NANOSIMS INVESTIGATION OF PRESOLAR SILICATES AND OXIDES IN PRIMITIVE SOLAR SYSTEM MATERIALS. J. Leitner[1], P. Hoppe[1], and J. Zipfel[2], [1]Max-Planck-Institute for Chemistry, 55128 Mainz, Germany (leitner@mpch-mainz.mpg.de), [2]Forschungsinstitut und Naturmuseum Senckenberg, 60325 Frankfurt, Germany.

Introduction: Primitive solar system materials contain varying amounts of presolar dust grains that formed in the winds of evolved stars or in the ejecta of stellar explosions [1]. Presolar silicates and oxides are among the most abundant types of these grains [2–6]. Although they belong to the most primitive chondrite groups, first studies of CR chondrites indicated only low presolar dust abundances [7,8]. Recent investigations, however, revealed much higher presolar dust abundances in some meteorites of this group [9–12].

Comets are believed to have formed in the cold, outer regions of the protosolar cloud, representing the most primitive matter in the solar system. NASA's Stardust mission collected dust from the coma of comet 81P/Wild 2 and successfully returned it to Earth in 2006 [13]. Preliminary examination revealed the dust to be an unequilibrated mixture of heterogeneous material of mainly solar system isotopic composition. To date, only three ^{17}O-rich presolar grains [14–16] and one presolar SiC grain (S. Messenger, private communication) were found.

Samples and Experimental: In this ongoing study, more than 300 small impact craters (d = 100–4400 nm) were found in a SEM high-resolution survey on Stardust Al foil C2037N. Impact residues in 76 small craters (d = 250–4400 nm) were investigated for O-isotopic compositions. On a thin section of the CR2 chondrite NWA 852, promising areas (i.e., those which show only little visible alteration) of fine-grained matrix material were identified by optical microscopy and subsequently analyzed for O-isotopic compositions. For the isotope measurements a ~100 nm primary Cs$^+$ beam was rastered over 2×2 µm²- to 10×10 µm²-sized sample areas in the NanoSIMS 50 at the MPI for Chemistry in Mainz, and ^{16}O$^-$, ^{17}O$^-$, ^{18}O$^-$, ^{28}Si$^-$, as well as ^{27}Al^{16}O$^-$ ion images were acquired in multi-collection mode. Presolar grains are identified in situ by their O-isotopic composition, and detection of ^{28}Si and ^{27}Al^{16}O allows a first distinction between silicates and Al-rich oxides.

Results: *Stardust samples.* The 76 investigated craters (total area: 98 µm^2, <2 pg of cometary matter) contain no presolar silicate/oxide grains. All residues are isotopically normal within 3σ, with δ^{17}O and δ^{18}O (normalized to foil contaminations of solar system isotopy) from -83±63 to +202±138 ‰ and from -46±45 to +111±48 ‰, respectively (Fig. 1). Together with crater residues investigated in earlier studies by us, an upper limit of ~30 ppm is calculated for the abundance of presolar silicates/oxides. Combining our data with the results from [15] yields an abundance of 11 ppm for presolar silicates and oxides in the cometary material (Fig. 2).

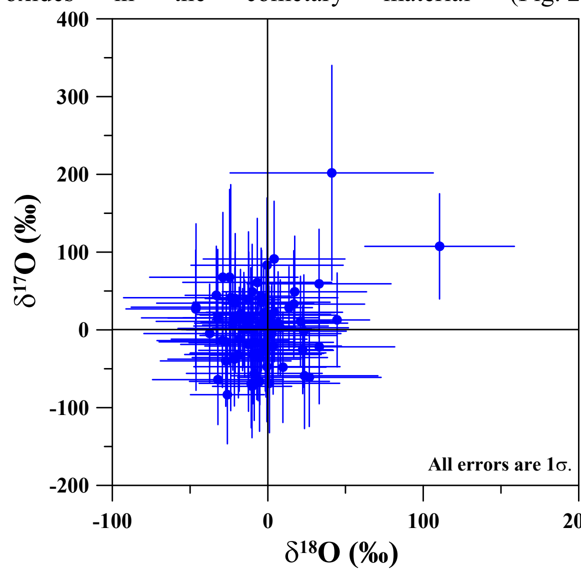

Fig. 1. *O-isotopic compositions of Wild 2 impact residues in 76 small craters on Stardust Al foil C2037N.*

NWA 852. About 12500 µm² of fine-grained matrix of the CR2 chondrite NWA 852 were investigated. 20 presolar silicate and 7 oxide grains were identified so far by their O-isotopic composition, representing an abundance of 104 ppm for silicates and 76 ppm for oxides, respectively (Fig. 2). Twenty-one of the grains belong to O isotope group 1, most likely originating from low-mass AGB-stars, while 6 grains fall into group 4 and have probably formed in the ejecta of Type II supernovae [6,17].

Discussion: *Stardust samples*. The abundance of presolar material in the analyzed cometary matter seems to be lower than in other reservoirs of primitive solar system materials [5,10,18,19], e.g., individual carbonaceous chondrites as well as a subgroup of interplanetary dust particles (IDPs) (Fig. 2). It has to be taken into account that the 11 ppm of presolar silicates/oxides for Wild 2 represent a bulk-normalized value, while the abundances for the different meteorites are matrix-normalized, i.e., for a direct comparison, corrections for the respective matrix content of each meteorite type have to be applied. For IDPs, the reported value is valid for 'primitive' dust particles (i.e., with isotopically anomalous bulk N) [18].

The current estimate on the abundance of presolar grains in matter from Wild 2 bears still large uncertainties. More than 90 percent of the investigated matter is from impact craters larger than 20 µm. The crater residues consist of shock-produced melts and fragments of the impacting cometary particle. If not all presolar grains survived the foil impact, their material mixed with matter of solar system composition, i.e., isotopic anomalies might have been lost by dilution. Although the identification of three presolar silicates/oxides in crater residues clearly demonstrates that at least some isotopically anomalous grains have survived the foil impacts, the abundance of presolar silicate/oxide grains in Wild 2 may be significantly higher than the current estimate. For craters smaller than ~2 µm, isotopic anomalies of a factor of 2 can be preserved at a level that permit their identification in the NanoSIMS even with total melting of the impacting cometary particle. Thus, small impact craters are the most promising objects to infer the abundance of presolar grains in Wild 2 matter.

NWA 852. Recent investigations of individual CR chondrites (MET 00426, QUE 99177, NWA 852) revealed high abundances of presolar silicates and oxides [9–12], comparable to those observed in other primitive meteorites and IDPs [2–6,18] (Fig. 2). Earlier analyses of the CR chondrites Renazzo and NWA 530 showed that these meteorites contain almost no presolar silicates and oxides [7,8].

According to [10], high silicate-to-oxide ratios are considered as characteristics for a low degree of alteration, since oxide grains are more resistant to parent body processes (thermal metamorphism, aqueous alteration) than silicates. Therefore, low silicate-to-oxide ratios are expected for more processed material. From Fig. 2, it can be seen that NWA 852 has by far the lowest silicate-to-oxide ratio from all materials with high presolar grain abundances (sil./ox.=1.4), while MET 00426 and one sample from QUE 99177 display ratios even higher than the one observed for IDPs. This observation can be explained by two possible interpretations. Either, NWA 852 was subject to more severe parent body alteration than the CR chondrites MET 00426 and QUE 99177 and lost a significant part of its presolar silicates. Then, its initial abundance of presolar silicate grains was significantly higher, and may have even exceeded the observations for primitive IDPs. Or, the difference is due to heterogeneities in the early solar nebula. These heterogeneities must have occured on such small scales that they are observable in matrices of different meteorites of the same class and parent body. Although the mineral identification in [12] bears some uncertainties, differing results from [10] and [12] for QUE 99177 may also be a hint for small scale heterogeneities in the early solar nebula.

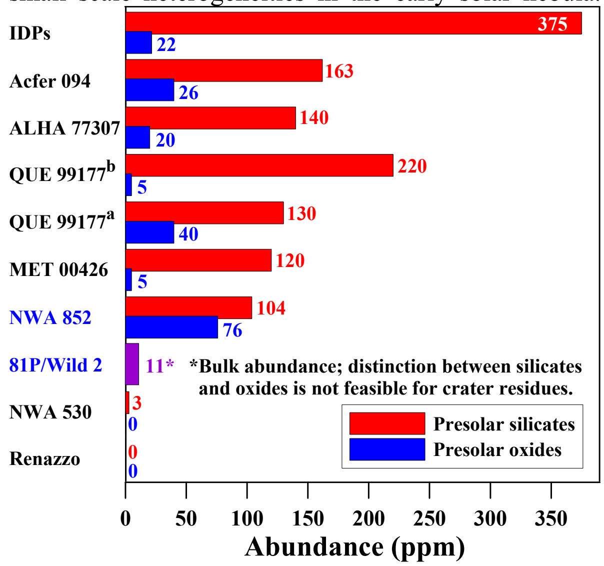

Fig. 2. *Presolar silicate/oxide abundances in the CR chondrites Renazzo, NWA 530, NWA 852, MET 00426, QUE 99177, and comet Wild 2, compared to the primitive meteorites ALHA 77307, Acfer 094, and IDPs. [a]Data from [12]. [b]Data from [10].*

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