東南極、リュッツォ・ホルム岩体に産出するグラファイトの起源の対比について；炭素同位体からの証拠

宗　勇人[1]、Ｍ．Ｓａｔｉｓｈ－Ｋｕｍａｒ[1]
[1]*静岡大学*

Contrasting origin of graphite in Lützow Holm Complex, East Antarctica; Evidence from carbon isotope geochemistry

H. So[1] and M. Satish-Kumar[1]
[1]*Shizuoka University*

"Graphite" is commonly present in metamorphic rocks of upper amphibolite facies to granulite facies in the Lützow Holm Complex (LHC), East Antarctica. In this study we attempt to clarify the origin of graphite across various localities in the LHC based on field occurrence and carbon isotope composition.

The Lützow Holm Complex, located in East Antarctica, is composed of high-grade metamorphic rocks, including pelitic and psammitic gneiss, mafic to intermediate and basic gneisses, subordinate lenses of ultramafic gneiss, marbles and calc-silicate rocks. The metamorphic grade of this complex increase from upper amphibolite facies to granulite facies from east to west and the whole terrain (except Cape Hinode region) has experienced a clockwise *P*-*T* path (Fig. 1). The peak metamorphism in the Rundvågshetta, the west of LHC was estimated to be about 1000 ºC and 11Kbar. The timing of peak metamorphism has been estimated between 650 and 520 Ma (Hokada and Motoyoshi, 2006).

Fifty-nine samples containing graphite from Cape Akarui, Rundvågshetta, Skallevikshallsen, Skarvsnes and Langhovde comprising various kinds of gneisses, quartzite, calc-silicate rocks and marbles, collected during the 46th JARE expedition, were analyzed in this study (Fig. 1). Based on the mode of occurrence, we classified graphite into three types, vein-type, small disseminated flakes (mm scale) and coarse aggregates (cm scale).

The results of the carbon isotope composition of graphite in various metamorphic rocks from the LHC are compiled in Figure 2. The $\delta^{13}C$ values, reported as ‰ with respect to PDB standard, display large variation (-1.8 to -25.1‰).

At Cape Akarui, graphite-bearing metapelite yielded $\delta^{13}C$ values in the -16.1 to -16.9‰. At Langhovde, coarse graphite in leucosome within garnet-biotite gneiss yielded $\delta^{13}C$ values in the range of -5.4 to -17.5‰. At Skarvsnes, calc-silicate rocks and gneiss yielded $\delta^{13}C$ values in the range of -11.6 to -25.1‰.

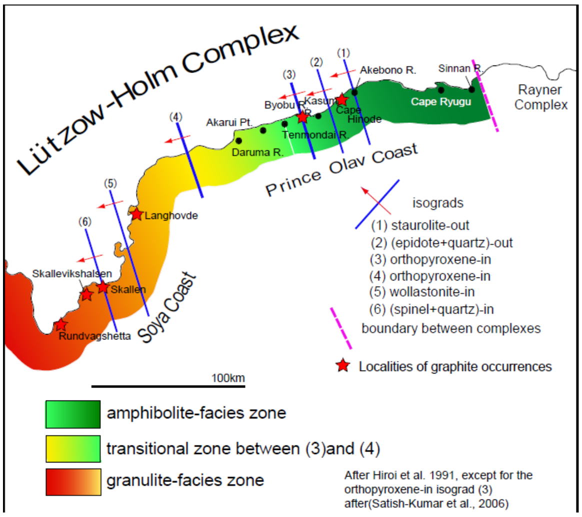

Figure 1. Simplified geological map of the Lützow-Holm Bay region. Progressive increase in metamorphic grade along the Prince Olav Coast to the Soya Coast is based on Shiraishi *et al*. (1989). Bold line show the isograds identified by Hiroi *et al*. (1991)

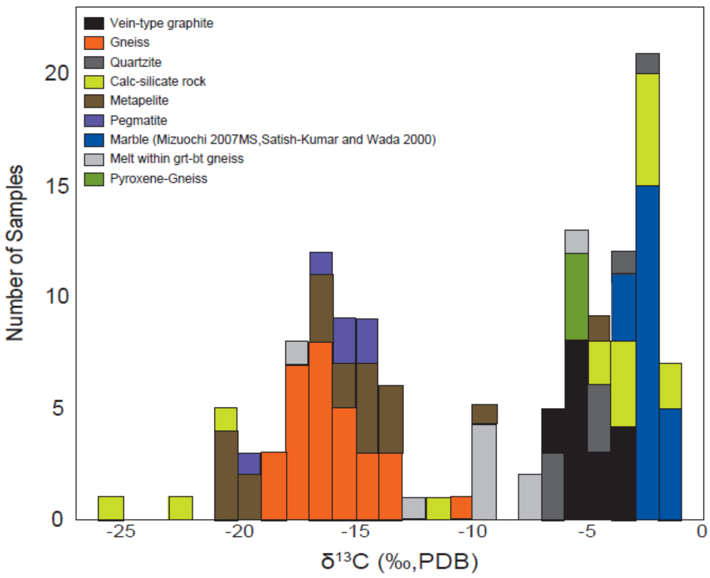

Figure 2. Carbon isotope compositions of different types of graphite in the Lützow Holm Complex. Note that the $\delta^{13}C$ values are having a bimodal distribution.

The $\delta^{13}C$ values of graphite from various metamorphic rocks of the Skallevikshalsen vary from -1.8 to -17.2‰. Vein-type graphite yielded $\delta^{13}C$ values in the range of -3.5 to -6.0‰. Graphite-bearing felsic gneiss and metapelitic gneiss yielded $\delta^{13}C$ values in the range of -4.6 to -17.1‰. Pyroxene gneiss yielded $\delta^{13}C$ values in the range of -5.1 to -17.2‰. Calc-silicate rocks yielded $\delta^{13}C$ values in the range of -1.8 to -4.6‰, whereas graphite grains within marbles have values between -1.4 and -3.4‰. Graphite in quartzite yielded $\delta^{13}C$ values in the range of -2.7 to -6.4‰. At Rundvågshetta, graphite-bearing gneiss, pegmatite and melt segregation yielded $\delta^{13}C$ values in the range of -13.3 to -20.5‰.

In general, based on carbon isotopic composition, there are three mode of origin for graphite in continental crust. They are graphite precipitated from mantle derived CO_2, graphite precipitated from CO_2 derived from decarbonation reactions and graphite formed from organic material. Our data on graphite from LHC suggest a bimodal distribution of $\delta^{13}C$ values, a group that has $\delta^{13}C$ values between -2‰ and -5‰ and a second group with $\delta^{13}C$ values between -15‰ and -20‰. Rarely graphite samples gave low as well as intermediate $\delta^{13}C$ values (Fig. 2).

Considering the geological setting of LHC, where large volumes of metasedimentary rocks are exposed, the possibility of graphite derived from organic matter should be more common in metapelitic rocks. However, we have found that the carbon isotope composition of graphite is relatively enriched than the normal "biogenic" values (~-25‰). The metapelitic rocks in the Lützow Holm Bay are largely affected by partial melting. We try to interpret the enrichment of carbon isotopic composition to a process of volatile escape containing lighter carbon isotopes during melting and recrystallization of graphite. Graphite grains in marbles have exchanged carbon isotopes during metamorphism and preserve equilibrium carbon isotope fractionation with carbonates that correspond to peak metamorphic temperature conditions (Mizuochi *et al.*, 2010)

The $\delta^{13}C$ values of graphite associated with and in the vicinity of metacarbonate rocks are considered to have formed either in equilibrium with calcite/dolomite in the marble or precipitated from fluids released from the decarbonation reactions in the marbles/calc-silicate rocks. Earlier studies in the LHC have suggested that during retrogression the *P-T* fluid evolution a shift in fluid composition from moderate CO_2 during peak to high CO_2 in the early retrograde and low CO_2 in the last phase (Satish-Kumar et al., 2006).

This study thus shows that the graphite in the LHC metamorphic rocks was formed during high-grade metamorphism. Processes involved in the modification of carbon isotopes in graphite include, volatilization and recrystallization during partial melting of graphite-bearing metapelite and mixing of carbonate derived carbon and organic carbon. At the present stage of our study we were unable to find any direct evidence for CO_2 fluids coming from deeper levels of crust. Indeed the vein type graphite was deposited from fluids, but the close proximity of vein to the marble horizon indicates a direct genetic relation with CO_2 released by the decarbonation reactions. The data presented in this study clearly draw the importance of graphite in tracing the carbon budget in the continental crust.

References

Hiroi, Y., Shiraishi, K. & Motoyoshi, Y., Late Proterozoic paired metamorphic complexes in East Antarctica, with special reference to the tectonic significance of ultramafic rocks. In: Geological Evolution of Antarctica (eds Thompson, M.R.A., Crame, J.A. & Thompson, J.W.), Cambridge University Press, Cambridge pp. 83–87, 1991.

Hokada, T. & Motoyoshi, Y.,. Electron microprobe technique for U-Th-Pb and REE chemistry of monazite, and its implications for pre-, peak- and postmetamorphic events of the Lu¨ tzow-Holm Complex and the Napier Complex, East Antarctica. Polar Geoscience, 19, 118–151. 2006

Mizuochi et al., Exsolution of dolomite and application of calcite-dolomite solvus geothermometry in high-grade marbles: an example from Skallevikshalsen, East Antarctica, Journal of Metamorphic Geology, 28, 509-526, 2010.,

Satish-Kumar M. et al., Carbonation of Cl-rich scapolite boudins in Skallen, East Antractica: evidence for changing fluid condition in the continental crust, Journal of Metamorphic Geology, 24, 241-261, 2006

Shiraishi, K., Hiroi, Y. & Motoyoshi, Y., Geological Map of Lützow-Holm Bay, Antarctica. Antarctic Geological Map National Institute of Polar Research, Tokyo, Series Sheet 12, 1989.