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Frictional properties of comminuted dolerite gouges at low to high slip velocities

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We investigated how frictional properties of ground dolerite gouges change according to grinding time. We have ground crushed and sieved grains of dolerite using an automated flint mill for 10 minutes, and 6, 12, 24, 36, 48 and 60 hours. Quantitative XRD analyses indicate that amorphous phase is absent in the gouges ground for 10 minutes, but that its amount increases linearly up to 40 wt% with grinding time up to 36 hours. Grinding for more than 36 hours, however, does not result in any further increase in amount of amorphous phase.

We have conducted friction experiments on the dolerite gouges ground for 10 minutes, 24 hours and 60 hours using a high-temperature biaxial apparatus at temperatures of room temperature and 120 degrees Celsius, a normal stress of 20 MPa, and slip velocities changed stepwise between 2 micrometer/s and 20 micrometer/s. Irrespective of temperature and grinding time, friction coefficients are ˜0.7 and decrease with increasing slip velocity or vice versa, i.e., velocity weakening. At room temperature, slip-dependent frictional behavior shows a correlation with grinding time; gouges ground for 10 minutes, 24 hours and 60 hours exhibit slip-softening, steady-state slip and slip-hardening, respectively. In contrast at 120 degrees Celsius, gouges exhibit steady-state slip irrespective of grinding time.

We also have conducted friction experiments on the dolerite gouges ground for 10 minutes, 12 hours and 60 hours using a low- to high-velocity rotary shear apparatus at room temperature, a normal stress of 2 MPa, and constant slip velocities ranging from 2 micrometer/s to 1.3 meter/s. Friction coefficients of gouges ground for a specific time do not change much according to slip velocities slower than 4centimeter/s, whereas they dramatically decrease with increasing slip velocity at velocities faster than 4 centimeter/s, down to ˜0.2 at 1.3 meter/s. At a specific slip velocity slower than 4 centimeter/s, the gouges ground for 12 and 60 hours show friction coefficients (0.56-0.69) larger than that of the gouge ground for 10 minutes (0.55-0.6), while at a specific slip velocity faster than 4 centimeter/s, the former gouges show friction coefficients (0.14-0.47) smaller than that of the latter gouge (0.21-0.54). In addition, as in the biaxial friction experiments, gouges ground for 10 minutes, 12 hours and 60 hours exhibit slip-softening, steady-state slip and slip-hardening, respectively.

The above frictional properties of dolerite gouges depending on grinding time can be explained by the amount of moisture adsorbed in amorphous phase. Submicron-size amorphous particles have a tendency to accrete around clast grains by moisture adsorbing and electrical forces. The gouge ground for a longer time contains a larger amount of amorphous phase so that a larger amount of moisture is adsorbed, which would then result in a higher friction due to moisture-adsorbing strengthening (Mizoguchi et al., 2006, GRL) if the slip surface temperature is lower than 100 degrees Celsius. If the slip surface temperature becomes higher than 100 degrees Celsius, however, moisture adsorbed in amorphous particles would be lost to result in a lower friction, which should be more pronounced in the gouge ground for a longer time. It is likely that the slip surface temperature became higher than 100 degrees Celsius at slip velocities faster than 4 centimeter/s. The difference in slip-dependent frictional behavior according to comminution time suggests that moisture adsorbing in amorphous phase occurs even during the friction experiments.

Keywords: Dolerite gouges, Amorphous phase, Frictional properties at low to high slip velocites