ALUMINUM-26, TITANIUM-44, AND VANADIUM-49 IN SIC AND SI$_3$N$_4$ GRAINS OF TYPE X FROM THE QINGZHEN (EH3) CHONDRITE.

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Introduction: Presolar SiC and Si_3N_4 grains enriched in ^{28}Si are referred to as type-X and most likely formed in ejecta from Type II supernovae. They represent only about 1% of presolar SiC from the Murchison (CM2) chondrite [1], and even less (0.3%) from the Qingzhen (EH3) chondrite [2]. Our previous analysis of SiC-X grains from Qingzhen revealed a bimodal distribution of δ^{29}Si and δ^{30}Si values, with about 25% of the grains being more depleted in ^{29}Si relative to ^{30}Si [2]. These grains have been referred to as X2 to distinguish them from the larger population of identified SiC-X grains (here called X1).

We continued the study of these Qingzhen SiC and Si_3N_4 X grains in order to determine whether the difference between the subtypes is reflected in the isotopic compositions of other elements. Twenty-four grains previously measured for Si, C, and N isotopes [2] were relocated. Their Mg, Ca, and Ti isotopic compositions were determined with the NanoSIMS.

Experiments and Results: Of these 24 X grains, 6 are Si_3N_4, 6 are SiC-X2, and 12 are SiC-X1. All grains were examined in an SEM and with energy dispersive X-ray spectrometry. In contrast to mainstream and other X SiC grains, these grains often show a significant presence of oxygen. Analysis of oxygen isotopes of a few X grains revealed a heterogeneous distribution of oxygen (possibly the result of the polycrystalline structure of X grains) but normal isotopic ratios. Thirteen SiC-X and 3 Si_3N_4 grains located away from Mg-rich grains were analyzed for Mg isotopes. Fifteen SiC-X and 4 Si_3N_4 grains were then measured for ^{40,44}Ca, ^{46,47,49}Ti, and ^{51}V.

All of the grains measured for Mg isotopes show large ^{26}Mg excesses from the decay of ^{26}Al. SiC-X1 grains have high inferred ^{26}Al/^{27}Al ratios from 0.15 to 0.38, two grains have smaller ratios (Fig. 1; one X1 grain didn't have its C ratio measured). In contrast, only 2 out of 5 X2 grains have ^{26}Al/^{27}Al > 0.1, while the other 3 X2 grains have ^{26}Al/^{27}Al ratios lower than 0.1 (Fig. 1). All 3 Si_3N_4 grains have high ^{26}Al/^{27}Al ratios (0.18-0.23), similar to X1 grains. One of them didn't have its C ratio measured.

SiC-X2 grains have lower ^{27}Al$^+$/^{28}Si$^+$ ratios (0.020-0.065, except for a grain with 0.18 and another grain with an unusually high value of 1.09) than SiC-X1 (0.08-0.9) and Si_3N_4 grains (0.06-0.11). The most Al-rich X2 grain (QZR5A-551-24) exhibits a unique depth profile. Relative to ^{28}Si, there is a region with a drop in ^{24,25}Mg and ^{27}Al and an increase of ^{26}Mg, indicative of an ^{26}Al-rich subgrain (with an inferred ^{26}Al/^{27}Al ratio of 0.20, compared to 0.08 of the whole grain; see Fig. 1). Another special grain is QZR4-482-20 (X1), containing almost pure ^{26}Mg with a ^{26}Mg/^{24}Mg ratio of 4.5×10^3.

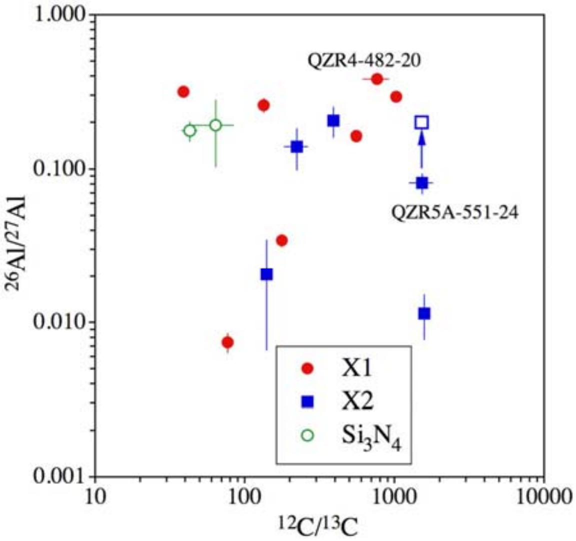

Figure 1: Plot of inferred ^{26}Al/^{27}Al vs ^{12}C/^{13}C. All plotted errors are 1σ.

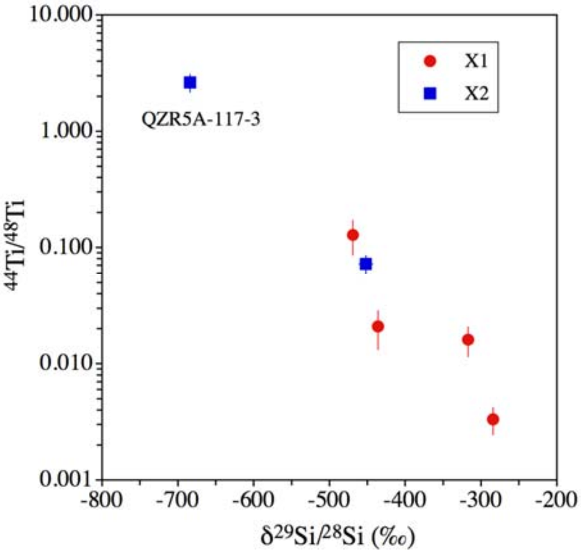

Figure 2: Plot of inferred ^{44}Ti/^{48}Ti vs δ^{29}Si/^{28}Si.

Four out of 11 SiC-X1 grains have ^{44}Ca excesses, probably due to the decay of ^{44}Ti ($t_{1/2}$ = 60 y). Under the assumption that the whole ^{44}Ca excess is due to ^{44}Ti decay, we infer ^{44}Ti/^{48}Ti ratios between 3.3×10^{-3}

and 1.3 × 10^{-2} (Fig. 2). The $^{44}Ca/^{40}Ca$ ratios of all 4 Si_3N_4 grains are solar within analytical errors. Two out of 4 X2 grains have the largest ^{44}Ca excesses ($\delta^{44}Ca/^{40}Ca$ of 4980‰ and 7580‰), with inferred $^{44}Ti/^{48}Ti$ ratios of 0.07 and 2.6, respectively. The other 2 X2 grains show no observable ^{44}Ca excess.

Titanium-49 excesses were found in 8 SiC-X1 grains ($\delta^{49}Ti/^{48}Ti$ from 180 to 1135‰, see Fig. 3). Inferred $^{49}V/^{51}V$ ratios are 0.71-2.7, if the ^{49}Ti excesses are the result of the decay of ^{49}V ($t_{1/2}$ = 337d). Two of the X2 grains have large ^{49}Ti excesses ($\delta^{49}Ti/^{48}Ti$ from 1140 to 2580‰, see Fig. 3), with inferred $^{49}V/^{51}V$ ratios of 1.2 and 4.2, respectively. The 4 measured Si_3N_4 grains show no detectible ^{49}Ti anomalies.

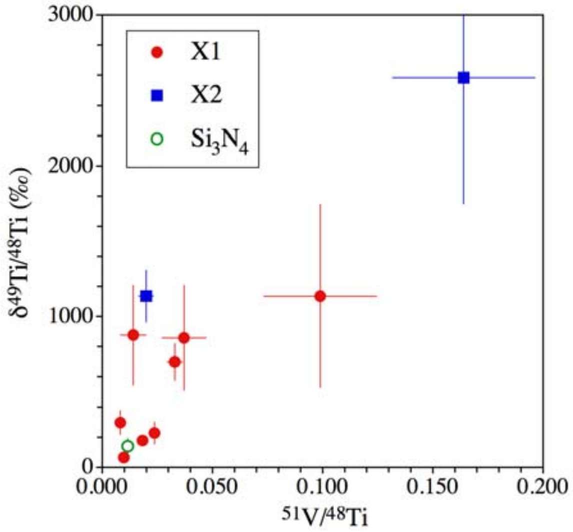

Figure 3: Plot of $\delta^{49}Ti/^{48}Ti$ vs $^{51}V/^{48}Ti$ ratio.

The Si_3N_4 grains have narrow ranges of $^{40}Ca/^{28}Si$ (3.4×10^{-2}) and $^{48}Ti/^{28}Si$ (2.0×0^{-4}), in contrast to X1 and X2 SiC grains ($^{40}Ca/^{28}Si$ of 3.2×10^{-4} to 2.4×10^{-2} and $^{48}Ti/^{28}Si$ of 2.1×10^{-5} to 9.0×10^{-3}). It appears that the X2 grains have lower $^{40}Ca/^{48}Ti$ ratios (0.6-16) than X1 grains (1.4-60, except for one grain with $^{40}Ca/^{48}Ti$ = 0.7). The Si_3N_4 grains have the highest $^{40}Ca/^{48}Ti$ ratios (53-500).

Discussion: All of the X grains measured here have large ^{26}Mg excesses from the decay of ^{26}Al. The inferred $^{26}Al/^{27}Al$ ratios are high, up to 0.38, in agreement with values observed in SiC-X grains from Murchison and other chondrites [3,4].

The depth profile of X2 grain QZR5A-551-24 and the variable inferred $^{26}Al/^{27}Al$ ratios suggest that it is an assemblage of subgrains that formed in different regions of heterogeneous supernova ejecta. In comparison to SiC grains of other types, X grains are commonly observed to be assemblages of very small (<100 nm) SiC crystals. Depth profiles with $^{29,30}Si$-poor and $^{29,30}Si$-rich regions were reported in a few SiC grains [5]. Alternatively, QZR5A-551-24 could have condensed as it passed through heterogeneous supernova ejecta. Its uniquely high and relatively constant Al/Si ratio is consistent with such a scenario.

One interesting X1 grain, QZR4-482-20, has almost pure ^{26}Mg. Its $^{24}Mg/^{28}Si$ ratio is lower by a factor of 50-2000 than the other SiC-X grains. This extremely low Mg concentration suggests special temperature conditions during the condensation of this grain.

The excess of ^{44}Ca is likely the result of the decay of ^{44}Ti; however, we cannot absolutely rule out nucleosynthetic Ca contributions, since we did not measure $^{42,43}Ca$. We find a correlation between the inferred $^{44}Ti/^{48}Ti$ ratios and $\delta^{29}Si$ (Fig. 2), similar to previous reports [3-5]. One of the three most Ti-rich grains ($^{48}Ti/^{40}Ca$=1.6) has a normal $^{44}Ca/^{40}Ca$ ratio. On the other hand, grain QZR5A-117-3 with the largest ^{44}Ca excess ($\delta^{44}Ca/^{40}Ca$ = 7580‰) has a very low $^{48}Ti/^{40}Ca$ ratio of 0.06. The inferred $^{44}Ti/^{48}Ti$ ratio is 2.6±0.9, higher than any ratio observed before [4, 5]. However, as already mentioned, we cannot exclude a nucleosynthetic origin of the ^{44}Ca excess in this Ti-depleted grain.

The SiC-X grains show a general correlation between the ^{49}Ti excesses and the V/Ti ratios (Fig. 3), evidence for the incorporation of live ^{49}V [6]. The slope of the regression line (or $^{49}V/^{51}V$ ratio) is 0.78, higher than the slope of 0.18 found previously [6]. However, some of the ^{49}Ti excesses could be due to neutron capture in the He/C and C/O SN zones.

The two subtypes of SiC-X grains show some differences in both isotopic and elemental ratios of Mg, Ca, and Ti. SiC-X1 grains tend to have higher ratios of $^{26}Al/^{27}Al$, $^{27}Al/^{28}Si$ and $^{40}Ca/^{48}Ti$ than the X2 grains. We also observed that the ^{26}Al-poor grains have no detectible ^{44}Ca excess, with the exception of QZR5A-117-3, which has an unusually high inferred $^{44}Ti/^{48}Ti$ ratio. As discussed above, this may be of nucleosynthetic origin.

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References: [1] Zinner E. 1998. *Meteoritics & Planet. Sci.* 33: 549-564. [2] Lin Y., et al. 2002. *Astrophys. J.* 575: 257-263. [3] Amari S., et al. 1992. *Astrophys. J.* 394: L43-L46. [4] Nittler L. R., et al. 1996. *Astrophy. J. Lett.* 462: L31. [5] Besmehn A. and Hoppe P. 2003. *Geochim. et Cosmochim. Acta* 67: 4693-4703. [6] Hoppe P. and Besmehn A. 2002. *Astrophys. J.* 576: L69-L72.