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

WADA, Jun-ichi[1] ; KITAJIMA, Hiroko[2] ; TAKAHASHI, Miki[2] ; OOHASHI, Kiyokazu[1] ; INOUE, Atsuyuki[1] ; KANAGAWA, Kyuichi[1*]

[1]Graduate School of Science, Chiba University, [2]Active Fault and Earthquake Research Center, Geological Survey of Japan

We investigated how frictional properties of ground dolerite gouges change according to grinding time. We have ground crushed and sieved grains (smaller than 500 microns) of dolerite using an automated agate mill for 10 minutes, and 6, 12, 24, 36, 48 and 60 hours. Quantitative XRD analyses indicate that amorphous phase is absent in the gouge ground for 10 minutes, but its amount increases up to 40 wt% with grinding time. Gouges ground for more than 6 hours contain abundant spherical grains composed of amorphous nano-particles. Such spherical grains are likely formed by accretion of amorphous nano-particles through their electrostatic attraction and moisture-induced binding, as accretionary lapilli. In fact, thermogravimetric analyses reveal that the amount of water adsorbed increases up to 14 wt% with grinding time in accordance with the amount of amorphous phase.

We have then conducted friction experiments on the ground dolerite gouges using a rotary shear apparatus at room temperature, a normal stress of 2 MPa, and constant slip velocities ranging from 20 micrometers/s to 1.3 m/s. At slip velocities slower than or equal to 1.3 cm/s, temperatures of gouges were lower than 70 degrees C, and steady-state friction coefficients range from 0.59 to 0.75, which tend to be higher for gouges with longer periods of grinding time at the same slip velocity. At the slip velocity of 4 cm/s, temperatures of gouges were over 100 degrees C, and steady-state friction coefficients range from 0.60 to 0.66, the difference of which among gouges with different periods of grinding time was relatively small. At slip velocities faster than or equal to 13 cm/s, however, temperatures of gouges reached higher than 180 degrees C, and steady-state friction coefficients dramatically decreased with increasing slip velocity. In addition, steady-state friction coefficients at the same slip velocity tend to be lower for gouges with longer periods of grinding time.

Such frictional properties of ground dolerite gouges depending on grinding time can be explained by the amount of water adsorbed in amorphous gouge. At slip velocities slower than or equal to 1.3 cm/s, temperatures of gouges were lower than 100 degrees C so that water adsorbed in amorphous gouge was retained. Thus, gouges ground for longer periods of time with larger amounts of adsorbed water likely became stronger in steady-state friction due to capillary bridging between amorphous gouge particles. At the slip velocity of 4 cm/s, temperatures of gouges became higher than 100 degrees C so that dehydration occurred from the amorphous gouge, which resulted in a small difference in steady-state friction among gouges with different periods of grinding time. At slip velocities faster than or equal to 13 cm/s, the moisture production rate from the dehydrated amorphous gouge was likely faster than its leak rate, which resulted in an increase in pore pressure in the gouge layer and hence a decrease in frictional strength. Thus, gouges ground for longer periods of time with larger amounts of adsorbed water became weaker in steady-state friction due to larger increases in pore pressure.

Keywords: dolerite, ground gouge, frictional properties, amorphous gouge, moisture adsorption