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Robust velocity-weakening frictional behaviour of plagioclase at hydrothermal conditions in the lower crust

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Seismic/aseismic fault slips are possible processes in the lower crust as indicated by some moderate earthquakes in the lower crust(Maggi et al., 2000; Bai et al., 2015) and tremors in the lower-crust portion of San Andreas fault(Shelly and Hardebeck, 2010). Previous experiments have shown that pyroxene and plagioclase (both separated from gabbro) and their mixtures all show velocity-weakening behavior in the lower-crust temperature range under effective normal stress 200 MPa, which property can lead to unstable slips and thus provides a clue for the origin of lower-crust unstable slips(He et al., 2013). However, question arises as to how robust this velocity-weakening property is in broader pressure conditions. This work is to examine whether the velocity-weakening behavior of plagioclase gouge also applies to a relatively broader range of effective normal stress. Three groups of experiments were designed to this end: two series at effective normal stress 100 MPa with pore water pressures of 30 MPa and 100 MPa, respectively, and another series with effective normal stress of 300 MPa with pore water pressure of 30 MPa, with temperatures of 100-600^{o}C for each series. The experimental results show the following observations into the problem.

(1) For temperature above 300^{o}C, velocity-weakening behavior occurred in all the explored pressure conditions, with $a - b$ decreasing with the increase of effective normal stress, suggesting that lower effective normal stress promotes unstable slips.

(2) Our detailed numerical fitting to a rate and state friction law shows that both the direct effect (a value) and evolution effect (b value) have an increasing trend for temperatures from 200-500^{o}C, a typical feature of thermally activated processes. However, a significant drop from the trend was found at 600^{o}C, probably due to slight change in the controlling mechanism.

To summarize, the effect of normal stress has an effect on the degree of velocity weakening without changing the sign of velocity dependence, thus unstable slips in the lower crust are possible in explored normal stresses of 100-300MPa.