

**APPLICATION OF THE OXYGEN MIXING MODEL TO NON CHONDRITIC METEORITES** R. H. Hewins<sup>1,2</sup> and B. Zanda<sup>1,2</sup>, <sup>1</sup>Dept. of Geological Sciences, Rutgers University, 610 Taylor Rd., Piscataway, NJ, ([hewins@rci.rutgers.edu](mailto:hewins@rci.rutgers.edu)). <sup>2</sup>Muséum National d'Histoire Naturelle, 61 rue Buffon, Paris, France ([zanda@mnhn.fr](mailto:zanda@mnhn.fr)).

**Introduction:** Non mass-dependent oxygen isotopic fractionation in meteorites have been known for 30 years [1] and although their actual cause still remains the object of controversy, they are now firmly established as an essential tool to study genetic relationships between meteorites.

The oxygen mixing model [2,3] is based on the correlations that exist between the oxygen isotopic signature of chondrites and the modal abundances of their various petrological components (type I and type II chondrules, refractory inclusions, matrix and metal). It views their oxygen 3-isotope distributions as the result of the mixing of 4 end-members each identified with one of the petrologic components (see Tab. 2 in [3]) and the correlations corresponding to meteorite groups within this plot as resulting from a secondary two-component mixing of primary mixing batches made from the 4 end-members [2]. Here we show that extending this approach to non-chondritic meteorites provides some insight on their chemical compositions.

**Method:** The data of [4,5] define linear arrays for pallasites and ureilites in the 3-isotope plot. The end-members of these arrays are chosen here as the simplest mixtures of chondritic petrological components or “super-groups” (primary mixing batches) from [2] which allow spanning the whole range of data (Table 1). These end-members are used to determine petrographic component modal abundances for the chondritic objects that would have had oxygen isotopic signatures identical to those of pallasites and of ureilites. These modal abundances are then compared to chemical data for pallasites and ureilites.

	$\Delta^{17}\text{O}$ (‰)	$\Delta^{18}\text{O}$ (‰)
<b>Pallasites</b>		
1 Type II chondrules	1.7	1.0
2 36% Matrix + 64% Mix 4*	-5.1	3.7
<b>Ureilites</b>		
3 50.5% Matrix + 49.5 %Type I **	0.2	4.6
4 72.8% RI + 27.2% Type I **	-28.8	1.0

Table. 1: End member mixes used to generate pallasite and ureilite isotopic compositions. \* Parent mix of COs and CMs in [4]; \*\* Metal is not calculated at this point. Based on [4], it would logically be associated with the RI-bearing mixes (#2&4 in this table).

## Results:

**1. End-member mixes :** The end-member mixes that may have been involved in the genesis of pallasites and ureilites are described in Table 1. For ureilites, the RI-bearing end-member listed is the simplest one possible, ie, it contains no matrix. However only an extremely small amount (less than 10%) of such a mix would be necessary to account for all the oxygen variations observed in ureilites, and it is more likely that the actual mix involved was much closer to ureilites in terms of its petrological/isotopic composition. This can be achieved if that mix also contained matrix and was located “higher” along the ureilite regression line.

## 2. Pallasites :

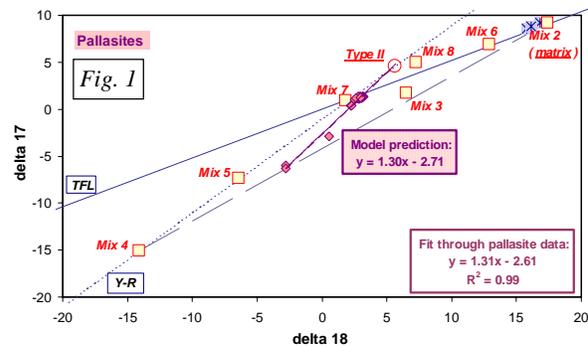


Fig. 1 Pallasite regression (excluding Springwater, from three presumed parent bodies) corresponds to a mixing line for Table 1 component batches.

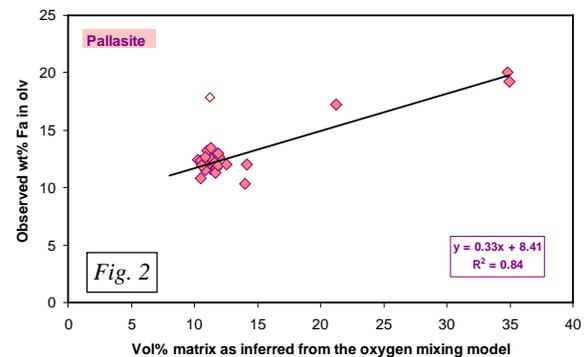


Fig. 2 Olivine composition reflects the amount of ferroan chondritic matrix accreted into the parent body.

## 3. Ureilites :

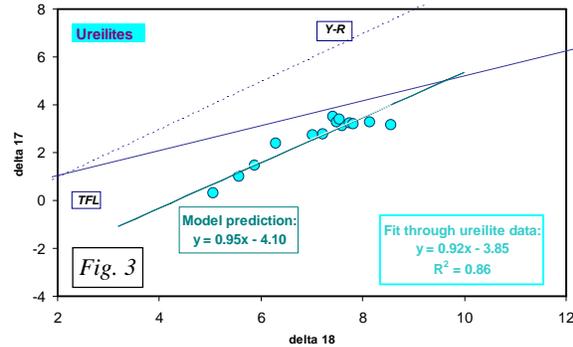


Fig. 3 The ureilite regression corresponds to mixing of batches of matrix + type I chondrules and refractory inclusions + type I chondrules.

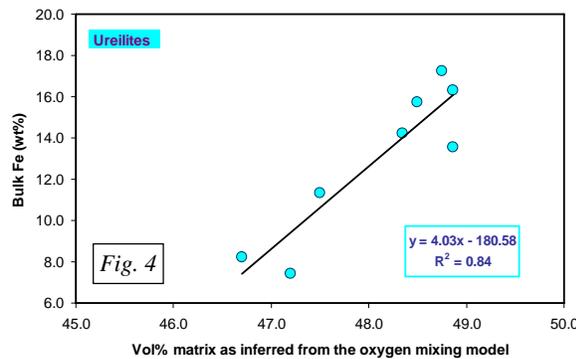


Fig. 4 Metallic, sulfide and silicate iron reflect the amount of matrix in the precursor chondrite.

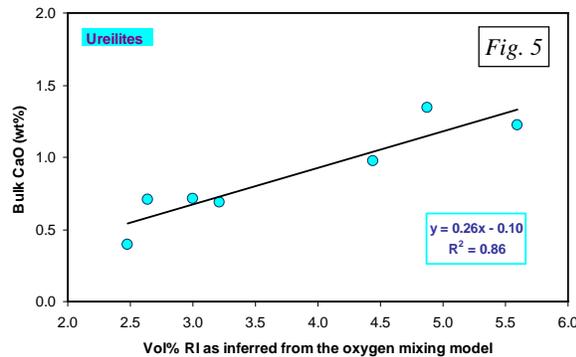


Fig. 5 Ca, though depleted in ureilites, correlates with initial refractory inclusion content.

**Discussion:** We have assumed the O isotopic composition of mantle is essentially that of the undifferentiated planetesimal to apply the chondrite oxygen isotope mixing model [2,3]. The most  $^{16}\text{O}$ -rich pallasites are the most ferroan, a pattern unlike those of chondrites, and might suggest that their falling on a correlation line is pure chance. However, the regres-

sion curve has an unusual slope. The  $^{16}\text{O}$ -poor samples were rich in type II chondrule material, while the  $^{16}\text{O}$ -rich were rich in both CAI and matrix. The correlation of  $\Delta^{17}\text{O}$  or  $\delta^{16}\text{O}$  with FeO is explained by the ferroan nature of chondritic matrix.

Ureilites have a pattern of O isotopic variation resembling those of carbonaceous chondrite groups [7]. However, they have achondritic textures and are highly depleted in Al and Ni, and may therefore be mostly residues of partial melting [6,7]. It has been suggested that they were initially heterogeneous in original bulk compositions [6,7,8] and heterogeneous accretion has been discussed. Our approach allows us to define this heterogeneity in terms of the proportions of the chondritic precursors to the ureilite body. The abundance of chondritic matrix, which is ferroan and  $^{16}\text{O}$ -depleted, is important in this respect. It is noteworthy that the data in Fig. 4 can only be explained if the RI & metal bearing end-member for ureilites also contained matrix as suggested above in section 1 of Results: only this would explain why small changes in the overall matrix modal abundances can be associated with large changes in the bulk Fe content of the objects. The ureilite bulk Fe and/or metal data might help constrain the actual position along the ureilite regression line of the RI-bearing precursor mix (i.e. the amount of matrix it contained).

We cannot usually explain meteorite data in terms of the abundances of isolated components like type I chondrules, but we can use mixture of batches of components. This suggests a time-dependent mixing process in the disk where materials formed in different processes and under varied conditions are assembled and accreted.

**Conclusions:** Application of the chondrite oxygen isotope mixing model to achondritic bodies yields the abundances of chondritic materials in the precursors. The distribution of achondrites in the oxygen three-isotope plot can be understood with this approach.

**References:** [1] Clayton R.N. et al. (1973) *Science* 182, 485-488 [2] Zanda B. and Hewins R. H. *LPS XXXVIII* (2007). [3] Zanda B. et al. (2006) *Earth Planet. Sci. Lett.*, 248, 650-660. [4] Clayton R.N. and Mayeda T.K. (1988) *Geochim. Cosmochim. Acta* 52, 1313-1318. [5] Clayton R.N. and Mayeda T.K. (1996) *Geochim. Cosmochim. Acta* 60, 1999-2018. [6] Goodrich C. (1998) *Meteoritics & Planet. Sci.*, 34, 109-119. [7] Mittelfehldt D.W. et al. (1998) in *Planetary Materials*, ed. J.J. Papike, 4-1 – 4-195. [8] Mittelfehldt D.W. et al. (2005) in *LPS XXXVI*, abstract #1040.