Changes in frictional properties of mud gouge with depth in the Nankai Trough accretionary prism

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In order to investigate the changes in frictional properties of mud gouge with depth in the Nankai Trough accretionary prism, we conducted triaxial friction experiments on gouge of a mud sample cored from 2183.6 mbsf (meters below seafloor) at IODP Site C0002, at three conditions supposed at depths of 1000, 3000 and 5000 mbsf there. We conducted two series of friction experiments; slide-hold-slide experiments for static friction data and rate-stepping experiments for dynamic friction data. In the former series of friction experiments, sliding at an axial displacement rate of 1 μm/s was held for periods ranging from 10s to 10^4s, after which sliding was resumed at the same rate. In the latter series of friction experiments, axial displacement rate was changed stepwise among 0.1, 1 and 10 μm/s.

The slide-hold-slide experiments show that the coefficient of static friction μ_s decreases from 0.37–0.38 at the 1000 mbsf condition to 0.30–0.31 at the 3000 mbsf condition, while it increases to 0.33–0.36 at the 5000 mbsf condition. Healing $\Delta\mu$ (increase in friction coefficient upon resuming sliding after a holding time t_h) was not noticeable at $t_h \leqq 1000$s during the 3000 mbsf condition experiment, while $\Delta\mu$ was recognized at $t_h \geqq 100$s during the other experiments. $\Delta\mu$ increases logarithmically with t_h, which was more prominent at the 5000 mbsf condition. Dehydration of smectite at the 3000 mbsf condition where temperature was 100˚C possibly increased pore pressure in the impermeable gouge layer, which was responsible for the minimum μ_s and non-healing effect at $t_h \leqq 1000$s at this condition. While lithification of gouge particles by pressure solution was possibly responsible for increasing μ_s and $\Delta\mu$ with t_h at the 5000 mbsf condition where temperature was 150˚C.

The rate-stepping experiments show that the steady-state friction coefficient μ_{ss} also decreases from 0.32–0.35 at the 1000 mbsf condition to 0.29–0.31 at the 3000 mbsf condition, while it increases to 0.32–0.33 at the 5000 mbsf condition. The minimum μ_{ss} at the 3000 mbsf condition is also attributable to dehydration of smectite as in the case of μ_s. a–b value (rate dependence of μ_{ss}) decreases with depth from 0.0018–0.0062 at the 1000 mbsf condition to −0.0005–0.0017 at the 5000 mbsf condition, suggesting that a transition from aseismic faulting to seismic faulting occurs around the depth of 5000 mbsf at IODP Site C0002. Thus the megathrust supposed to be present at ≈5200 mbsf there is likely at a seismogenic condition. Dependence of a–b value not only on temperature but also on displacement rate suggests that thermally activated pressure solution is relevant to this change in frictional stability.

Keywords: frictional properties, mud gouge, Nankai Trough accretionary prism

