PRESOLAR GRAPHITE FROM MURCHISON.

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Introduction: Presolar graphite contains the isotopically anomalous noble gas component Ne-E(L) [1], one of the components that served as beacons to isolate presolar grains from meteorites. Presolar graphite exists only in very primitive meteorites [2] and Murchison [3] and Orgueil [4] are the only meteorites from which a substantial amount of presolar graphite has been extracted and studied. We have analyzed 1642 grains from graphite-rich Murchison fractions KE3 (1.65–1.72 g/cm^3), KFA1 (2.05–2.10 g/cm^3), KFB1 (2.10–2.15 g/cm^3), and KFC1 (2.15–2.20 g/cm^3) using the CAMECA IMS-3f and the NanoSIMS at Washington University in St. Louis. Part of the data was reported by [5-8].

Results and Discussion:

Carbon isotopic ratios. Figure 1 shows distributions of ^{12}C/^{13}C ratios of the graphite grains we analyzed. KE3 and KFA1 exhibit broad distributions, while KFB1 and KFC1 have two distinct peaks, one peak around ^{12}C/^{13}C of ~ 10 and the other around ^{12}C/^{13}C of ~ a few hundred. The distributions of all fractions have a spike-like peak at ^{12}C/^{13}C close to solar. We interpret this as a result from the addition of solar grains to presolar graphite populations. Assuming that the presolar grain distributions are smooth, we can estimate the numbers of presolar grains in the peaks and concentrate on presolar graphite in the subsequent discussion.

Hoppe et al. [7] classified graphite grains into 4 groups based on their C isotopic ratios: Group 1 for grains having ^{12}C/^{13}C around 10 (2-10), Group 2 for grains having ^{12}C/^{13}C between 20 and 80, group 3 with normal and close-to-normal ^{12}C/^{13}C, and group 4 for those with isotopically light carbon. We classify grains also based on their ^{12}C/^{13}C ratios but into three populations. Excluding solar grains, grains with ^{12}C/^{13}C less than 20 are classified as Population I, those with ^{12}C/^{13}C between 20-200 as Population II, and those with ^{12}C/^{13}C larger than 200 as Population III. As indicated in both Fig. 1 and Table 1, the carbon isotopic distributions of KE3 and KFA1 and those of KFB1 and KFC1 are very similar.

Supernova (SN) grains. Supernova grains are characterized by ^{18}O excesses, ^{28}Si excesses and high ^{26}Al/^{27}Al ratios (~ 0.1) [8]. Previous studies [8, 9] indicate that many KE3 grains formed in supernovae. In this study, 70 percent of the grains show ^{18}O excesses. The number is lower, 40 percent, in KFA1. (Fig. 2).

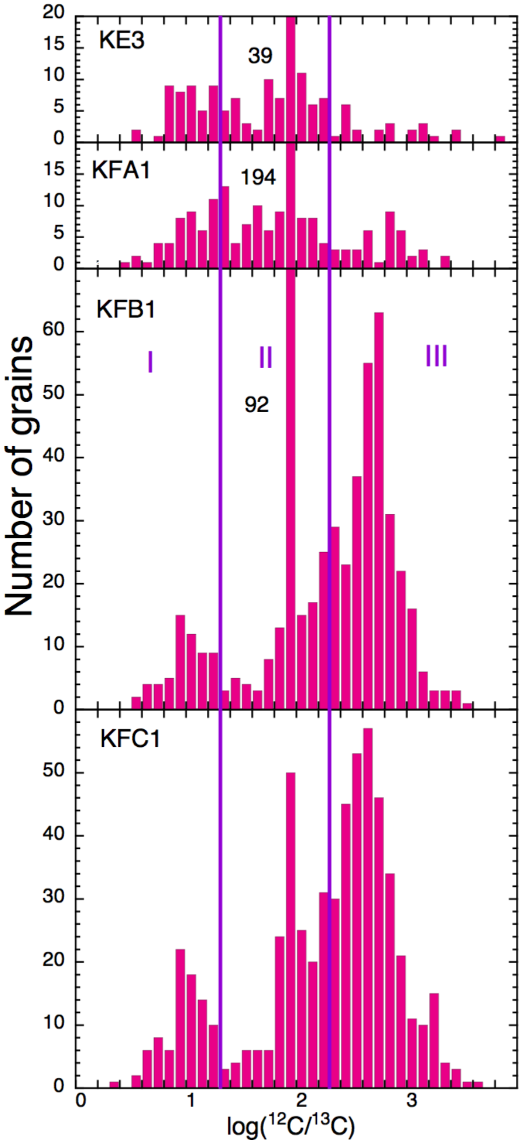

Fig. 1. Carbon isotopic distributions of Murchison graphite grains.

In contrast, mere 4% of the KFB1 grains and only one KFC1 grain are ^{18}O-rich. Interestingly, ^{18}O-rich grains are most abundant in Population II (Fig. 2). This is puzzling: ^{18}O is produced in the He/C zone where ^{12}C is synthesized via partial He-burning. If there is no elemental fractionation, we expect that ^{12}C/^{13}C and ^{18}O/^{16}O are positively correlated and that more grains in Population III are ^{18}O-rich in KE3 and KFA1. However, except the 3 KE3 grains with ^{18}O/^{16}O > 0.1, many grains in Population III have much lower ^{18}O/^{16}O ratios than those in Population II (Fig. 2). This indicates that elemental fractionation took place either in the gas and/or during condensation and care has to be taken when considering mixing between different zones. The same conclusion on the elemental fractionation has been derived from Fe-Ni analyses of SiC X grains [10].

Table 1. Abundances of grains in the Populations

	Population I (%)	Population II (%)	Population III (%)
KE3	32	51	17
KFA1	28	48	24
KFB1	13	23	64
KFC1	15	27	58

The fact that SN grains are most abundant in Population II, where ^{12}C/^{13}C ratios are moderately anomalous, suggests that the H-rich outer zone played a role in grain condensation. It has been argued that the He/N and He/C zones are the only C-rich zones, thus that graphite most likely formed from mix of the material of these two zones with a small amount of contributions from other zones. These two zones have most extreme ^{12}C/^{13}C, that of the He/N zone being ~3 and that of the He/C zone being almost infinity. It is hard, if not impossible, to reproduce the moderate ^{12}C/^{13}C ratios in abundance by the mixing of solely these two zones. To reproduce ^{12}C/^{13}C ratios around solar, an addition of material isotopically close to solar is a more likely explanation. Thus, it is likely that material in the H-rich envelope contributed during the grain formation. This is also consistent with observations of supernovae and grain formation in supernovae. Of observed core-collapse supernovae, 70-80% are Type II, which show the spectral feature of H (among which II-P is most frequently observed), while 20-30% are Type I (Ib and Ic) that are deficient in H [11]. Grain formation is observed in only a few supernovae, SN1987A and three Type II-P and one Type Ib [12].

Grains from AGB stars. From bulk noble gas analysis [13] and trace element analysis of subgrains in KFC1 graphite grains [14], it has been proposed that KFC1 grains originated from low-metallicity AGB (asymptotic giant branch) stars. The ^{12}C/^{13}C ratios of the second peak in KFC1 as well as in KFB1 agree with the predicted ratios of the envelope of 3M$_{sun}$ stars of low metallicity (Z = 0.006) [15]. Furthermore, Si in KFB1 and KFC1 grains from Population III are also consistent with the low-metallicity AGB star model.

Grains in Population I. A few of these grains show ^{18}O and ^{28}Si excesses, clearly indicating their SN origin. Born-again AGB stars have been also proposed as a stellar source of these grains [4]. It remains to be seen whether or not any other stellar sources produce those grains.

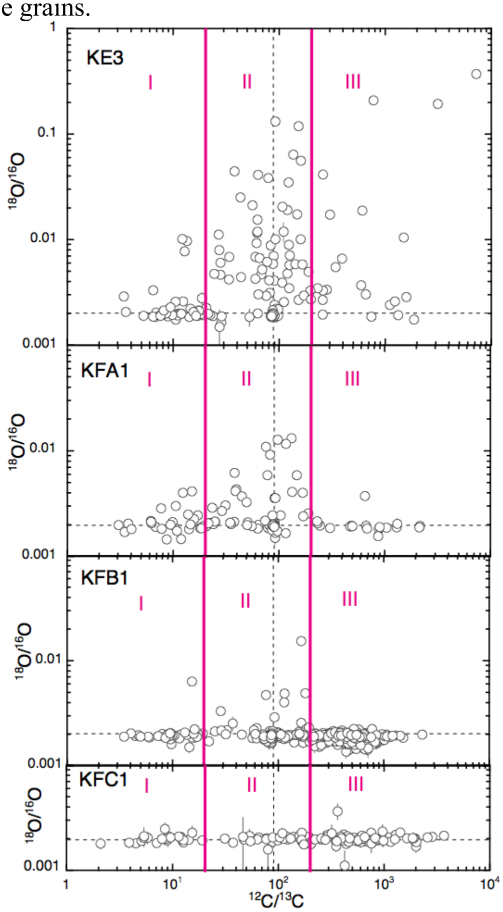

Fig. 2. Carbon and ^{18}O/^{16}O ratios of Murchison graphite grains.

References:

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