-up structures. The shortening is distributed in a large zone.
- Without erosion high plateaus are constructed during the shortening.
- A systematic erosion causes a concentration of the deformation and the shortening in a main structure.

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