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Neogene tectonic evolution of the San Andreas Fault System in central and northern California: numerical modeling approach

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The San Andreas Fault System formed in response to collision of the Farallon ridge with North America plate margin during the Oligocene. At present the system accommodates the relative motion between the Pacific plate and the North American plate along the complex network of sub-parallel faults. Using the 3D thermo-mechanical numerical models we study the major factors controlling simultaneous activity of these sub-parallel faults and the overall landward migration of the plate boundary (accretion of the North America terranes to Pacific plate). The details of the employed numerical modeling technique can be found in Popov and Sobolev (2008) PEPI, 171: 55-75.

In the context of ridge-trench collision, two basic concepts can be identified: the so-called "slab window" hypothesis and the "stalled slab" hypothesis. The difference between the concepts consists in a fact whether or not the remnants of subducting Farallon plate get stuck in the fossil subduction zone. Accordingly, two different scenarios can be proposed to explain the accretion of the North America terranes to Pacific plate. In the slab window model, the accretion is caused by conductive cooling of the upwelling mantle, while the microplate model explains terrane accretion by the increasing coupling between the captured microplate and the continent via extinct subduction interface. Both these concepts are tested by the numerical models presented in this study. The typical model starts at about 20 Ma and spans 1000 km laterally and 100 km in depth. It includes the subducting and migrating Gorda slab on the northern part, and the Great Valley block in the eastern part. We study the influence of the pre-existing structures (Salinian block) and the magnitude of the effective friction on the strain localization in the crust. We make no assumptions about the spatial styles of the deformation; our models are completely three-dimensional and thermo-mechanically coupled.

The results show that the landward "jump" of the SAFS plate boundary related to the cooling of the slab window adjacent to Pacific plate is inhibited by the slip-related frictional weakening and heating of the mantle roots beneath the older fault zones. The plate boundary migration is also slowed by the tectonic forces resulting from the jump-induced transpression. The models confirm that a series of microplate capture events has been the most likely reason of the inland migration of the San Andreas plate boundary over the recent 20 Ma. The presence of a slip weakening mechanism in the frictional part of the lithosphere is an essential parameter to keep the surface heat flow in agreement with the observations, if we account for the shear heating to full extent. Moreover, we demonstrate that a lack of the slip weakening (which implies strong major faults) fails to predict the distinct zones of strain localization in the brittle crust. Our best-fit model requires the friction coefficient on major faults to be about 0.1, which is far less than typical values 0.6 – 0.8 obtained by variety of borehole stress measurements and laboratory data. Therefore, we side with a "weak fault" theory, and favor importance of the slip-related weakening.

Additionally, we present the first results of the extended models which span horizontally about 2000 km and include substantial portions of the North America crust to the north of Mendocino Triple Junction and to the east of Great Valley.