Development of simulation software for non-linear deformation and slip processes at the deeper part of the seismogenic zone

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It is very important to understand how shear zone is localized and how the plastic instability starts and grows at the deeper extension of the fault zone. In the lower crust, due to high temperature, non-linear power-law flow process such as dislocation creep is dominant. However, in previous modeling of earthquake generation processes, only the linear visco-elastic material is considered in the deeper part of the seismogenic zone. To construct a realistic model of the slip and deformation processes at the deeper part of the seismogenic zone, we need to develop a code including analysis of the non-linear visco-elasticity where viscosity depends on strain rate. In this study, we extend the parallel finite element code GeoFEM to have a function of the non-linear visco-elastic analysis. We report the method and some numerical results.

GeoFEM platform: The GeoFEM is a parallel finite element analysis system intended for various solid earth application to multi-physics/multi-scale problems and is being developed at the Research Institute for Information Science and Technology (RIST). The system has a platform feature from which various solid earth models may be read in plug-in style. The non-linear visco-elastic analysis function, which is developed in this research, was built on a GeoFEM platform, as a new function module. The merits of using GeoFEM system consist of reducing the development cost and common model data. Furthermore, the system is equipped for highly effective parallel computing. These features are advantageous to large-scale simulation.

Non-linear visco-elastic analysis: There are two methods of solving non-linear visco-elastic problem by incremental time scheme; the explicit and the implicit method, which method depends on whether viscous deformation can be explicitly described or not. The explicit method is easy to install, uses less memory and computation power, but a relatively minor increment was required to content stable time limit. The implicit method has the opposite feature; the most effective method is selected depending on the viscous model feature. In this research, explicit and implicit schemes were installed and computational efficiency and numerical accuracy were investigated. The explicit method is sometimes useless because it requires an extremely small time step, when viscous law has a large power number under high stress field.

In this research, non-linear visco-elastic simulation software was developed on the GeoFEM platform, to investigate deformation processes at the deeper part of the seismogenic zone. We will install other functions such as (1) analysis of plasticity (Mohr-Coulomb failure criterion), (2) large deformation analysis, (3) frictional constitutive law, and (4) thermomechanical coupling, to execute simulation that is more realistic.