Phase Transformation Mechanism Responsible for Deep-focus Earthquakes by The Multi-Phase-Field Methods

*澤 燦道[1]、木戸 正紀[1]、白石 令[1]、武藤 潤[1]、長濱 裕幸[1]
*Sando Sawa[1], Masanori Kido[1], Rei Shiraishi[1], Jun Muto[1], Hiroyuki Nagahama[1]

1. 東北大学理学研究科地学専攻
1. Department of Earth Science, Tohoku University

One of the possible mechanisms for deep-focus earthquakes is the faulting associated with phase transformation from olivine to spinel under high pressure. Burnley et al. (1991) conducted deformation experiments of Mg_2GeO_4 under conditions at confining pressures of 1~2 GPa, temperature of 900~1500 K and strain rates of 2×10^{-5} ~ 2×10^{-3} s^{-1}. The spinel is observed like microscopic lenses in place of microcracks. They form perpendicular to the maximum compressive direction, which is called "anticracks." They connect with each other, eventually, cause the faulting. Spinel anticracks can be formed by intracrystalline nucleation and nucleation at grain boundaries. As the mechanism, it has been advocated that they form by nucleation whose crystal orientation is random, martensitic transformation or along the dislocation. However, we don't know which is a dominant mechanism forming spinel anticrack. So, to reveal how spinel anticracks are formed, we have studied the transformation mechanics by the Multi-Phase-Field (MPF) method. The MPF method is a phenomenological model based on continuum mechanics and has widely used in material sciences. We can reveal temporal change of material morphology by MPF method, that is, easily follow crystal interfaces with probability. We developed the numerical model taking into account of both intracrystalline nucleation and nucleation at grain boundaries. Furthermore, to constrain physical conditions of the numerical model, we also conducted experiments by a Griggs type piston-cylinder apparatus using solid NaCl as a confining medium based on Burnley et al. (1991) to observe microstructure of a deformed sample. We compressed Mg_2GeO_4 as an analogue material under conditions at confining pressure of 1.2 GPa, temperature of 1200 K and strain rate of 2.0×10^{-4} $s^{-1}$where Burnley et al. (1991) reported faulting by anticrack mechanism. As a result of the experiment, the sample was ductile deformed. According to the microstructural observation on the deformed sample, there are many bands composed of very-fine grained materials. The particle size is very small and there are small faults in the vicinity, so we think that superplastic deformation in these fine-grained portions might cause faulting, as proposed by Burnley et al. (1991). Also, compared to hydrostatic experiment in which fine grain materials were observed but phase transformation didn't occur, we inferred that phase transformation is difficult to occur without differential stress. Therefore, we modified the conditions of numerical model to consider superplastic deformation and particle size, finally, built up new numerical model.

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