

Graphite-bearing pseudotachylytes in metasediment: Implication for CO₂ degassing by oxidation of graphite

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Graphite in fault rocks has important role in controlling the redox states in COH fluid, and many researchers have pointed out that the behavior of fluid in pore water or hydrous minerals dramatically change the physical and chemical property of fault rocks. Recently, the CO₂ degassing, from possible biogenic sources, along the faults is monitored in various active faults (e.g. Lewickie and Brantley, 2000). It is expected that the behavior of graphite in fault rocks play a key role about the fluid composition and the physicochemical properties. Here we present a detailed analysis of graphite found in pseudotachylyte and discuss the relationship between graphite and fluid during earthquake activity.

Graphite-bearing pseudotachylyte in Hidaka metamorphic belt, Hokkaido, Japan was examined using SEM, EMPA, and XRD. In pseudotachylyte-bearing cataclasite, melt-induced textures such as biotite microlites, shell textures of Fe-oxide, flow textures, spherulites and vesicles in Fe-oxide are observed. On the basis of microtextures, mineral assemblages of melted and survived minerals, pseudotachylytes are divided into two types; Pst I and Pst II. The matrix of Pst I is composed of sanidine, hematite and vesicles in Fe-oxide, and plagioclase and quartz are remained. These observations suggest that they are solidified from silicate melts by dehydration of biotite at around 700 - 1150 degree Celsius based on the experimental data. In addition, we can also deduce the stability of biotite and graphite in silicate melts of Pst I from the reaction of biotite equilibria on the T-fO₂ plane at 200MPa based on the experimental data of graphite and biotite. Mineral assemblages of sanidine, hematite and volatile in vesicles are stable only in high fO₂ fields, suggesting fO₂ in the range of over 10⁻¹¹ at around 700 degree Celsius by frictional melting of Pst I phase. In this phase, graphite in Pst I is unstable and will be converted to COH fluid in silicate pseudotachylyte melts. On the other hand, in Pst II matrix, these phyllosilicates but also quartz, plagioclase and apatite are found to be melted or have formed embayment textures, whereas only zircon has survived. These data indicate that the Pst II has formed at a peak temperature of around 1200 - 1400 degree Celsius by the breakdown of plagioclase, sulfide and apatite. The graphite content in Pst II decrease from 1.5 wt.% to 0.9 wt.% with increasing degree of frictional melting and alter the $\delta^{13}\text{C}$ values, which shows wide range of $\delta^{13}\text{C}$ values between -20.9 and -33.1 permil, when compared with the $\delta^{13}\text{C}$ values of graphite from associated fault rocks and host metamorphic rocks (-24.8 +/- 0.67 permil). These data suggest that the host graphite has been converted to the COH fluids and then a part of fluid deposited graphite are re-precipitated from COH fluid during isobaric cooling and other carbon expelled as COH fluid due to the oversaturated melt.

Thus it is evident that frictional melting and dehydration of sheet silicates during coseismic slip generates CO₂ 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 / cm³, the fusion of 10⁻³ m³ (i.e. 1mm thickness × 1m² fault plane) of cataclasite into Pst II releases 50g of excess CO₂. The estimation of CO₂ degassing in this study is comparable to those reported by Famin et al. (2008). Thus, not only carbonates but also organic matters, including graphite and carbonaceous materials in crustal rocks, are potential to be a source of CO₂ by frictional melting, and the release of CO₂ into fault planes may drastically change the dynamic properties of flash fluid pressure and frictional properties of fault planes during seismic activity.

Reference: Famin. et al., 2008. EPSL, 265, 487-497. Lewicki. & Brantley., 2000. GRL, 27(1), 578.

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