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Formation of the geometry of fault system and dynamic earthquake rupture process

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Introduction

While geometrical complexity of fault system is not fully understood, some progress is made in recent studies. It is shown in those studies that interactions among fault segments play an important role in the formation of fault system geometry. However no simulations had been carried out, which consider the effects of dynamic interactions among fault segments and spontaneous bending of faults on formation of fault system geometry and dynamic rupture process because of mathematical difficulty and limitations of computational resources. Hence the above two effects are still not clear and our objectives are to investigate these effects on formation of fault geometry and dynamic rupture process.

Method and model

In order to investigate the formation of fault system geometry and dynamic rupture process, new numerical scheme using a boundary integral equation method (BIEM) is developed, and the dynamic rupture process assuming interactions among fault segments and non a priori constraint on the fault tip path is simulated. We assume fracture criterion that the fault tip extends in the direction where the shear traction takes local maximum. We first examine the formation of the fault geometry due to interactions between faults assuming two interactive faults as a fundamental problem. Next we investigate the mechanism of the rupture transfer between two interactive faults.

Result 1. Formation of fault geometry

We obtain qualitative properties of the effects of the interactions on the formation of fault geometry. We find that the resulting fault geometry significantly depends on its initial arrangement and approaching or separating of each fault tip is simulated. We also find that the resulting geometry highly depends on the fault tip velocity, which implies quasi-static analyses not inappropriate for the understanding of dynamic processes.

Result2. Dynamic rupture process

From the simulation of the spontaneous rupture transfer process of the interactive faults, we find that the arresting of the rupture could occur in the interactive fault system, because of abrupt bending of fault tip, and the released shear traction is negative on the bent segment of the fault. Comparing our results with the 1992 Landers, California, earthquake, we find similarity on heterogeneous distribution of the slip on the fault, the geometry of the fault trace, and the time delay of the rupture transfer.

One of the differences between our bending fault system and the straight fault system is the existence of stopping phase due to the time delay of rupture transfer, which appearing in our bending fault system.

Result3. Dynamic rupture in fault zone

Finally the spontaneous dynamic rupture process in fault zone is simulated; fault zone is approximated by arrays of micro-cracks in our study. We show that the rupture process depends on the initial micro-crack geometry rather than simply on the micro-crack density, and rupture arresting could occur due to the interactions among micro-cracks.

Conclusion

We simulate the formation of fault geometry and dynamic rupture process considering interactions among fault segments and spontaneous bending of fault for the first time ever. Our results consist with the characteristics of natural faults and show that the complexity of fault system geometry and dynamic rupture process could be understood as the results of interactions among fault segments and spontaneous fault bending during dynamic rupture process.