CONTINUED INVESTIGATION OF PRESOLAR SILICATE GRAINS IN THE CARBONACEOUS CHONDRITE NINGQIANG. X. Zhao[1,2], C. Floss[1], F. J. Stadermann[1], M. Bose[1], and Y. Lin[2], [1]Laboratory for Space Sciences and Physics Dept., Washington University, One Brookings Dr., St. Louis, MO 63130, USA. [2]Key Laboratory of Earth's Deep Interior, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China. (Email: xzhao@physics.wustl.edu)

Introduction: As the newest major presolar phase found in extraterrestrial materials, silicate grains can help us investigate the nucleosynthetic processes and evolution of their parent stellar sources. Numerous studies have been carried out to search for presolar silicate grains in a number of primitive meteorites and IDPs [1-3].

Ningqiang is an ungrouped C3 chondrite containing a high abundance (50%) of dark, fine-grained matrix [4], which is suitable for in situ searches for presolar grains. We previously identified five presolar silicate grains in 14,000 μm^2 of area, resulting in an abundance of 115 ppm [5]. Here, we report results from further searches for presolar silicate grains in Ningqiang.

Experimental: We used the Cameca NanoSIMS 50 at Washington University to carry out isotopic mapping of matrix areas in a polished thin section of Ningqiang. A less than 1 pA focused Cs^+ primary ion beam, with a diameter of ~100 nm, was rastered over 10×10 μm^2 areas (256^2 pixels). Negative secondary ions of two C isotopes (^{12}C, ^{13}C) and three O isotopes (^{16}O, ^{17}O, ^{18}O), as well as secondary electrons, were collected simultaneously. The total matrix area mapped was 5800 μm^2. Carbon and O isotopic compositions were normalized to the average composition of matrix material, which was assumed to be solar. Grains with O isotopic compositions that deviated from the average surrounding material by more than 3σ in three consecutive image layers were considered presolar [e.g., 3].

Isotopically anomalous grains were subsequently analyzed for their elemental compositions with the Washington University PHI 700 Auger Nanoprobe. Following sputter cleaning with an Ar^+ ion beam to remove surface contamination, complete elemental Auger energy spectra from 50 to 1750 eV were obtained following standard procedures [6]. High-resolution maps for selected major elements (O, Si, Mg, Fe, Al, and Ca) were also acquired for most grains. These maps give detailed information about elemental distributions within and around the grains of interest, and allow inhomogeneous elemental distributions and rims to be recognized.

Isotopic compositions: This time we found eleven O-anomalous grains in the matrix of Ningqiang. The O isotopic ratios of these grains are plotted in Fig. 1. Based on the classification system of [7], ten of the grains belong to Group 1, with enrichments in ^{17}O and close to solar $^{18}O/^{16}O$ ratios. The eleventh grain has an excess in ^{18}O and belongs to Group 4. Group 1 grains are believed to have formed in the atmospheres of low- to intermediate-mass red giant branch and asymptotic giant branch stars [7], whereas Group 4 grains could come from supernovae [8].

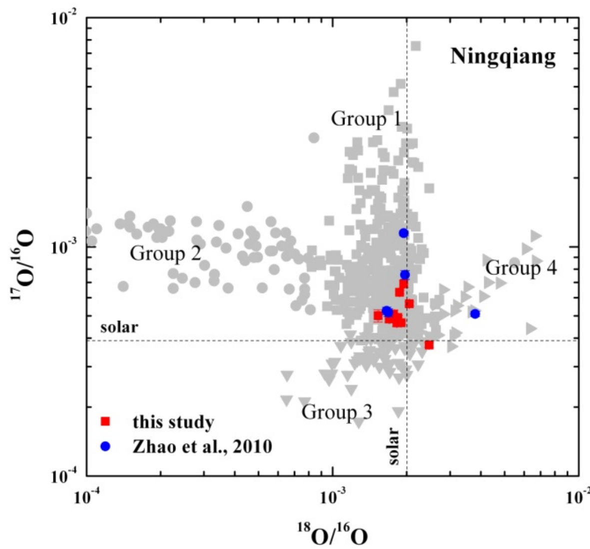

Figure 1. Oxygen three-isotope plot showing O-anomalous grains from Ningqiang. Error bars are 1σ. Other data (gray dots) are from the Presolar Grain Database [9].

Elemental compositions: Ten of these grains were analyzed for their elemental compositions using the Auger Nanoprobe; the remaining grain could not be relocated, probably because it was sputtered away during the NanoSIMS measurement. Based on the Auger spectra of the ten grains, we identified seven ferromagnesian silicates, two oxides, and one complex grain.

Of the seven silicate grains, two have (Fe + Mg)/Si ratios that are similar to olivine ([Fe + Mg]/Si ≈ 2), one is pyroxene-like ([Fe + Mg]/Si ≈ 1), and one has an intermediate composition between olivine and pyroxene. Another three silicate grains, including the only Group 4 grain, are depleted in Si ([Fe + Mg]/Si: 3.1-4.3) relative to olivine and pyroxene. All seven silicate grains are Fe-rich, with mg#s (mg# = Mg/[Mg + Fe]*100) that range from 31 to 44.

Two oxide grains are Al- and Fe-rich, and have spinel-like compositions. The final grain is described as "complex" because of its multiple components. From the Auger elemental distribution map shown in Fig. 2, it consists of adjacent oxide and silicate portions. The oxide is Al-rich, and has a trace amount of Fe and Mg, while the silicates are Ca-rich.

Discussion: Including the five presolar silicate grains we reported before [5], we have identified 16 presolar O-anomalous grains in Ningqiang. Based on the surface areas of the grains and the total area of matrix measured in Ningqiang, we can calculate abundances of 143 ppm for the 16 presolar O-anomalous grains, 127 ppm and 3 ppm for the 12 presolar silicates and the two presolar oxides respectively. The surface areas of most of the grains were determined from the Auger SE images, while the size of the grain that sputtered away was determined from the NanoSIMS ion image.

The abundance of presolar O-anomalous grains we calculated above is similar to the 125-220 ppm seen in other primitive carbonaceous chondrites [3, 10, 11], but it should be noted that most of the grains (15/16) found in Ningqiang are located in a single large (10,800 μm^2) matrix area. The abundance of presolar O-anomalous grains in this area is 256 ppm. Likewise, we can obtain abundances of 228 ppm for presolar silicates, and 6 ppm for presolar oxides for this matrix area. Compared with this unusual matrix area, the other matrix areas (9000 μm^2) we analyzed in Ningqiang have a much lower abundance (~6 ppm based on the single presolar silicate grain found).

The origin of this unusual matrix material remains uncertain, but it is possible that it experienced less secondary processing than other matrix areas with fewer presolar grains. Scanning electron microscopy imaging shows that the presolar grain-rich matrix area is less abundant in Fe-Ni metal and sulfide, and also has a smaller average grain size than areas that contain no presolar grains. This suggests that presolar grain-free matrix areas may have experienced some thermal metamorphism, which could increase grain sizes and destroy the presolar grains. Such processing probably took place in the solar nebula, since the area rich in presolar grains is closely associated with presolar grain-free areas; parent body processing would be more likely to affect all areas similarly.

All presolar silicate grains found so far in Ningqiang are Fe-rich, with mg#s ranging from 29 to 45, except for one grain that contains no Fe [5]. This Fe-enrichment could be related to the secondary alteration processes experienced by this meteorite. Like other CV3 meteorites, Ningqiang appears to have undergone Fe-alkali-halogen metasomatism [12], which could enrich presolar silicate grains in Fe.

References: [1] Messenger S. et al. (2003) *Science 300,* 105-108. [2] Nguyen A. N. and Zinner E. (2004) *Science 303,* 1496-1499. [3] Floss C. and Stadermann F. J. (2009) *GCA 73,* 2415-2440. [4] Weisberg M. K. et al. (1996) *MAPS, 31,* A150–A151. [5] Zhao X. et al. (2010) *LPS XLI,* Abstract #1431. [6] Stadermann F. J. et al. (2009) *MAPS, 44,* 1033-1049. [7] Nittler L. R. et al. (1997) *ApJ 483,* 475-495. [8] Nittler L. R. et al. (2008) *ApJ 682,* 1450-1478. [9] Hynes K. M. and Gyngard F. (2009) *LPS XL,* Abstract #1198. [10] Vollmer C. et al. (2009) *GCA 73,* 7127-7149. [11] Nguyen A. N. et al. (2007) *ApJ 656,* 1223-1240. [12] Krot A. N. et al. (1995) *Meteoritics 30,* 748-775.

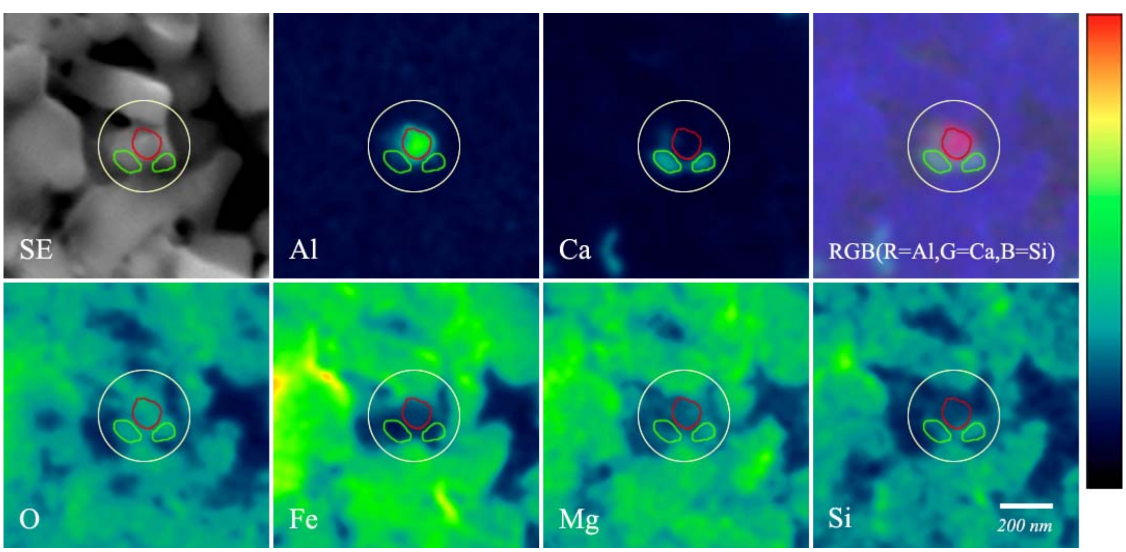

Fig 2. Secondary electrons and Auger elemental maps of the complex grain (white circle) from Ningqiang. (Al-rich oxide, red circle; Ca-rich silicates, green circle)