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Effects of mesoscopic-scale fault structure on dynamic earthquake ruptures: dynamic formation of geometrical complexity of earthquake faults

R. Ando (1), T. Yamashita (2)

(1) Lamont-Doherty Earth Observatory, Columbia University, NY, USA, (2) Earthquake Research Institute, University of Tokyo, Japan, (ando@ldeo.columbia.edu)

Geological observations illustrate the existence of geometrical complexity of fault zones in the scale from few m to few hundreds m. This scale, called mesoscopic scale, is much larger than laboratory scales and much smaller than spatial resolution of seismic inversion analyses, therefore hardly considered in previous studies. We theoretically investigate the effects of these geometrical structures on earthquake dynamics by introducing newly developed multi-hierarchy earthquake rupture model taking account of microscopic-, mesoscopic- and macroscopic-scales. In this study, we focus on the dynamic formation process of branch faults distributed along a principle slip plane or a main-fault, which are commonly observed in natural fault zones. In a 2-D infinite elastic medium, we assume mode II ruptures obeying a slip weakening law. Following a geological observational fact, we assume the zone of weakness distributed over certain thickness, which is much wider than the width of slip planes. As the result, we observe the following significant phenomena. (1) Sequential secondary faulting are induced associated with the growth of the initial fault, termed main-fault here, by stress concentration at its tip. (2) The lengths of the branches become proportional to the length of the main-fault L by arrest of the branch growth if L is less than a critical length; we term these branch fault as mesoscopic branches because they are obvious fault planes but much smaller than the main-fault length. (3) If the main-fault is propagated beyond the critical length, some of subsequent branches start to be propagated spontaneously; these branch faults termed macroscopic branches emerge the further complexity of the fault geometry. (4) The rupture velocity of the main-fault is reduced at a certain value less than Rayleigh wave speed as a terminal velocity; this reduction due to interactions between the main-fault tip and branch faults also can be explained

by the increase of fracture energy dissipated on the branch faults based on energetics.