Generation of pseudotachylyte and interseismic plastic deformation under granulite-facies, lower crustal conditions at Tonagh Island in the Napier Complex, East Antarctica

Tsuyoshi Toyoshima[1], Norio Shigematsu[2] Yasuhito Osanai[3], Masaaki Owada[4], Toshiaki Tsunogae[5] and Tomokazu Hokada[6]
[1]*Niigata University, Niigata, Japan*
[2]*National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan*
[3]*Kyushu University, Fukuoka, Japan*
[4]*Yamaguchi University, Yamaguchi, Japan*
[5]*Tsukuba University, Tsukuba, Japan*
[6]*National Institute of Polar Research, Tokyo*

Seismic faulting (pseudotachylytes-producing faulting) and crystal plastic deformation (formation of ultramylonite) alternated under lower continental crustal conditions in Tonagh Island (Toyoshima et al., 1999). We illustrate interseismic crystal plastic deformations related to the Tonagh pseudotachylytes as examples of ancient seismogenic zones in lower crust. Seismic faulting (formation of pseudotachylyte and cataclasite) and crystal plastic deformation (formation of ultramylonite) alternated along thin shear zones under granulite-facies conditions (Toyoshima et al., 1999；Yamamoto et al., 2001).

There are many granulite-facies shear zones in Tonagh Island, the Napier Complex, East Antarctica. Several of them are composed of alternation of thin ultramylonites, cataclasites, pseudotachylytes, and mylonitized pseudotachylytes, showing that multiple generations of pseudotachylytes, cataclasites and ultramylonites and suggesting paleo-seismic fault (PSF) zones (pseudotachylyte-producing fault zones). Geothermometer and geobarometer suggest that PSF zones were formed under granulite-facies conditions (700-800C, 800 MPa). Granulite-facies ultramylonites occur also abundant outside PSF zones.

There are two types of granulite-facies ultramylonites with different microstructures of recrystallized plagioclase grains: type 1 and 2.

Type 1 ultramylonites have polygonal recrystallized grains (30-100 μm), with abundant triplejunctions, of plagioclase with smooth grain boundaries and very weakly undulose extinction. Dynamically recrystallized quartz grains also have polygonal shapes. Microstructures of recrystallized plagioclase and quartz suggest high-temperature or low-strain rate crystal plastic deformation.

Type 2 ultramylonites include very fine grains (2-5 μm) and irregular-shaped elongated grains (40-80 μm) of plagioclase with strongly undulose extinction and irregular grain boundaries with bulges. Elongated plagioclase grains are surrouded by bulges and fine grains of plagioclase. Irregular shapes of elongated plagioclase grains seem to be a cataclastic origin. Irregular-shaped plagioclase fragments are also often found in cataclasites and pseudotatachylytes in PSF zones. Elongated plagioclase grains surrounded by bulges and fine grains of plagioclase result from dynamic recrystallization of plagioclase fragments in cataclasites and pseudotachylytes. Most of type 2 ultramylonites may be mylonitized cataclasites and pseudotachylytes. Quart of type 2 ultramylonites is strongly elongated quartz porphyroclasts with bulges and fine recrystallized grains. Quartz ribbons are also abundant in type 2 ultramylonites. Type 2 ultramylonites occur only in PSF zones (granulite-facies pseudotachylytes-generating fault zones) and have been cut by fault veins of pseudotachylyte. Type 2 ultramylonites include porphyroclasts of plagioclase aggregates of type 1 ultramylonites. Microstructures of recrystallized plagioclase and quartz in type 2 ultramylonites suggest high-strain rate crystal plastic deformation.

Pseudotachylytes include fragments of plagioclase aggregates of both type 1 and type 2 ultramylonites. Some of the granulite-facies pseudotachylytes were mylonitized and became type 2 ultramylonites, which have also been cut by other granulite-facies pseudotachylytes. The microstructures of quartz of type 2 ultramylonites appear occasionally to have become polygons, which observed in type 1 ultramylonites. Many of pseudotachylytes were subjected to type 2 mylonitization and show a mylonitic foliation.

There are differences in microstructural features and evolution between outside and inside paleo-seismic fault zone developed under granulite-facies conditions.

Outside	Fault rocks: type 1 ultramylonites
Inside	Evolution of shape and size of dynamically recrystallized grains take place in PSF zone. Fault rocks: pseudotachylytes (including mylonitized ones), cataclasites (including mylonitized ones), and type 2 and 1 mylonites Grain shape evolution of plagioclase: polygonal → cataclastic→elongated + bulge → cataclastic → polygonal? Grain shape evolution of quartz: polygonal → elongated + bulge → ribbon → polygonal

Microstructural evolution in PSF zone suggests that high-strain rate crystal plastic deformation and cataclasis, generation of pseudotachylyte, and low-strain rate crystal plastic deformation occurred by turns under lower crustal conditions.
The strong crystal-preferred orientations of plagioclase porphyroclasts and their rims are observed in the type 1 ultramylonites. The recrystallized plagioclase grains in the type 1 ultramylonites are generated on the sheared rims of the plagioclase porphyroclasts by subgrain rotation and dislocation creep, inheriting the orientation of the porphyroclasts. The crystal-preferred orientations of plagioclase porphyroclasts and their rims result from dislocation glide on system (010)<001>. The small plagioclase grains located in tails of plagioclase porphyroclasts and recrystallized plagioclase ribbons have random fabric that are interpreted as the result of deformation by grain-boundary sliding.

We recognized the following two interseismic plastic deformations under lower crustal, high-temperature conditions.

(1) Low strain rate or low differential stress plastic deformation

(2) High strain rate or high differential stress plastic deformation

The microstructural and petrological features of lower crustal shear zones point to locally and temporally, high strain rate or high differential stress at paleo-seismic fault zones immediately before and after seismic faulting.

These features also suggest continuous low strain rate or low differential stress plastic deformation punctuated by episodes of high strain rate or high differential stress plastic deformation, leading of following to seismic events. This is imaged acceleration of strain rate or stress relaxation before or after seismic events, respectively. The switch in deformation mechanism from dislocation creep to grain-boundary sliding, associated with the grain-size reduction, attests of the mechanical softening during deformation, which contributed to the localization of the strain within the mylonite, as suggested by Raimbourg et al. (2008).

References

Raimbourg, H. Toyoshima, T. Harima, Y. Kimura, G., Grain size reduction mechanisms and rheological consequences in high-temperature gabbro mylonites of Hidaka, Hokkaido, Earth Planet. Sci. Lett., 267, 637–653, 2008.

Toyoshima, T., Osanai, Y., Owada, M., Tsunogae, T., Hokada, T. and Crowe, W. A., Deformation of ultrahigh-temperature metamorphic rocks from Tonagh Island in the Napier Complex, East Antarctica, Polar Geosci., 12, 29-48, 1999.

Yamamoto, K., Toyoshima, T., Osanai, Y., Owada, M., Tsunogae, T. and Hokada, T., Microstructures and deformation conditions of granulite-facies pseudotachylytes from Tonagh Island in the Napier Complex, East Antarctica, Abstract of Japan Geoscience Union Meeting 2001, 2001.