# Extreme $^{13}C$ depletion in ultrahigh pressure eclogites from the Dabie and Sulu terranes in China

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The Dabie-Sulu orogenic belt contains two rare geological features: (1) the occurrence of coesite- and diamond-bearing ultrahigh presssure (UHP) metamorphic rocks, (2) anomalous $^{18}O$-depleted metamorphic rocks in the world. Here we report the third rare feature that the UHP eclogites are significantly depleted $^{13}C$ with respective to the normal mantle.

## Methods

The 24 eclogite samples used in this study were collected from Shuanghe in the eastern part of the Dabie Mountains and Donghai in the western part of the Sulu terrane. The oxygen isotope compositions of mineral separates from the eclogites have been determined previously, which show extreme $^{18}O$-depletion in eclogite and quartz-schist from Qinglongshan within the Donghai district (Zheng *et al.*, 1998).

Both concentration and isotope ratio of carbon in the eclogite whole-rocks were determined by EA-MS on-line techniques in an EA1110 elemental analyser and Delta+ mass spectrometer. The combustion temperature was 1200°C and thus both high- and low-temperature carbons were extracted for isotopic analysis. $\delta^{13}C$ is expressed with reference to the PDB standard and duplicate analyses give a reproducibility better than $\pm 0.5‰$. The oxygen isotope ratios of the eclogites were also determined by the conventional $BrF_5$ method.

## Results

As depicted in Fig. 1, the $^{13}C$ depletion of carbon in the eclogites is very remarkable. Most of the $\delta^{13}C$ data (21 of the 24 samples) are normally distributed between $-28.5$ and $-17.9‰$ with carbon concentrations varying from 200 to 1200 ppm, whereas only the other 3 samples from Shuanghe are enriched in $^{13}C$ with $\delta^{13}C$ values of $-7.1$ to $-2.8‰$ and carbon concentrations of 2400 to 4300 ppm. The high-temperature combustion precludes the possibility that the low $\delta^{13}C$ values of the $CO_2$ extracted from the eclogites result from surficial organic contamination.

There is a large $\delta^{18}O$ variation from $-9.6$ to $+6.0‰$ in the $^{13}C$-depleted eclogites (Fig. 1). It has been determined that oxygen isotope equilibrium is preserved among the eclogite minerals (Zheng *et al.*, 1998). This not only demonstrates that the UHP rocks acquired the low $\delta^{18}O$ values prior to the eclogite-facies metamorphism by interaction with $^{18}O$-depleted meteoric water, but also precludes the infiltration of external fluids during retrograde metamorphism as the cause for the $^{18}O$-depletion in the eclogites. Therefore, the $^{18}O$-depletion in the eclogites reflects the oxygen isotope feature of the eclogite protoliths prior to the UHP metamorphism.

The mantle normally has $\delta^{13}C$ values of $-3$ to $-7‰$, which precludes the possibility of mantle metasomatism as a cause for the low $\delta^{13}C$ values of $-28.5$ and $-17.9‰$ in the eclogites during the UHP metamorphism at mantle depths. Thus the $^{13}C$-depletion in the eclogites also reflects the carbon isotope feature of the eclogite protoliths prior to the UHP metamorphism. Ancient meteoric water could have $\delta^{13}C$ values as low as $-20$ to $-30‰$ and cause the eclogite protoliths to be significantly depleted in $^{13}C$ by hydrothermal alteration. However, it is unlikely because meteoric water normally has very low carbon contents, which is not able to considerably change the carbon isotope composition of the eclogite protoliths in terms of a calculation for mass balance.

With respect to the origin of the eclogite protoliths prior to the hydrothermal alteration, both sedimentary marls and igneous basalts are possible in terms of their chemical compositions. Igneous basalts normally have $\delta^{13}C$ values similar to the mantle ($-5 \pm 2‰$), whereas sedimentary marls usually have $\delta^{13}C$ values close to or slightly lighter than the marine limestone ($0 \pm 2‰$). Sediments with negative $\delta^{13}C$ values are usually interpreted as resulting from participation of organic matter, which has a mean $\delta^{13}C$ value around −25‰.

Since neither carbonate nor graphite has been observed in our eclogite samples under microscope, it precludes the isotopic mixing of the eclogite protoliths with organic matter to acquire the very low $\delta^{13}C$ values. Thus it is unlikely that the low $\delta^{13}C$ values of −28.5 to −17.9‰ for the eclogites would be caused by the diagenetic and metamorphic processes of either sedimentary marls or igneous basalts. Consequently, the significant $^{13}C$-depletion in the 21 eclogite samples presumably suggest that the protolith of the eclogites was igneous basalts in origin. In this regard, the basaltic protolith of the eclogites has been highly depleted in $^{13}C$ prior to the hydrothermal alteration before recycling into the mantle by plate subduction. However, the 3 eclogite samples from Shuanghe have not only the high $\delta^{13}C$ values of −7.1 to −2.8‰ but also the high carbon concentrations of 2400 to 4300 ppm, suggesting that their protolith would probably originate from igenous basalts with significant contamination to marine sediments.

Although the mantle is normally assumed to have $\delta^{13}C$ values between −3 to −7‰, a very large variation in $\delta^{13}C$ has been reported for the total carbon of basalts (−37 to −5‰; Deines, 1989). The diamond $\delta^{13}C$ frequency distribution shows a major mode at −5.5‰ and probably a minor one between −15 and −19‰ (Deines, 1992). This has led to the suggestion that different parts of the mantle may have a distinct carbon isotope record and the average $\delta^{13}C$ values may be lower at greater mantle depth (Deines, 1992). According to the carbon isotope compositions of diamond and graphite eclogites, loos diamonds, and diamonds with oxide and silicate inclusions, Deines *et al.* (1993) concluded that the $\delta^{13}C$ value of the shallow mantle is 'normal' and restricted between −4 and −8‰; as inferred depth of origin increases the $\delta^{13}C$ range widens and, on average, becomes much lighter (to −22‰).

If there does exist a higher relative abundance of $^{13}C$-depleted carbon in lower parts of the mantle which is under-represented among the mantle samples analysed to date, the $^{13}C$-depletion in the UHP eclogites from the Dabie and Sulu terranes may provides such a complement. In this regard, the protolith of the 21 eclogite samples in question could be originally derived from the lower parts of the mantle with the $\delta^{13}C$ values of about −25‰. Within the framework of an initially homogeneous mantle which has differentiated into two reservoirs, significant recycling of carbon to the lower mantle is consistent with the present conclusion.

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