SOLAR NOBLE GASES IN THE ANGRITE PARENT BODY – EVIDENCE FROM VOLCANIC VOLATILES TRAPPED IN D'ORBIGNY GLASS. H. Busemann, S. Lorenzetti and O. Eugster, University of Bern, Institute of Physics, Sidlerstr. 5, 3012 Bern, Switzerland, busemann@phim.unibe.ch.

Introduction: Angrites are meteorites that formed particularly early and rapidly during solar system evolution, only ~5-10 Ma after the CAIs, and remained mostly unaltered ever since [1]. Angrites are presumably products of igneous processes [2,3], although nebular condensation was also suggested [4]. D'Orbigny ("D'O", 16.6 kg) is special in being the first angrite containing abundant glass [5]. As for the bulk angrites, most workers assume an igneous origin for the glass, whereas [4,5] suggest a nebular origin. Most importantly, D'O glass might contain fossil ^{247}Cm, which could explain unreasonably old Pb-Pb ages [6]. Bulk samples of D'O and Sahara 99555 also show too old ^{244}Pu-Xe ages [7].

Here, we compare the trapped, radiogenic and spallogenic noble gases in both D'O glass and bulk. Possibly, D'O glass was formed 10 Ma after the bulk silicates. D'O glass contains interior solar noble gases that may originate from early volcanic activity on the angrite parent body (APB) and were trapped upon fast cooling of the glass.

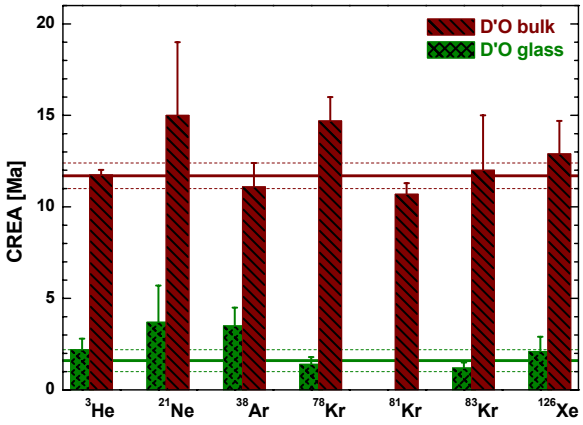

Fig. 1. CRE ages of D'O bulk and glass. While D'O bulk was exposed to CRs for 11.7±0.7 Ma (4π irradiation), the glass shows an CRE age of 1.6±0.6 Ma.

Results: We measured the noble gases in D'O glass (2 analyses) and bulk (3). The latter yields an average cosmic-ray exposure (CRE) age of 11.7±0.7 Ma. D'O glass, however, shows a CRE age of only 1.6±0.6 Ma (Fig. 1), implying a pre-exposure of the bulk relative to the glass. The ages obtained from spallogenic ^{3}He and ^{21}Ne agree well with those from the heavier noble gases, indicating that neither D'O glass nor bulk did suffer significant diffusive loss.

Surprisingly, the glass contains significant amounts of trapped Ne, whereas Ne in the bulk is dominated by spallogenic Ne (Fig. 2). Extrapolation towards trapped Ne implies that trapped Ne in the glass is solar with ^{20}Ne/^{22}Ne = 11.9±0.4, which is between SW and SEP composition, the typical solar range [8]. The solar composition of the trapped Ne in D'O glass agrees well with the clearly solar element pattern found in D'O glass (Fig. 3): The trapped noble gases in D'O glass are enriched in He and Ne relative to Xe and the typically trapped meteoritic compositions, as found e.g. in the bulk samples of D'O, angrite Sahara 99555 [9,10] and CV 3 chondrite Grosnaja [11].

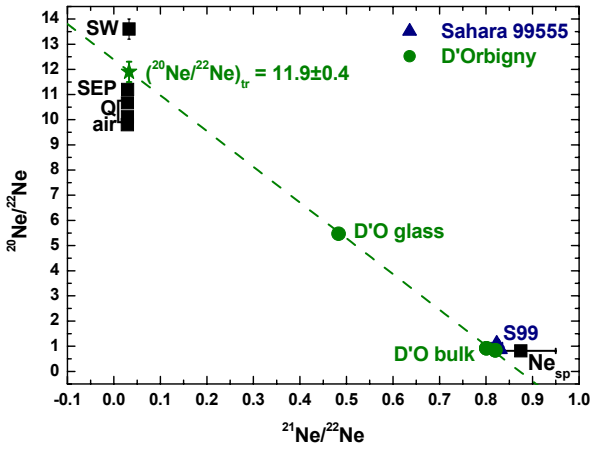

Fig. 2. D'O glass contains significant amounts of trapped Ne of solar composition (star) with ^{20}Ne/^{22}Ne between SW and SEP [8]. In contrast, Ne in bulk D'O is dominated by spallogenic Ne (Ne_{sp}), as expected for the volatile-poor angrites. Data for Sahara 99555 ("S99"): [9] and Q: [11].

Discussion: *Pre-exposure of the D'O crystalline material.* The pre-exposure of D'O bulk relative to the glass (Fig. 1) occurred most likely on the APB, as discussed below. We can exclude mistakes in the laboratory e.g. during weighing or calibration, because glass and bulk samples were analyzed each independently in two laboratories. Otherwise, the glass aliquots could have contained identical fractions of ~85 % gas-poor glass, e.g. introduced into D'O during entry into the terrestrial atmosphere. Addition of gas-free glass is conceivable in view of the much lower U/Th-^{4}He- (glass <0.8 Ga, bulk 4.2±0.6 Ga) and ^{244}Pu-Xe retention ages for the glass [7]. However, the K-Ar age of the glass (3.9±1.3 Ga) is higher than that of the bulk

(1.9±0.3 Ga), which then must be the result of terrestrial K contamination. ^{81}Kr in the glass was too little to be conclusive. Xe-analyses of single glass grains are planned to solve the issue of potentially gas-free glass.

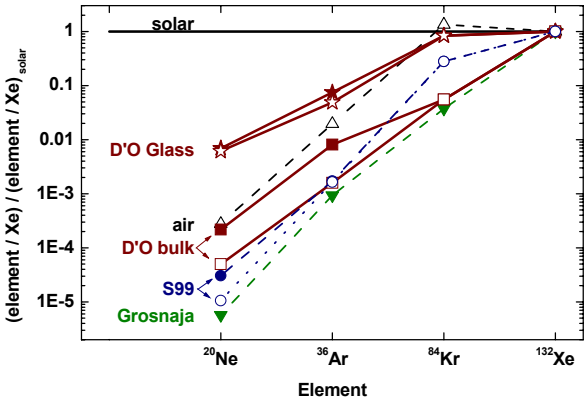

Fig. 3. The element patterns of the trapped noble gases in D'O glass (stars) and bulk (squares) normalized to Xe and solar composition [8]. D'O glass clearly contains solar noble gases, while D'O bulk is dominated by the typical trapped meteoritic component, as found in Sahara 99555 [9,10] and Grosnaja [11].

Solar noble gases in D'O glass. Various mechanisms can result in the presence of solar noble gases in D'Orbigny. However, their exclusive presence in the *glass* is difficult to reconcile, while the *crystalline* phase appears solar gas-free. We suggest that the solar gases in D'O glass originate from the interior of the APB. They were transported with volcanic CO_2 in rising magma and trapped in the rapidly forming glass during quenching near the surface of the APB. Indeed, mm-sized vesicles found by x-ray CT examination of D'O and Sahara 99555 prove that volcanic activity occurred on the APB [12]. The APB is assumed to have a radius of <100 km [13]. Explosive volcanism could have occurred on such small bodies within the first 10 Ma [14]. While the vesicles in the bulk probably completely degassed, the µm-sized bubbles, which were observed in the glass [5] could have kept their gases. Other potential mechanisms to incorporate solar gases into the glass are unlikely: Exposure to solar wind of the glass in a regolith appears impossible without evidence for solar gases in adjacent crystalline material. Furthermore, D'O is not brecciated [3]. Trapping of an APB atmosphere in shock-produced glass similar to that observed in Martian meteorites can be excluded, because D'O does not show shock features [3] and the APB is too small to keep an atmosphere [13]. Nebular condensation of the glass [4,5] could have trapped ambient gas, provided that the nebula did not dissipate before condensation. However, the pre-exposure to CRs of the crystalline portions of D'O is inconsistent with such a model. In contrast, the late introduction of rapidly quenched, freshly produced magma agrees well with a pre-exposure as with the petrographic observation that the glass filled pre-existing empty spaces in the D'O rock [5] and the formation of D'O within a meter from the surface of the APB [2].

Solar noble gases in the APB interior. We suggest that glass in D'O sampled solar noble gases from the interior of the APB, analogous to the terrestrial, solar-like mantle noble gases trapped in ocean basalts [15] and solar Xe in meteorites supposed to originate from the Martian interior [16]. While the large planets could have incorporated these gases via dissolution of early, gravitationally captured, thick atmospheres into magma oceans [16], this mechanism is not applicable for the small APB. Another mechanism must be responsible for the incorporation of solar-like gases into meteoritic material and hence possibly also precursors of the terrestrial planets. The presence of significant amounts of solar He and Ne makes adsorption unlikely. However, exposure to strong solar wind of primitive, pre-accretional material in the early solar system might be capable to result in solar-gas-rich planetesimals [17]. Such a scenario is consistent with the observation of solar-like noble gases in the enstatite chondrites, once thought to be "subsolar" [18].

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References: [1] Carlson R.W. and Lugmair G.W. (2000) in *Origin of the earth and moon*, pp. 25-44. [2] Floss C. et al. (2003) *GCA, 67,* 4775-4789. [3] Mittlefehldt D.W. et al. (2002) *M&PS, 37,* 345-369. [4] Kurat G. et al. (2004) *GCA, 68,* in press. [5] Varela M.E. et al. (2003) *GCA, 67,* 5027-5046. [6] Jagoutz E. et al. (2003) *M&PS, 38,* A81. [7] Busemann H. and Eugster O. (2003) *M&PS, 38,* A104. [8] Wieler R. (2002) *Rev. Min. Geochem., 47,* 21-70. [9] Eugster O. and Lorenzetti S. (2001) *M&PS 36,* A54. [10] Busemann H. and Eugster O. (2002) *M&PS, 37,* 1865-1891. [11] Busemann H. et al. (2000) *M&PS, 35,* 949-973. [12] McCoy T.J. et al. (2003) *M&PS, 38,* A65. [13] Nyquist L. and Bogard D.D. (2003), Antarct. Met. *XXVIII, in press*. [14] Wilson L. and Keil K. (1991) *EPSL, 104,* 505-512. [15] Graham D.W. (2002) *Rev. Min. Geochem., 47,* 247-317. [16] Pepin R.O. (2002) and Porcelli D. (2002) *Rev. Min. Geochem., 47,* 191-246. [17] Podosek F.A. et al. (2000) *J. Conf. Abstr.,5(2),* 804. [18] Busemann H. et al. (2003) *GCA, 67,* A50.