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Frictional strength of dolerite at an intermediate slip rate dependent on background temperature

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We have conducted friction experiments on dolerite using a high-temperature rotary shear apparatus, and investigated the dependence of its frictional strength at an intermediate slip rate on background temperature. The protolith is dolerite from Ireland, and composed of plagioclase, clinopyroxene, orthopyroxene, hornblende, quartz, K-feldspar, biotite, ilmenite, magnetite, hematite and apatite. We have conducted two types of experiments at a constant normal stress of 1 MPa and a constant slip rate of 1 cm/s; one at a fixed background temperature between room temperature and 1000 degrees Celsius, and the other at variable background temperatures from room temperature to 1000 degrees Celsius changed by steps while holding. After the former type of experiments, we have collected wear materials and specimens in order for material and microstructural analyses. In both types of experiments, frictional strength rapidly decreases with the increase in background temperature from room temperature to 100 degrees Celsius, and decreases gradually with increasing background temperature up to 400 degrees Celsius. From 400 to 800 degrees Celsius, however, frictional strength gradually increases with increasing background temperature, and it decreases again with increasing background temperature from 80 0 to 1000 degrees Celsius.

Gouge particles derived by comminution of the host rock are present on sliding surfaces at background temperatures from room temperature to 800 degrees Celsius. Gouge particles larger than 1 micron are crystalline, while X-ray diffraction analyses revealed that those smaller than 1 micron are largely amorphous. The amount of amorphous gouge particles increases with increasing temperature from room temperature to 200 degrees Celsius, while it decreases with increasing temperature at temperatures above 400 degrees Celsius, and diminishes at 1000 degrees Celsius. At a background temperature of 1000 degrees Celsius, iron-bearing minerals in the host rock such as pyroxenes, hornblende and biotite are decomposed into very fine-grained (smaller than 1 micron) polymineralic aggregates of oxidation reaction products. Very fine-grained aggregates of rounded and equant grains with a flowage structure are also present on sliding surfaces. They are composed of the same mineral grains as the oxidation reaction products in the host rock. But crystallographic preferred orientations of the latter are very strong, while those of the former are very weak.

Frictional strength at background temperatures from room temperature to 800 degrees Celsius is likely dependent on the amount of amorphous gouge particles as well as the amount of water absorbed by gouge particles. With the increase in background temperature from room temperature to 100 degrees Celsius, dehydration of gouge particles in addition to the increase in amount of amorphous gouge particles results in a large decrease in frictional strength. The amount of amorphous gouge particles reaches maximum at background temperatures of 200 to 40 0 degrees Celsius, and frictional strength reaches minimum at this range of background temperature. At background temperatures above 400 degrees Celsius, the amount of amorphous gouge particles decreases and hence frictional strength increases with increasing background temperature. At background temperatures above 800 degrees Celsius, granular flow of oxidation reaction products of iron-bearing minerals on the sliding surfaces possibly reduced frictional strength.

Keywords: frictional strength, dolerite, background-temperature dependence, intermediate slip rate