Ancient volcanic xenon in single glass grains from the D'Orbigny angrite

Conference or Workshop Item

ANCIENT VOLCANIC XENON IN SINGLE GLASS GRAINS FROM THE D'ORBIGNY ANGRITE. H. Busemann[1,2], A. Busfield[3] and J. D. Gilmour[3], [1]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington DC 20015, USA. [2]Institute of Physics, University of Bern, Switzerland, [3]SEAES, University of Manchester, UK. (busemann @dtm.ciw.edu).

Introduction: Angrites are basaltic meteorites that cooled rapidly early in the evolution of the solar system [1]. They are widely thought to be products of differentiation and partial melting [2-4], though it has been suggested that they condensed from vapor in the solar nebula [5,6]. D'Orbigny ("D'O") is vesicular and has abundant glass [2,5-7]. This has been interpreted as volcanic and seen as further evidence for magmatism on the angrite parent body ("APB").

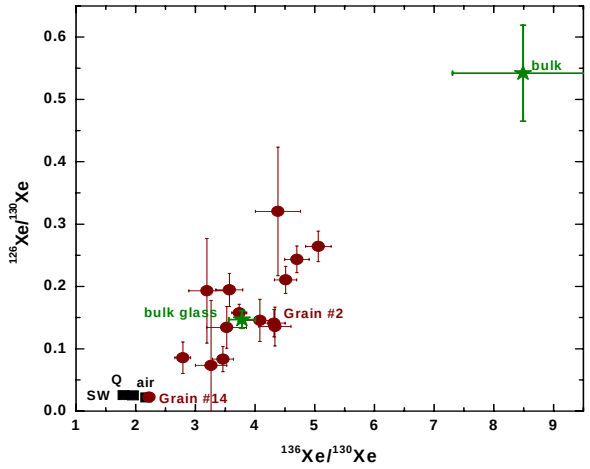

Fig. 1 $^{126}Xe/^{130}Xe$ vs. $^{136}Xe/^{130}Xe$ plot. Fission Xe (from ^{244}Pu) and spallation Xe (from Ba and REE) are perfectly correlated. Results for D'O bulk and bulk glass are given for comparison.

Previous Xe isotopic analyses of D'O glass revealed a signature containing an isotopically "normal" trapped component (tr), spallation Xe (sp), fission Xe (fiss) and a monoisotopic excess of ^{129}Xe [8,9]. It was unclear whether the radiogenic contributions were inherited, suggesting late formation of the glass, or generated *in situ*. Cosmic-ray exposure and gas-retention ages of the glass were younger than those of the surrounding crystalline material [8], suggesting late formation of the glass compared to the bulk. However, Mn-Cr ages of D'O glass and bulk are identical [10] and Pb-Pb ages [11] indicate an old age for the glass. These observations might be reconciled if D'O glass contains a fraction of grains with little Xe but high concentrations of spallation targets, perhaps formed during atmospheric entry.

Experiment: We analyzed 12 single glass grains ranging between ~0.1-1.9 mg with RELAX [12]. The gas was released in several extraction steps for each grain, yielding 15 major gas releases over all grains. Twelve grains totaling 6 mg may not be representative, but Xe concentrations in the 12 grains are 2-4 times higher than results based on 94 mg sample [8]. This suggests the presence of a gas poor phase in the bulk glass.

Results: Grain #14 exhibited a large signature of atmospheric Xe. It is not discussed further since the Xe may be attributed to observed contamination of the sample holder at this position. $^{129}Xe^*$ was present in one grain. Fission and trapped components were widespread, while Xe_{fiss} correlated well with Xe_{sp} (Fig. 1).

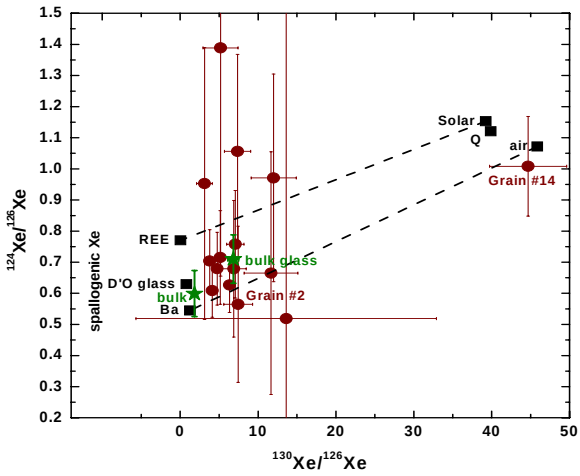

Fig. 2 $^{124}Xe/^{126}Xe$ vs. $^{130}Xe/^{126}Xe$ plot. "D'O glass" represents the predicted composition [13] based on the Ba and REE concentrations in the glass [4,6]. Most data points confirm this composition.

Spallation Xe. Spallation^{126}Xe in the grains is on average more than twice the concentration obtained earlier [8]. Using the concentrations of target elements (Ba and the REE) given for the glass [4,6] yields a cosmic-ray exposure age (~5 Ma) that is closer to that of the bulk (~ 12 Ma). However, the discrepancy is still significant, indicating either that some grains may have lost Xe, or - more likely - that Ba and the REE are inhomogeneously distributed. However, the relative abundance of Ba to REE appears to be constant, albeit within large uncertainties (Fig. 2).

Fission Xe. All grains indicate the presence of fission Xe (Fig. 3). The isotopic composition is entirely consistent with a ^{244}Pu parent. The ^{244}Pu-Xe ages

based on Xe_{fiss} and Xe_{sp} in each single grain indicate closure ~100-200 Ma later than the formation of Angra dos Reis. This agrees with the results obtained with the large batch of glass [9], since both Xe_{sp} and Xe_{fiss} are present in higher concentrations in the single grains.

Excess ^{129}Xe. Grain #2 shows a large excess of ^{129}Xe that can account for the excess observed in the earlier study (Fig. 4). The other Xe isotope ratios for this grain appear similar to those found in the other grains (Figs 1-4). In contrast to other components, the carrier of the ^{129}Xe anomaly is inhomogeneously distributed in the glass.

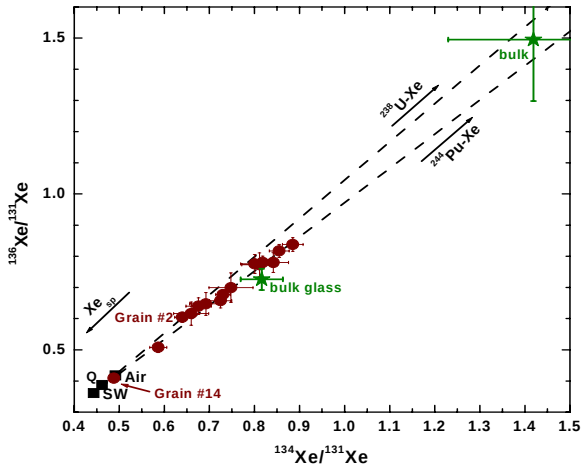

Fig. 3 $^{136}Xe/^{131}Xe$ vs. $^{134}Xe/^{131}Xe$ plot. Fission Xe in all grains originates from decay of ^{244}Pu.

"Normal" Xe. The abundant fission and cosmogenic components make identification of the "normal" endmember difficult - isotopic data are consistent with both solar and air compositions. However, the intimate mixture of "normal" and fission Xe in all grains (Figs. 3-4) is difficult to reconcile with a late addition of terrestrial Xe. The He-Kr element and Ne isotope composition clearly indicates the presence of solar noble gases in D'O [8] suggesting a solar composition for the non-radiogenic Xe component.

Discussion: The presence of $^{129}Xe^*$ and ^{244}Pu-Xe in D'O glass supports the view that it is old [10,11]. A late formation e.g. due to impact can be excluded.

The correlation between fission and spallation components demonstrates that Xe_{fiss}, like Xe_{sp}, was produced *in situ.* The ratio of Xe_{fiss} (from ^{244}Pu) to Xe_{sp} (from Ba/LREE targets) suggests closure of the glass to Xe loss about 100-200 Ma later than closure of Angra Dos Reis. However, the discrepancy in cosmic-ray exposure ages between glass and crystalline phases may indicate that bulk concentrations of target elements are higher than concentrations in fission-bearing glass, leading to this interval being an overestimate.

The isotopically "normal" Xe component present in the glass is identified with solar on the basis of the elemental signature of its associated noble gases. It is most readily understood as the isotopic signature of Xe being degassed from the interior of the APB. This and its associated gases are the first sample of volcanic gas from a planetary body other than the Earth and potentially provide an invaluable insight into the early outgassing of the Earth's atmosphere. It is notable that solar Xe and the ^{244}Pu parent of fission Xe appear to have been associated, while $^{129}Xe^*$ (or its parent ^{129}I) was sequestered in a separate site. We are not aware of previous reports of $^{129}Xe^*$ in an angrite, suggesting the source region sampled precursor material to the angrite parent body.

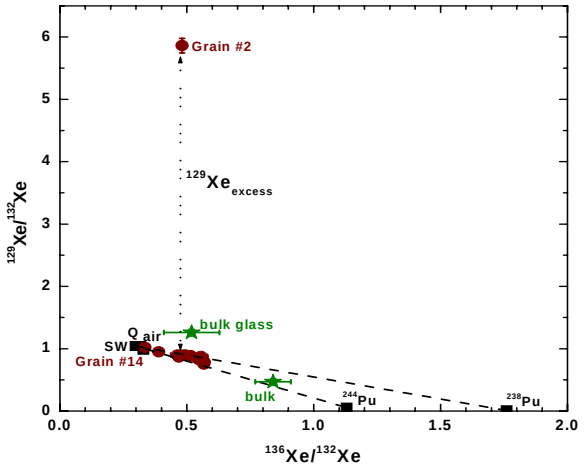

Fig. 4 $^{129}Xe/^{132}Xe$ vs. $^{136}Xe/^{132}Xe$ plot. Grain #2 contains large amounts of excess ^{129}Xe from decay of extinct ^{129}I. Trapped and fission Xe in all grains (except for grain #14) are remarkably well mixed.

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References: [1] Carlson R. W. and Lugmair G. W. (2000) in *Origin of the Moon*, eds R. M. Canup and K. Righter, University of Arizona Press, pp. 25-44. [2] Mittlefehldt D.W. et al. (2002) *M&PS 37*, 345-369. [3] Taylor G.J. and Keil K. (1993) *Meteoritics 28*, 34-52. [4] Floss C. et al. (2003) *GCA, 67*, 4775-4789. [5] Kurat G. et al. (2004) *GCA, 68*, 1901-1921. [6] Varela M.E. et al. (2003) *GCA, 67*, 5027-5046. [7] McCoy T.J. et al. (2002) *LPS XXXIII*, Abstract #1213. [8] Busemann H. et al. (2004) *LPS XXXV*, Abstract #1705. [9] Busemann H. et al. (2003) *M&PS 38*, A104. [10] Glavin D.P. et al. (2004) *M&PS 39*, 693-700. [11] Jagoutz E. et al. (2003) *M&PS 38*, A81. [12] Gilmour J.D. et al. (1994) *Rev. Sci. Instrum. 65*, 617-625. [13] Hohenberg C.M. (1981) *GCA 45*, 1901-1915.