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Amorphization of clay minerals by thermal and mechanochemical processes, and its implications for seismic faulting

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Amorphous nanoparticles on the slip surface have been paid much attention since they give significant influences on the frictional properties. They are considered to be formed by combined processes including mechanical, chemical and thermal ones. It is well known that clay minerals are easily transformed into amorphous materials mechanochemically by grinding. We performed experimental studies on amorphization of kaolinite and saponite, common clay minerals under a surface environment.

Heat treatment: Crystalline kaolinite was completely decomposed and transformed into amorphous phase after 1 hour heating at 600 degrees Celsius and also after 1 minute heating at 1000 degrees Celsius. Saponite was completely decomposed and transformed into enstatite after 5000 minutes at 680 degrees Celsius and after 60 minutes at 800 degrees Celsius. The activation energy of amorphization of kaolinite was estimated to be 98kJ/mol.

Mechanochemical process: Dry grinding experiments of crystalline kaolinite and synthetic saponite using a planetary ball mill were conducted. Amorphization is completed after 3 hours milling (400 rpm) for kaolinite and 9 hours for saponite. Aggregates of nanoparticles were observed with FE-SEM. The injection energy during the experiment is estimated to be 9550 kJ/kg for kaolinite and 28700 kJ/kg for saponite.

The maximum temperature on a fault surface could be as high as 1000 degrees Celsius by frictional heating. The fracture energy in large earthquakes is estimated to be 1000 to 10000 kJ/kg. Thus kaolinite can be transformed into amorphous phase in faulting. Saponite is less easily amorphized than kaolinite. This is concordant with the observation at Taiwan Chelungpu fault core (Hirono et al., 2008).

Keywords: clay minerals, amorphous, mechanochemical, frictional heating, faulting