論文の内容の要旨

O(N) method for spatio-temporal boundary integral equation method and a refined evolution law of the frictional strength - Toward realistic fault modeling

(現実的な断層モデリングに向けた、摩擦強度発展則の精密化と時空間境界積分方程式法のO (N) 法の開発)

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As the computational sciences and geosciences develop, physics-based fault modeling has become improved. In this research, I treat two major issues related to the significant components of the physics-based fault modeling: elasticity and friction.

In the elastic part, I solve the numerical cost problems in the algorithm of the spatiotemporal boundary integral equation method (ST-BIEM). Because of its accurate description of the complex fault geometries and the stress singularities around fault edges, BIEM has been widely used in the earthquake sciences. However, the numerical cost of the spatiotemporal formulations is scaled by O(N^2M) for the given number of elements N and that of time steps M, and the numerical cost thus become a major issue of the ST-BIEM when large scale computations is required for the realistic modeling. To overcome this cost problem, I propose a novel algorithm that achieve the numerical cost of O(N log N) for the elastodynamic ST-BIEM, for the first time. Our propositions are called the FDP=H-matrices, the basis of which comprises the Fast Domain Partitioning Method (Ando, 2016) and the H- matrix method (Hackbusch, 1999), and physically corresponds to the plane-wave expansion. FDP=H-matrices greatly reduce the current numerical cost problem in modeling the fault.

In the friction part, I propose a refined evolution law of the rate and state friction law (the RSF law). The RSF law is known as an established friction law at the low slip rate around or smaller than mm/sec, and applied wide range of physics-based fault modeling. However, currently available evolution laws of the state variable in the RSF law cannot describe the representative tests to give the basis of the RSF law. This problem results in the large un- certainty in the fault modeling related to the choice of the evolution laws. Assembling the experimental requirements, I propose an evolution law, called the modified-composite law, that can explain both experiments consistently. The key trick of the modified-composite law to describe both the experiments is to make the cutoff velocity to truncate the time dependent healing term introduced by (Kato & Tullis, 2001) inversely propositional to the state variable. More generally, the trick can be viewed as a switching between the aging and slip-induced evolution of the friction coefficient depending on the distance from the steady state measured by the frictional state variable. The modified-composite law will clear the current ambiguity in the modeling caused by the evolution law choice.