Series of fluid activities during brittle-viscous shear deformation in amphibolite on the southern side of the Main Shear Zone, Ketelersbreen, Sør Rondane Mountains, East Antarctica

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Fluid flow in the crust causes hydration reactions, which induce mass transport, change the rheology of rocks, and plays a crucial role in triggering earthquakes, tremors, and slow slip events. Recent geophysical findings of slow earthquakes revealed that source regions of slow earthquakes locate brittle-viscous transition zones, and are high in fluid pressure (Behr and Burgmann, 2021). Geological observation of fluid-induced shear fracturing at brittle-viscous transition zones would provide important constraints on the physico-chemical processes in the source region of slow earthquakes. This study provides a primary analysis of series of fluid activities in amphibolite samples collected nearby the Main Shear Zone (MSZ) exposed along the Ketelersbreen, Sør Rondane Mountains (SRM), East Antarctica, and reveal their temperature conditions of fluid infiltration related to brittle-viscous shear deformation.

A series of amphibolite samples were collected from the southern side of the MSZ exposed along the Ketelersbreen, Sør Rondane Mountains, East Antarctica (S 72.103°, E 23.199°) during the 61st Japan Antarctic Research Expedition in 2019-2020. The MSZ is one of the major shear zones in the eastern Dronning Maud Land, lasting approximately 120 km, with a width of several hundred meters. MSZ is characterized by dextral high-strain ductile deformation under peak amphibolite-facies conditions (Ruppel et al., 2015). MSZ at the SRM was first defined by Kojima and Shiraishi (1986) and represented the boundary between northern amphibolite-facies metamorphic rocks and southern older meta-tonalite.

The amphibolite is associated with foliation parallel quartz veins (Fig. 1a), are cut by light-coloured muscovite-calcite-amphibole (Ms-Cc-Amp) bearing veins (Fig. 1b, c). Epidote alteration layers occur along high-angle dark-coloured amphibole veins and/or along foliation, and cut all the structure mentioned above (Fig. 1d, e).

Amphibolite host rock mainly consists of tschermakite, plagioclase, quartz, sphene and relict clinopyroxene. The relict clinopyroxene (X_{Mg} = 0.75) is found as inclusion in the quartz grains. Ms-Cc-Amp-bearing veins contain muscovite, calcite, amphibole, plagioclase, quartz, zoisite, and apatite. Along the Ms-Cc-Amp-bearing veins, mm-sized echelon veins occur in the amphibolite (Fig. 1e), and consist of tschermakite, chlorite, plagioclase, quartz, magnetite, and apatite. The dark-coloured amphibole veins contain actinolite, hornblende, calcite, epidote, quartz, apatite, and relict clinopyroxene. In the dark-coloured amphibole veins, an actinolite rim surrounds the hornblende core. Epidote alteration layer consist of epidote, calcite, sphene, plagioclase, actinolite, quartz, and apatite.

We observe shear displacement along the Ms-Cc-Amp-bearing vein (Fig. 1b). On the other hand, the host rocks and echelon veins are deformed along the Ms-Cc-Amp-bearing veins, and record brittle-viscous shear deformation (Fig. 1c).

The range of X_{Ab} in plagioclase in the amphibolite host rock is 0.60-0.64, while that in the echelon vein is 0.54-0.62. The Si contents in amphiboles are 6.7-6.8 atoms per formula unit (a.p.f.u., O=23), and Na contents are 0.4 a.p.f.u. Hornblende plagioclase thermobarometer (Holland and Blundy, 1994) was used to estimate temperature conditions of host rock metamorphism. Temperature conditions estimated for the amphibolite host rock are 595±65 °C in the range of 0-1.5 GPa.

We analysed Cl content in amphibole in the Ms-Cc-Amp veins and the host rock. The highest Cl concentration was detected in the vein centre (0.62 wt%), and the lowest one was in the host rock (0.01 wt%).

Several fluid activities are suggested from the presence of different veins with different types of amphiboles and alteration layers. At the first stage of hydration, clinopyroxene in the host rock is likely to have broken down to tschermakite. As the host rock lacks carbonate nor carbonaceous materials, infiltration of CO_2-bearing fluids along foliation and veins are required to form calcite. Secondly, Cl and CO_2-bearing fluids infiltrated to form Ms-Cc-Amp veins, accompanying brittle-viscous shear deformation. Thirdly, CO_2-bearing fluids infiltrated along fractures and foliation, to form high-angle amphibole veins and epidote alteration, that contains actinolite formed at low-temperature consistent with later stage of fluid infiltration. These series of fluid activities had occurred during the brittle-viscous transitions and the cooling of the southern part of the Main Shear Zone, and would provide physico-chemical insights for fluid-induced rock fracturing during brittle-viscous transitions in the crust.

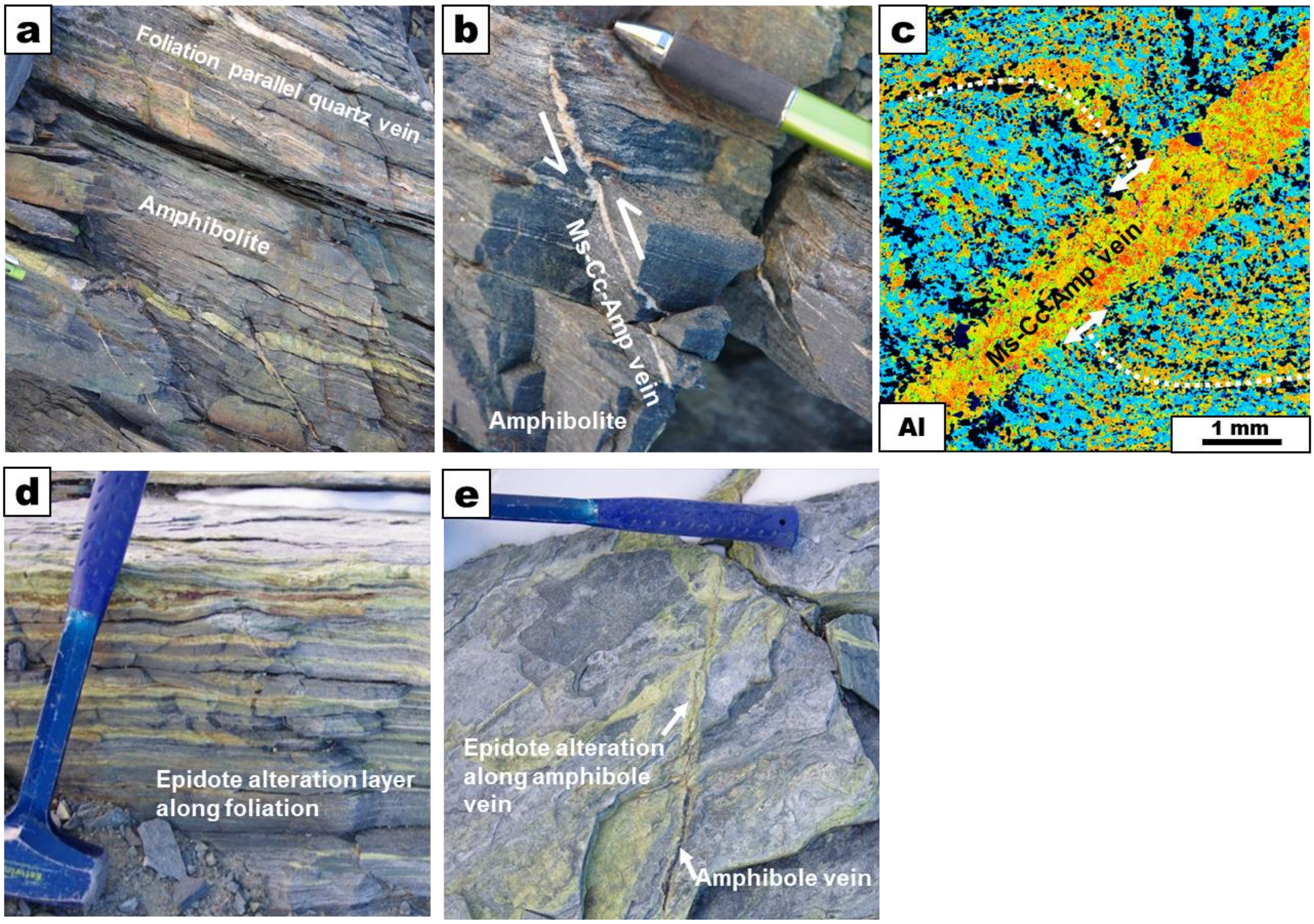

Figure 1. (a) Outcrop photographs of amphibolite containing foliation parallel quartz veins. (b) Light-colored muscovite-calcite-amphibole bearing veins. The white arrow showing the direction of the shear. (c) X-ray elemental map of Al showing viscous shear displacement along a muscovite-calcite-amphibole bearing vein. Echelon veins are shown by white dotted lines. (d) Epidote alteration layer along foliation in amphibolite. (e) Epidote alteration along high-angle dark-coloured amphibole veins.

References

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