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Morphostructural and tectonophysical features of strike-slip and extensional fault zones (*results of analog modeling*)

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Abstract

The formation of the relief of fault zones is considered in relation to the evolution of their internal structure during faulting. The study was carried out by analog modeling with subsequent digital elevation modeling of the experimental surface of the deformed sample. The vertical displacement gradient was calculated based on the digital elevation models. It has been found that the relief of strike-slip and extensional fault zones depends on their internal structure. Each element of the internal structure makes its own contribution to the relief formation. The process depends on experimental conditions, such as the viscosity of the model material and the model deformation rate. The relief of the fault zone is different at each of three main stages of its formation.

Keywords: strike-slip fault zone; normal-fault zone; analog modeling; digital elevation models; vertical displacement gradient

Introduction

In accordance with the tectonic approach, faults develop in the Earth's crust as wide zones consisting of various types of structural elements, among which the main role is played by fracture systems paragenetically related to the formation of the main fault plane (Sherman et al., 1983; Seminsky, 2003).The internal structure of these zones is characterized by spatio-temporal inhomogeneity, expressed, in particular, in the stage development of the fault and the presence of regions of specific structural development, called duplexes, pull-apart, and others. Depending on the presence or absence of these specific forms, determined by the mechanisms and history of the formation of a fault zone, the latter will be characterized by significantly different morphostructural expressions in the field, on topographic maps, and aerial and satellite images. Thus, the relief and structure (Fig. 1) of the left-lateral Levant fault zone have distinct pull-apart regions (basins of the Gulf of Eilat and the Dead Sea) and a region of strong compression—a horst (the Palmyra fold belt). In turn, in the relief and structure (Fig. 2) of the right-lateral San Andreas fault zone, large-scale extensional and compressional features are not observed, but the main fault plane of the zone and en-echelon R and R' shears are well expressed.

Relief formation within natural fault zones is difficult to study because this process, first, occurs over a long geological time and, second, is complicated by exogenous processes. In addition, the application of morphotectonic field methods to major fault zones is hindered by the impossibility of studying large natural areas with the same quality. An effective method for studying crustal deformations in this case is analog modeling. In analog experiments, changes that have occurred in the Earth's crust for millions of years can be simulated on a model within tens of minutes to a few hours. Analog modeling using an elastic-plastic material (clay paste) is currently an effective method for studying faulting processes (Bornyakov, 2012). At the same time, current analog modeling studies of relief focus on the development of a special model material to achieve the greatest similarity with nature and the dynamics of relief formation under exogenous influences and, less frequently, the relationships between exogenous and endogenous (tectonic) processes during relief formation (Crave et al., 2000; Dooley and Schreurs, 2012; Graveleau and Dominguez, 2008; Graveleau et al., 2011; Guerroue and Cobbold, 2006; Marques et al., 2007; Strak et al., 2011).

The aim of our experiments was to study regularities in the formation of proper tectonic relief not complicated by exogenous influences. It should be noted that the exogenous factor plays an important role in the transformation of the Earth's topography as a whole, but it is not crucial to the development of the relief of tectonically active areas, so that it was not

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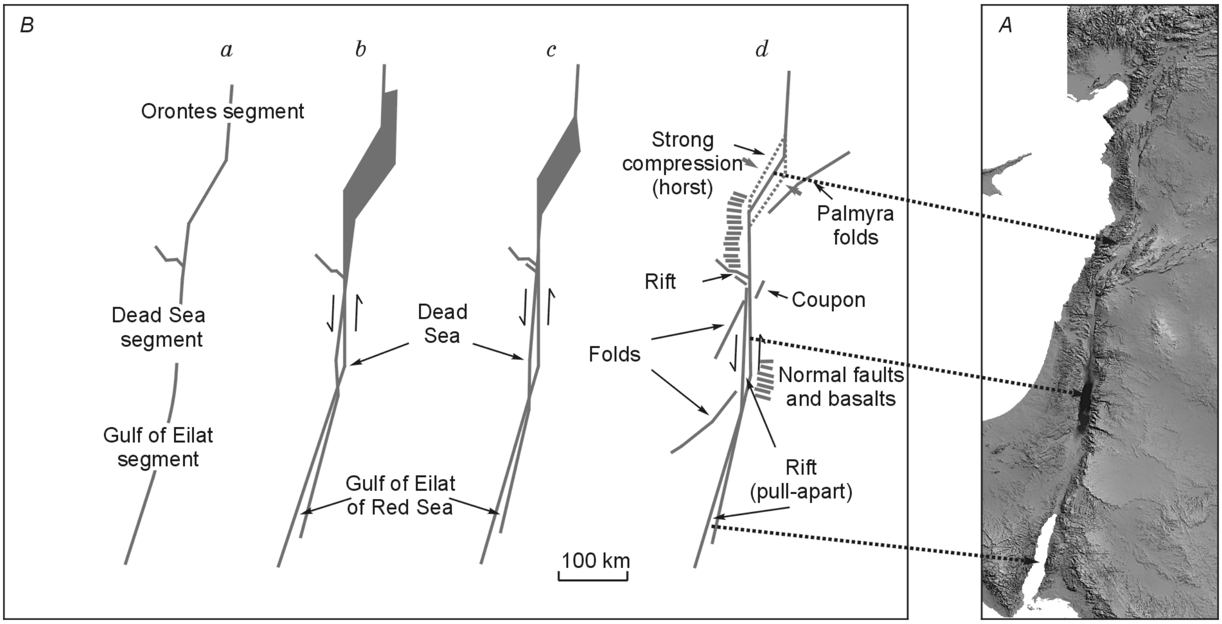

Fig. 1. Relief and internal structure of the Levant fault. *A*, A portion of the area of influence of the Levant fault on the SRTM digital elevation model; *B*, the internal structure of the Levant fault zone (*d*) and the stages of its formation (*a–c*) according to (Price and Cosgrove, 1990).

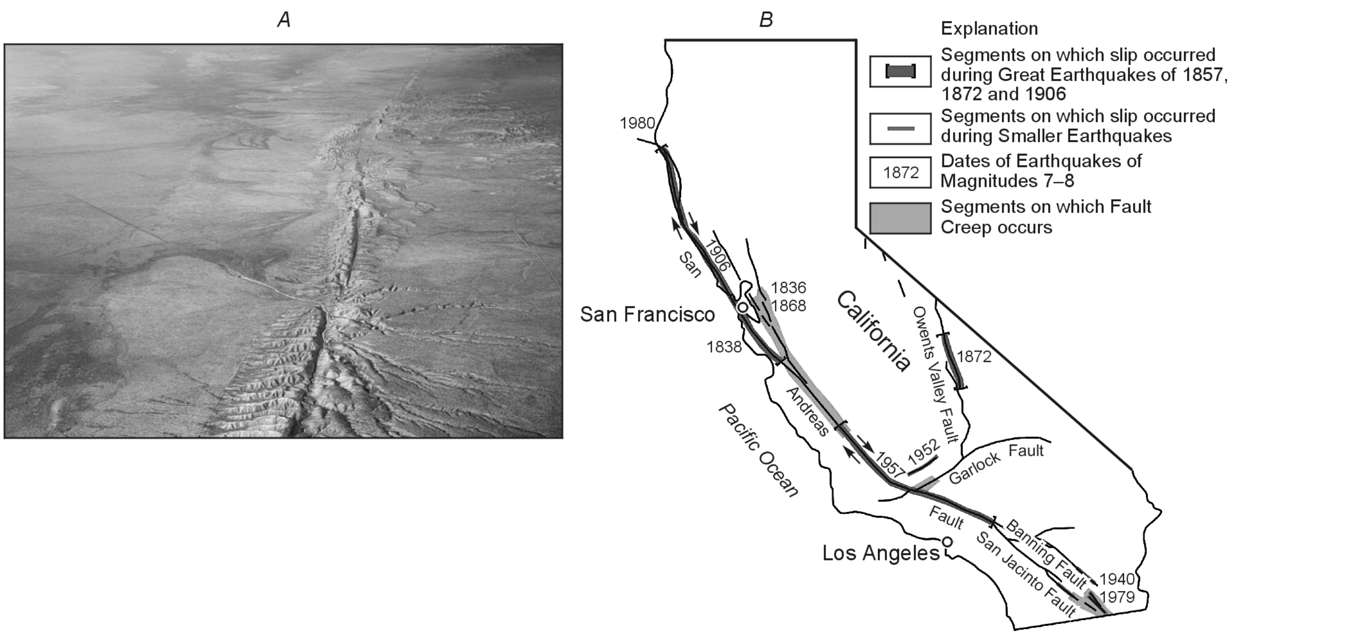

Fig. 2. Relief and the internal structure of the San Andreas fault. *A*, aerial photograph of a portion of the San Andreas fault zone; *B*, diagram of major faults in the San Andreas region and the relative slip rates on them during earthquakes from (Molnar and Dayem, 2010; Romanyuk et al., 2012).

taken into account in the experiments. Such data can then be used to address problems of the origin of relief in natural fault zones and their mapping. The objectives of the study were: (1) to carry out experimental modeling of strike-slip and extensional fault zones in an elastic-plastic medium to investigate the formation of tectonic relief; (2) to examine the influence of faulting and boundary conditions on the paste viscosity, deformation rate, and thickness of the experimental model on the relief of a strike-slip zone as an example; (3) to construct digital elevation models and distributions of the vertical displacement gradient for experimental surfaces and perform their comprehensive analysis to elucidate the specificity of the expression of the internal structure of the fault zone in the relief.