Pressure-temperature-time dependence of structural evolution of CM to graphite: Implication for fast graphitization in metamorphic terrain

*Yoshihiro Nakamura[1], Takashi Yoshino[2], Madhusoodhan Satish-Kumar[3]

1.Graduate School of Science and Technology, Niigata University, 2.Institute for Study of the Earth's Interior, Okayama University, 3.Department of Geology, Faculty of Science, Niigata University

The structural evolution of carbonaceous material (CM) to graphite is one of the most important thermal indicators for geological regimes of very low to medium metamorphic temperature. The process *sensu stricto* depended not only on peak metamorphism but also lithostatic pressure, tectonic deformation and catalytic effects. Some studies argued that the pressure dependence during graphitization was one of the most important factor to recrystallize from CM to graphite (e.g. Beyssac et al. 2003). However, the natural and experimental studies regarding the pressure dependence on graphitization are very limited.
We report here new experimental data on the structural evolution of CM to graphite at various pressures of 0.5 to 8 GPa at 1200 degree C for 1 hour. Natural CMs extracted from sedimentary rocks in the Shimanto accretionary complex and the Hidaka metamorphic belt transformed its morphology and crystallinity with increasing pressure. Both the starting materials were converted to a graphitic structure above 2 GPa, suggesting either the termination of crystal growth or only sluggish growth. Based on the results of pressure dependence, we compared the relation between the effective activation energies and experimental pressures by combining our results with previous studies. It was found that the effective activation energy empirically decreases with increasing pressure. The pressure dependence was given by:
$Ea = -71.66\ln(P) + 789$ ($R^2 = 0.98$)
Thus we are able to express the effective activation energy Ea at any pressure conditions using the above regression curve. Combining the previous experimental data on thermal dependence of graphitization (Nakamura et al. 2015), the structural evolution of CM can be expressed by three different factors of pressure P, metamorphic temperature T and duration t:
$f(P, T, t) = C_{min} + (C_{max} - C_{min}) / \{1+[((A\exp(-71.66\ln(P)+789)/RT)/t]^h\}$,
where C_{min} and C_{max} are respectively the maximum and minimum values of each parameter, A the intercept of the Arrhenius plot, R the gas constant, and h is the reaction rate of the sigmoid function (named as the “Hill coefficient”). Based on the equation combining the thermal and pressure dependences, we attempted to extrapolate to the low-temperature condition (300-1000 degree C) at the pressures of 0.1 to 1 GPa (Fig.1). Detailed results between natural and experimental data will be discussed in the presentation.
Reference: Beyssac et al. (2003) EJM. Nakamura et al. (2015) AGU fall meeting abstract.

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