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Analogue Modeling of the Multi-Layer Over-Thrust System in South China

YI Jin[1] and LIN Ge[2]

1 Guangdong Nonferrous Metals Geological Exploration Institution, Guangzhou 510080, China.
2 Key Lab of Mineral and Mineralization, CAS, Guangzhou Institute of Geochemistry, Guangzhou 510640, China.

1 Introduction

The structural evolution of a thrust system depends on stratigraphy, mechanical property of the rocks, duration and rate of deformation and uplift versus subsidence ratios. In particular, the mechanical property of the deformed rocks (e.g. presence of competency contrasts) and the detachment layer appear to be of great significance in influencing the final geometry of the structures and the kinematics of the thrust system. In South China, detachment is a common structural phenomenon that has absorbed a large portion of intra-continental deformation in sedimentary rocks with a various mechanical contrast (Yan et al., 2003, 2009). It normally took place in and along incompetent layers, and produced kinds of detachment structures. Multi-layer detachment structures of South China had been identified by geophysical and geological data (Yan et al., 2003, 2009). The present paper aims to analyze the role played by multiple detachment layers in the Mesozoic over-thrust system in South China by analogue modeling.

2 Geological Background

A thickness of more than ten kilometers of sedimentary rocks has been deposited in the South China Block. Due to high competency contrasts among strata, multi-layer detachment structure, multi-layer thrust fold structure, and multi-layer nappe structure of several stages are developed

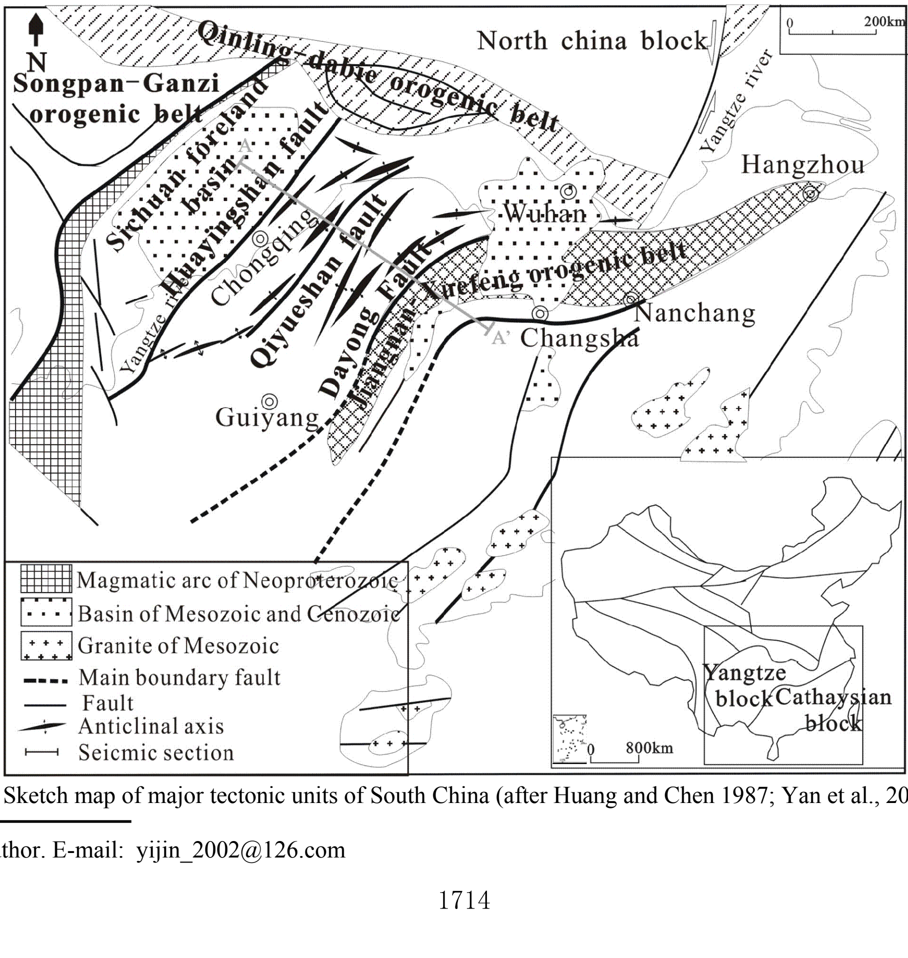

Fig. 1. Sketch map of major tectonic units of South China (after Huang and Chen 1987; Yan et al., 2003)

* Corresponding author. E-mail: yijin_2002@126.com

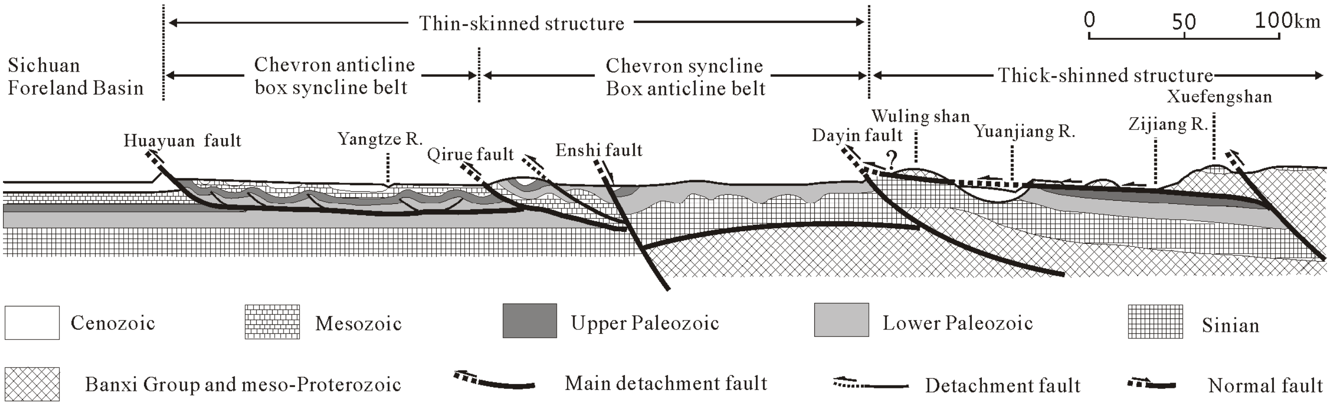

Fig. 2. Synthetic structural section (A–A' in Fig. 1) from Huayun to Huaihua (after Yan et al., 2003)

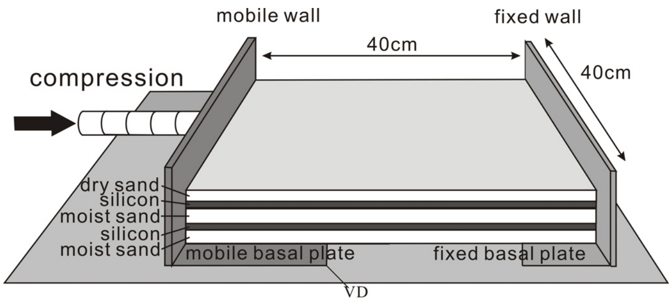

Fig. 3. Experimental apparatus

in the South China Block which is characterized by detachment structures in upper crust and rheological structure in middle crust (Wang et al., 2005). Especially, thin-skinned structure belt in the south Qin-ling orogenic belt, northwest Xuefengshang thick-skinned structure belt and east Sichuan Basin is characterized by later-Mesozoic multi-layer detachment structures, and strata at different depths have different deformation styles(fig.1 and 2) (Yan et al., 2003).

3 Model Construction and Experimental Set Up

In order to better understand the geometrical and kinematic implications of this setting in the evolution of a thrust belt, we put forward four analogue models. Each model consists of two weak layers, at two different stratigraphic levels. The weak layers being used to simulate detachment layers are composed of silicone putty, whereas the competent rocks are simulated by quartz sand. The depths of the weak layers are varied for various models, so as to investigate the effects of depth of detachment layers on deformation styles (Fig. 3) .

3.1 Set-up and boundary conditions

The right edge of the models was fixed. Models were laterally shortened from left to right by a motor with a velocity of 5.4 cm/h. This process was simulating that of compression from southeast to northwest in the South China Block in late-Mesozoic. The other two sides are free.

3.2 Analogue materials

The complicated rock combination was simplified into four types, and was simulated by four kinds of analogue materials: (1) Moist sand, a Mohr-Coulomb material with density of 1800 kg m-3 and an angle of internal friction between 35°and 40°, was composed of sand mix with 5.6% of water, had a higher cohesion (1000-5000 MPa) than dry sand; (2) Dry sand, a Mohr-Coulomb material with a diameter vary from 0.1 mm to 0.3 mm, a density of 1700 kg m-3 and an angle of internal friction between 30°and 32°; (3) Silicone, Laboratory tests on this material indicated a Newtonian behavior with viscosity of 1×104 Pa s at room temperature (28 ℃) , a density of about 950-1000 kg m-3; (4) More viscous silicone (Sand + Silicon, Laboratory tests on this material indicated a Newtonian behavior with viscosity of 105 Pa s at room temperature (28 ℃), a density of 1200 kg m-3.

4 Comparison Analogue Models With Natural Examples

The modeling results display most of the characteristics described for natural structural styles of Mesozoic multi-layer over-thrust system in South China such as fault related folds, detachment folds, fault bend folds and flat-ramp-flat geometries. If similarity conditions are satisfied, this good correspondence indicates a similarity in dynamic processes, which means that the models can be used to understand better the mechanics of the geological processes. From a geometrical point of view, the detachment folds, flat-ramp-flat geometries, fault bend folds can be qualitatively compared with patterns known from field examples of the Mesozoic multi-layer over-thrust system in South China(Fig. 4).

5 Conclusions

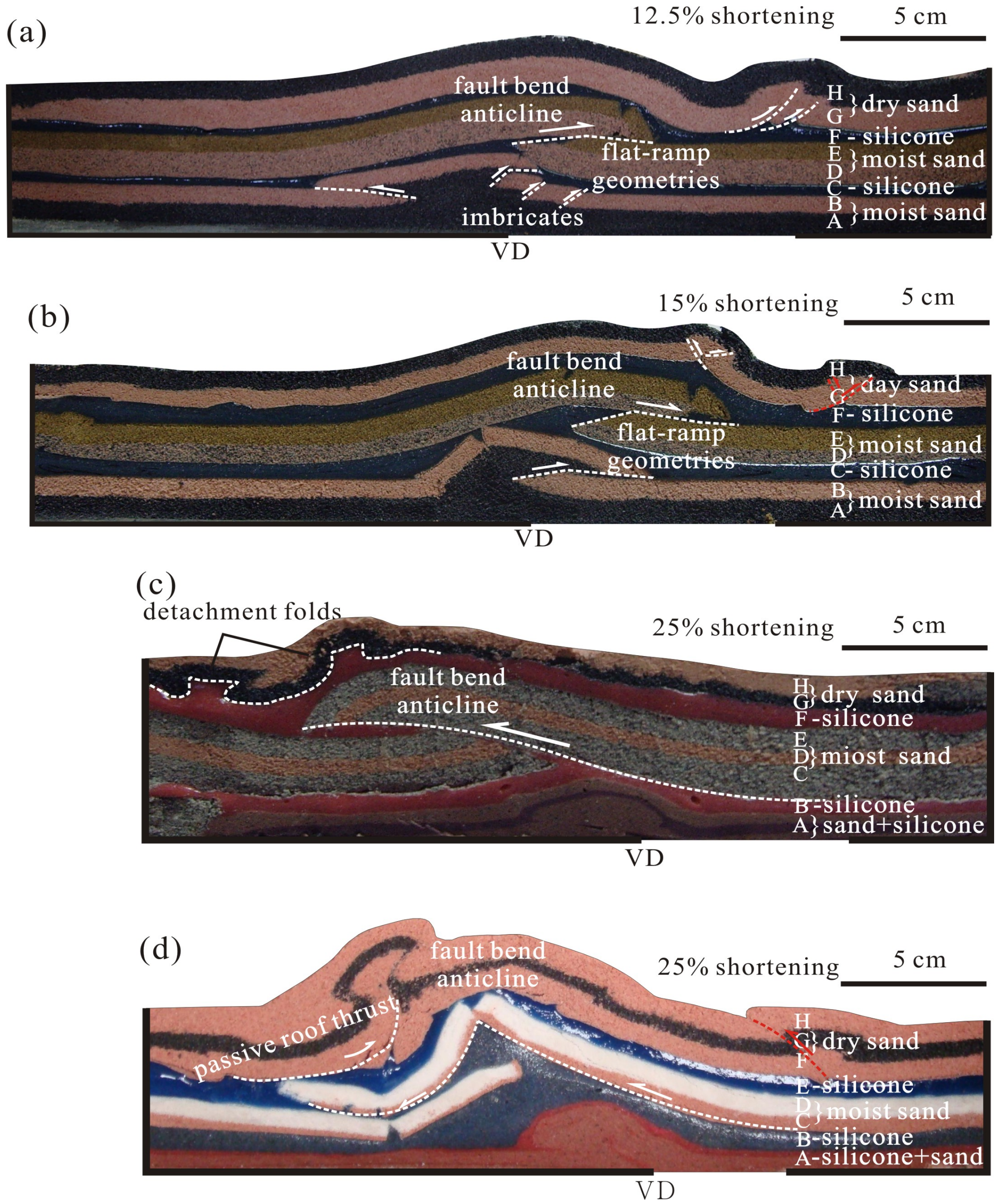

Fig. 4. The section of models

Both modeling results and natural examples indicate that the structure and evolution of the Mesozoic over-thrust system in South China are generally dominated by the deep-seated structures, and locally complicated by the shallow-seated structures. The structural dimension and style greatly depend on the depth of detachment; deep-seated structures are systematically larger than shallow-seated structures. Deep-seated detachment layers nucleate large structures such as major detachment thrusts and large duplexes. However, shallow-seated detachment layers nucleate small structures such as numerous splay faults, shallow imbricates, detachment folds and fault related folds. Moreover, the structural styles of the cap formation are mainly depending on the depth of the shallow-seated detachment layers. Besides, the presence of detachment layers give rise to decoupling between deeper and shallower structures. Therefore, two detachment layers nucleate two sets of structures at different levels, with different geometrical characteristics and significance.

Analogue modeling results suggest that the brittle or competent layers at deep levels were deformed by major reverse faults, and fault bend folds whose flat-ramp-flat geometry depends on competency contrast among strata; the upper brittle layers were always characterized by reverse faults, fault propagation folds, shallow imbricates, detachment folds and passive roof thrust, which are nucleated in the upper weak ductile layers. Detachment folds always occurred in the thin cap formation above or at the front of the fault bend fold. The passive roof thrust always occurred in the thick cap formation, and has an opposite thrusting direction. Ductile or incompetent layers played a role of accommodating those deformation styles.

Acknowledgments

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