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ローソン石の高温高圧変形実験による結晶方位定向配列の観察：沈み込むスラブに見られる地震波の低速度異常層の解釈
High pressure and high temperature deformation on lawsonite: Implication for low velocity layers in subduction zones

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Low-velocity layers (LVLs) located in the upper portions of subducting slabs, are regions of lower seismic wave velocities than those in the surrounding mantles. LVLs apparently persist to depths of 100-250 km [1,2]. Hydrated mafic rocks provide a plausible explanation for the origin of LVLs and trench-parallel/normal S-wave fast polarization. Lawsonite ($CaAl_2Si_2O_7(OH)_2 \cdot H_2O$), which is stable at depths greater than serpentine minerals, is considered to be one of the prime candidate hydrous minerals that can be present deep in the cold subduction zones [3,4]. Single crystals of lawsonite have a high elastic anisotropy, suggesting that the development of the crystallographic preferred orientations (CPOs) when it deformed might strongly affect the seismic properties [5].

This study reports deformation experiments on lawsonite aggregates that were conducted at high pressure and high temperature corresponding to 150 km depth in the subduction zone, to investigate the development of CPOs and the seismic properties of lawsonite. Experiments were performed using a multi-anvil apparatus with six independently acting rams installed at Bayerisches Geoinstitut, Bayreuth University. The starting material consisted of fine-grained (<25 μm) natural lawsonite powder, which was loaded in a Pt capsule and annealed for >20 h at 5 GPa, between 500 and 800 ℃. The samples were then deformed using pure or simple shear geometry at strain rates of 10^{-4}-10^{-6} s^{-1} and a finite strain of 0.3-1.0. Recovered samples were analyzed using a scanning electron microscope (SEM) coupled with an electron backscatter diffraction (EBSD) detector and a transmission electron microscope (TEM).

The deformed lawsonite aggregates display a porphyroclastic texture characterized by a bimodal grain size distribution. The microstructures with dynamically recrystallized grains imply the evidence for the deformation through grain-boundary sliding accommodated by diffusion creep due to the grain size reduction, whereas the porphyroclasts (20-50 μm in size) have undulose extinction, deformation lamellae, irregular grain boundaries, and many sub-grain boundaries. The porphyroclasts also display a CPO characterized by a girdle distribution of the [100] axes in the shear plane with a maximum concentration close to the shear direction. The [010] axes form a maximum subnormal to the shear plane. The microstructures and the occurrence of a CPO show that the dominant deformation mechanism for the porphyroclasts is dislocation creep. These results of CPOs diverge from those of previous studies of natural lawsonite rocks [e.g., 6], which might result from differences in experimental or natural conditions. TEM images show a variety of dislocations with a high density of $\{110\}$ wedge-shaped mechanical twins. Lawsonite seems to have numerous potential slip systems with [100](010) appearing to be the most dominant. The calculated anisotropies of the seismic wave velocities (AVp = 2% and AVs = 6%, respectively) are characterized by the fast propagation of P-wave is oriented subnormal to [010] maxima of the deformed lawsonite aggregates and the polarization of the fastest S-wave is perpendicular to the foliation. This indicates that lawsonite can contribute to the LVL observations and trench-normal S-wave splitting observed at depth of >150 km in the cold subducting slab of northeastern Japan [7].

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