New evidence of ultrahigh-pressure metamorphism in the Cretaceous low *P/T* metamorphic terrane, Higo Metamorphic Rock, Central Kyushu, Japan

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This paper reports a new finding of diamond-graphite aggregates (DGA) from the Higo Metamorphic Rock (HMR), a Cretaceous low *P/T* metamorphic terrane, Central Kyushu, Japan. There are three occurrences of DGA. One is inclusions in a chromitite in a spinifex-like textured metaperidotite, which is already reported by Nishiyama, et al. (2014). This time we found another two occurrences of DGA: one from garnets in pelitic gneisses and the other from a garnet-bearing amphibolite. Arai (2010) proposed a mantle migration model for the genesis of microdiamond-bearing chromitites, therefore, the occurrence of the DGA-bearing chromitite in the HMR itself does not reveal that the whole metamorphic terrane has experienced the ultrahigh-pressure metamorphism. Our new finding of DGA-bearing pelitic gneisses and a amphibolite, however, clearly indicate that the HMR has undergone a ultrahigh-pressure metamorphism as a whole prior to the low *P/T* metamorphism of Cretaceous in age. All thin sections of rock samples in which the occurrence of DGA is confirmed are made with Al_2O_3 sheets without using diamond paste to avoid possible contamination of diamond. No carbon coating was used for observation of DGA under a SEM.

DGA-bearing pelitic gneisses are found at three localities around Mt. Kousa (Sakamoto, Taira, and Kawagoe from east to west). They all belong to the garnet-cordierite zone (Obata et al., 1994; Miyazaki, 2004). Garnets in these rocks show doubly zoned structures consisting of black core surrounded by pink mantle, which are distinct even in naked eyes. This type of garnet occurs ubiquitously in the HMR, however, both simply zoned garnets and doubly zoned garnets occur frequently in the same outcrop, depending on the bulk compositions of the host rocks (Ishimaru et al., 2015). DGA occurs as platy grains of 10 mm in size in the garnet cores, but not in the mantles. We confirmed C peaks for the grains with EDS analysis under Au coating on the sections. DGA shows Raman spectra with 1335 cm^{-1} diamond-band together with 1580 cm^{-1} (G band) and 2680 cm^{-1} (S1 band) of graphite. These features are quite similar to those from the Nishisonogi metamorphic rocks (Nishiyama et al., 2017; this meeting), however, the wave number of the diamond-band is slightly shifted to be higher (1335 cm^{-1}) compared to that (1330 cm^{-1}) in the Nishisonogi DGA. The grain size (10 mm) is larger than that (1 mm) of the Nishisonogi DGA. The SEM-SXES (scanning electron microscope combined with soft X-ray emission spectrometer) analysis confirmed coexistence of sp^3 and sp^2 structures in the grains, showing that the grains consist of diamond and graphite. The result is consistent with the Raman spectra. Radial alignment of tiny inclusions of rutile is occasionally observed in the garnet cores, however, coesite has not been identified yet from the inclusions. Quartz inclusions occur in the garnet mantles.

The garnet-bearing amphibolite occurs as a block of 50 ×100 cm in size within pelitic gneisses at a stream near Kawagoe, Tomochi Town. It consists mainly of magnesio-hornblende and biotite with small amounts of plagioclase, quartz, and ilmenite. Garnet ($Alm_{64}Prp_{17}Grs_{18}$) occurs locally as anhedral crystals, several millimeters across, and decomposes into a symplectite consisting of orthopyroxene (En_{47}) + plagioclase (An_{85}) from the periphery. The orthopyroxene contains a small amount of Al_2O_3 (0.02 apfu based on 3 oxygens) and is frequently altered to chlorite. The garnet-hornblende geothermometry gives a temperature of 450 °C, whereas the garnet-orthopyroxene geothermometry does 640 °C (at 0.5 GPa) -

670 °C (at 1 GPa). This indicates that the rock was initially equilibrated at 450 °C and then heated up by about 200 °C, forming the symplectite. The DGA occurs as granular materials 100 mm across in this symplectite. It does not occur in garnets. EDS analysis of the sample coated with Au reveals C peaks. Raman spectra shows a 1335 cm^{-1} diamond-band together with 1580 cm^{-1} (G) and 2680 cm^{-1} (S1) bands of graphite. Although the diamond band shows a slightly higher wave number, other features are the same as those of DGA in the pelitic gneiss. The SEM-SXES method also shows coexistence of sp^2 and sp^3 structures, indicating that this material is a mixture of diamond and graphite.
Our new finding of DGA from four localities in two types of rocks confirms that the HMR has undergone the ultrahigh-pressure metamorphism and that the Cretaceous low *P/T* metamorphism has superimposed on it.

Keywords: Higo Metamorphic Rock, ultrahigh-pressure metamorphism, diamond-graphite aggregate, Raman spectrometry, Soft X-ray emission spectrometry

