Carbon dioxide degassing process by oxidation of graphite in crustal faults

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Carbonaceous material (CM) is one of the most important accessory minerals in meta-sedimentary rocks, and plays an important role during deformation process. During prograde metamorphism, CM progressively changes to graphite and its crystallinity parameters have been widely used as a reliable geothermometer (e.g. Nakamura and Akai, 2013). However, the processes relating to deformation of graphite in metamorphic rocks are yet to be revealed. Here we tried to understand the chemical process of graphite-bearing pseudotachylyte by the coseismic slip. The study area is distributed in the central part of Hidaka Mountains, belonging to the Hidaka metamorphic belt. Hidaka Metamorphic Belt (HMB) is composed of a progressive sequence of greenschist to granulite faces metamorphic rocks and magmatic intrusive rocks. In this study, we sampled the graphite-bearing metamorphic rocks and its highly deformed varieties such as mylonites, cataclsites and psuedotachylytes. These fault rocks are suitable to discuss deformation-induced behavior of graphite, because of the occurrence of various types of graphite-bearing fault rocks formed under different P-T conditions and deformational regimes.

Graphite-bearing pseudotachylyte was examined using micro-Raman spectroscopy, XRD, SEM and stable carbon isotope analysis. Melt-induced textures such as biotite microlites, shell textures of Fe-oxide, spherulites and vesicles in Fe-oxide are observed in the graphite-bearing pseudotachylyte. Pseudotachylytes are divided into two types; Pst I and Pst II based on textures and mineral assemblages of melted and survived minerals. The matrix of Pst I is composed of sanidine, hematite and vesicles that hosted volatiles. This texture suggests that they are solidified from silicate melts by dehydration of biotite at around 650 - 700 °C. We deduced the stability of graphite in silicate psuedotachylyite melts from the reaction of biotite equilibria onto the fO_2-T plane at 200MPa based on the experimental data of graphite and biotite. Mineral assemblage of sanidine, hematite and volatile in vesicles are stable only in high fO_2 fields, suggesting fO_2 in the range of 10^{-12} to 10^{-11} at 650 – 700 °C by frictional melting. In addition, stable carbon isotope analyses revealed that the graphite in Pst I and host metamorphic rocks show similar $\delta^{13}C$ signatures. The graphite in the host metamorphic rocks have a narrow range of $\delta^{13}C$ values between -23.6 and -25.8 ‰, and Pst I have similar range of values between -25.2 to -27.0 ‰. On the other hand, the Pst II shows the embayment textures of plagioclase in matrix. This suggests an increase in temperature of frictional melting to around 1100 °C. In addition, stable carbon isotope analyses of graphite in the spherulites show a broad range of values between -27.8 and -33.5 ‰. These data clearly show the deposition of graphite in silicate melts by lowering of fO_2. Deposition of pristine graphite is observed as inclusions within sanidine spherulites.

Thus it is evident that the frictional melting and dehydration of sheet silicates during coseismic slip generates CO_2 gas by the oxidation of carbonaceous materials. During the transformation of cataclasite to pseudotachylyte the total carbon content has decreased by about 0.5 wt.%. Assuming a rock density of 2.7g / cm^3, the fusion of 10^{-3} m^3 (i.e. 1mm thickness × 1m2 fault plane) of cataclasite into Pst II yields 50g CO_2. The estimation of CO_2 degassing in this study is similar to those reported by Famin et al. (2008). Thus, not only carbonates but also CM in crustal rocks are potential to be a source of CO_2 by frictional melting, and by releasing CO_2 into fault planes may drastically change the dynamic properties of flash fluid pressure and frictional properties of fault planes during seismic activity.

References

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