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Parallel normal faults and a thin viscous channel

T. J. Nagel (1) and W. R. Buck (2)

(1) Geologisches Institut Bonn, Germany, (2) Lamont-Doherty Earth Observatory, New York, USA (tnagel@uni-bonn.de / Phone: 49-228-739335)

Based on the results of physical experiments, arrays of parallel-dipping normal faults have previously been attributed to uniform horizontal shear stress as a result of a consistent flow direction in the viscous substratum of the brittle material (e.g. Brun et al. 1994). However, the observation of transfer zones and varying dip polarity along strike in many rift systems casts doubt on the paramount significance of this scenario.

We present numerical experiments exploring fault patterns within a brittle layer on top of a viscous substratum as a function of varying viscosity and thickness of the viscous layer. Parallel-dipping faults form only if a thin layer of moderate viscosity is sandwiched between the brittle layer on top and a lower boundary that resists vertical distortion. Using this stratification, parallel normal faults form even if the lower boundary is shear-stress-free. We explain this behavior through the particular way of how faulting in the upper layer is accommodated in a thin viscous channel. First, a thin weak layer allows for closely spaced single faults in the brittle layer. A high viscous substratum tends to reflect faults at the brittle-viscous interface (Montesi and Zuber 2003, Huismans et al. 2005), thus causing the formation of local grabens (instead of a single fault) at each place the brittle layer fails. A thick weak substratum leads to the formation of widely-spaced core complexes rather than the required close fault spacing. We find that a thin weak channel allows for efficient boudinage while still not posing so much resistance at the fault tip as to promote the graben geometry of failure. Second, flow in a thin channel can explain why closely spaced single faults arrange to a parallel-dipping array. Within the viscous layer, material flows from narrowing channel segments (i.e. hangingwall sections) into widening channel segments (i.e. footwall sections). An array of parallel faults minimizes the average distance between narrowing and widening channel segments. Since the viscous work rate depends quadratically on the average segment length, the parallel fault geometry minimizes the

work rate in the viscous layer.

Our model provides an explanation of parallel-dipping faults in areas such as the Basin and Range province where dip polarity varies along strike. This would imply that in these areas a thin weak channel exists in the mid crust that has a lower boundary with a certain stiffness. Hence, the lower crust would have to be considerably stronger than the middle crust.

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