Re-Os ISOCHRON FOR ALLEGAN (H5): RECONCILING Re-Os AND U-Pb CHRONOLOGIES.

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Introduction: Beta decay of ^{187}Re is characterized by the lowest known decay energy, which makes direct counting determination of the decay constant very difficult. The best direct estimate for λ^{187}Re ($1.64\cdot10^{-11}$ y^{-1} ±3.1%) was obtained by the radiochemical in-growth method [1]. This result was generally accepted for geochronology, although its uncertainty precludes precise comparison of Re-Os ages with other isotope dating systems, in particular, with U-Pb. Recent advances in counting techniques resulted in two λ^{187}Re values reported with better analytical errors: $1.682\cdot10^{-11}$ y^{-1} ±2.6% [2], and $1.605\cdot10^{-11}$ y^{-1} ±0.5% [3]. These results are in agreement with the value of [1] within its error limits. However, the mutual discrepancy of 4.9% between [2] and [3] implies that there are underestimated systematic errors, and, in the present state, these studies just confirmed the result of [1], but did not improve the accuracy of λ^{187}Re.

The high resolution of the Re-Os method achieved in the mid-90s prompted attempts to improve the situation by relative reconciliation of λ^{187}Re with the U-Pb system [4-7], based on precise Re-Os isochrons for various classes of iron meteorites. These studies yielded similar λ^{187}Re values $(1.658 - 1.666)\cdot10^{-11}$ y^{-1}. However, the U-Pb system can not be applied directly for dating Fe-Ni metal. Therefore, all these results bear two weaknesses: (a) an assumption that iron meteorites dated with Re-Os originate from the same parent body as reference objects dated by U-Pb, and (b) that the Re-Os clock in metal was set at the same time as the U-Pb system in the reference objects. Together, these problems result in uncertainty which is difficult to estimate.

H chondrites are much better objects for reconciliation: Their formation history was shorter and simpler than that of differentiated asteroids, and their U-Pb chronology is well-developed.

Analytical methods: *Chemical procedures* were similar to [8] with several modifications mostly improving blanks and performance for small samples. Samples were digested by Carius tube technique at 240 ºC. Rhenium and Os separation consisted of solvent extraction followed by micro-distillation for Os and anion exchange chromatography for Re. Osmium was measured by conventional NTIMS techniques, while Re isotopic runs were done by MC ICP MS, which greatly reduces error associated with instrumental fractionation correction. Total analytical blanks were ~ 0.5 pg for both Re and Os. *The Re-Os spike* was the same as in our previous studies [5,7], and initially we estimated an uncertainty in spike calibration as 1.2%. However, our results demonstrate agreement with other labs to better than 1%. In particular, statistical analysis of Re-Os data for iron meteorites analyzed in three labs (UMCP [5,7], Caltech [4], and Paris [9])

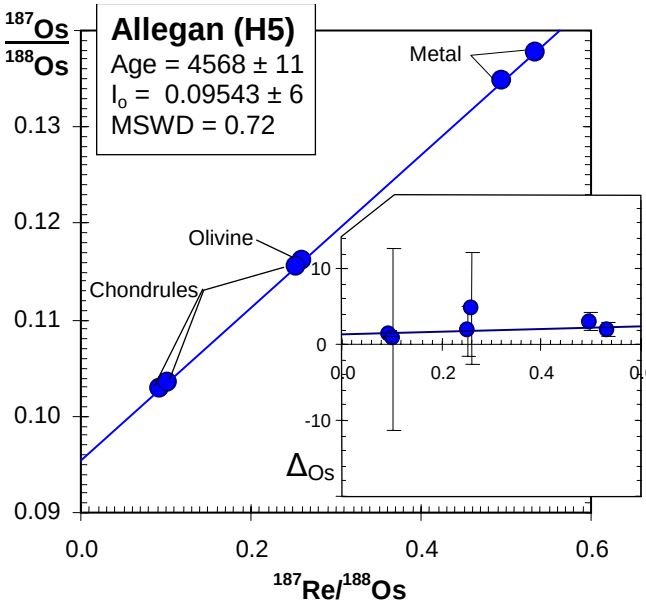

Figure 1. Re-Os systematics in Allegan. The inset shows vertical deviations of data from the reference line, IIIA iron isochron [5]. The error bars take into account errors in both ^{187}Re/^{188}Os and ^{187}Os/^{188}Os.

Table 1: Re-Os results for Allegan separates.

Smp. ID	Wt., mg	Re, ppb	Os, ppb	^{187}Re/^{188}Os	^{187}Os/^{188}Os
{1}	3.29	1259.	12230	.4963 ± 15	.13475 ± 2
{2}	4.95	557.9	5040	.5342 ± 11	.13763 ± 2
{3}	14.43	1.94	35.95	.2594 ± 90	.11624 ± 18
{4}	20.86	3.33	63.36	.2528 ± 17	.11543 ± 30
{5}	13.59	5.03	258.93	.0933 ± 4	.10281 ± 4
{6}	7.63	0.68	32.14	.1022 ± 60	.10345 ±110

Errors are 2σ and refer to the last digits, for Re/Os ratio, the errors reflect both instrumental and blank correction uncertainties. Data are corrected for fractionation using ^{192}Os/^{188}Os = 3.0827. Sample IDs: {1} – fine metal; {2} – medium metal; {3} – coarse olivine (large crystals from porphyritic chond., free of matrix or rim material); {4} – brown porphyritic chondrules; {5} – "nice" chondrules (perfectly shaped chondrules, medium- to strong-magnetic, with no matrix); {6} – "white" chondrules (well shaped light-colored chondrules, weakly- to non-magnetic, with no matrix).

shows that the interlaboratory systematic discrepancy does not exceed ±0.4%. Correspondingly, we now re-evaluate our spike calibration uncertainty as ±0.4%.

Samples: For this work we chose Allegan (H5) because it is an observed fall with no signs of weathering and very low shock alteration. We confined study to the primitive components, chondrules and metal. All the fractions presented here are hand-picked, and repeatedly ultrasonicated in distilled ethanol to remove matrix from chondrule rims and metal surfaces.

Results and Discussion: Rhenium-Os data for all chondrules and metallic fractions of Allegan (Fig. 1 and Table 1) form a line that yields a precise age of 4568 ± 11 Ma (using $\lambda^{187}Re = 1.666 \cdot 10^{-11}$ y^{-1}), in a very good agreement with the similarly precise IIIA iron isochron [5]. On Fig. 1, the two left-most chondrule points have the least-radiogenic Os reported so far in any meteoritic samples. The $^{187}Re/^{188}Os$ ratios in these samples are ~ 3 times lower than that of the least radiogenic irons, therefore the present isochron gives the most reliable estimate of the initial $^{187}Os/^{188}Os$ ratio of Solar System. This result not only allows independent reconciliation of $\lambda^{187}Re$, but also places firm cosmochronological constraints on the uncertainty of the link between Re-Os and U-Pb systems, as illustrated on Fig. 2. Our present isochron comprises chondrules and chondritic metal. Chondrules in H-chondrites were directly dated by U-Pb [10] (Fig. 2, middle dashed line). Chondritic metal mostly regarded as early nebular condensate formed soon after or at the same time with CAIs (Fig. 2, upper dashed line). On the other hand, it is conceivable that the isotopic systematics of metal was reset during thermal metamorphism, and its duration is constrained by U-Pb ages of chondritic phosphates (Fig. 2, lower dashed line). Thus, the time interval between dashed lines (~20 Ma) represents all possible variation for $\lambda^{187}Re$ reconciliation using the Allegan isochron. Translated into $\lambda^{187}Re$ uncertainty, these 20 Ma give 0.22%. Combined isochron (0.24%) and spike (0.4%) errors yields 0.5%. Or, in absolute terms, we recommend a $\lambda^{187}Re = (1.666 \pm 8) \cdot 10^{-11}$ y^{-1}.

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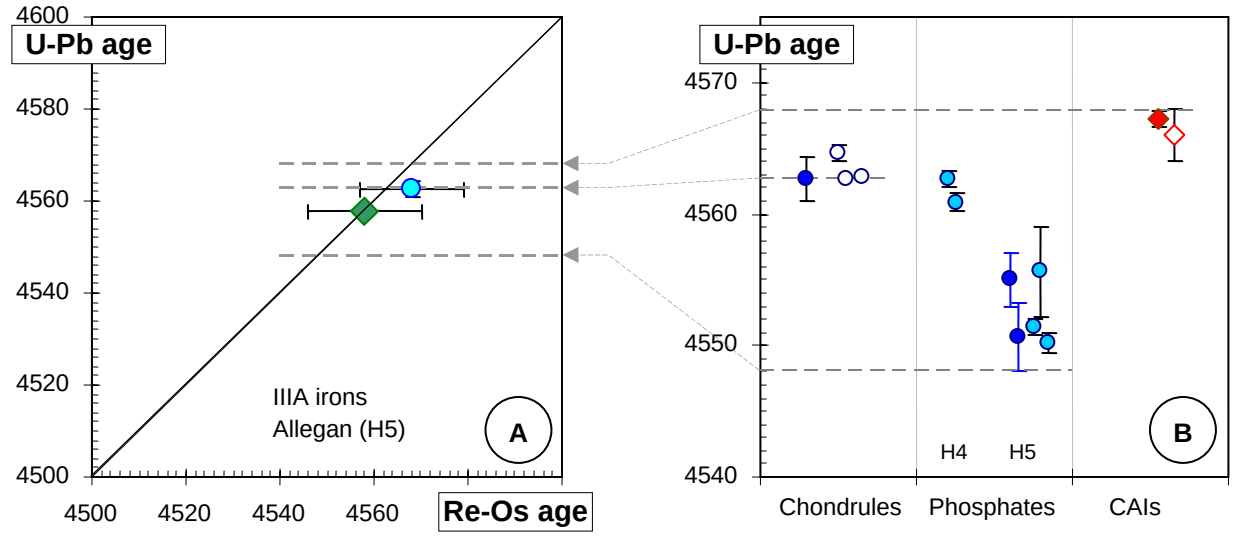

Figure 2A: Reconciliation of $\lambda^{187}Re$ by age comparison. Diamond shows the initial reconciliation by [5]. These authors assumed U-Pb age of angrites from [11] for their IIIA iron meteorite isochron and calculated $\lambda^{187}Re = 1.666 \cdot 10^{-11}$ y^{-1}. The diagonal line represents exact agreement with this value. Error bars show Re-Os isochron errors only. Circle shows our present Re-Os isochron assuming U-Pb age for chondrules from Richardton (H5) [10], and the dashed lines represent cosmochemical confidence limits for this assumption. **Figure 2B** gives details of U-Pb chronology of chondrites at magnified scale. *Chondrule section*: solid circle shows the best estimate for chondrules from Richardton (H5) [10], open circles [12,13] show chondrules from other chondrite classes for comparison. *Phosphate section*: data from [10,14]. *CAI section*: solid diamond is the average for CAIs from Efremovka (CV) [12], open diamond shows the best estimate for Allende CAIs from [15].