Re-Os DIFFUSION INTO MASSIVE SCHREIBERSITE AND POSSIBLE INTERNAL ISOCHRONS FOR IRON METEORITES; D. A. Papanastassiou[1], G. J. Wasserburg[1], and J. J. Shen[1,2]. [1]The Lunatic Asylum, Div. Geol. & Planet. Sci.,Caltech, Pasadena,CA. [2]Now at: Inst. Earth Sci., Academia Sinica, Taipei, Taiwan.

For age determinations it is essential to obtain a reasonable range of parent-daughter physical-chemical fractionation between whole rock samples for the determination of whole rock isochrons, and between constituent phases for the possible determination of internal isochrons. For the application of Re-Os to iron meteorite evolution, the stages of evolution which can, in principle, result in Re-Os fractionation include: a) condensation of PGE and of FeNi in the solar nebula; b) subsequent oxidation of part of the Fe by reaction with S; c) segregation of massive FeS during melting on parent planetesimals; d) melting and fractional crystallization of the metal phase; e) element redistribution during subsolidus phase transformations, including the precipitation and exsolution of schreibersite. Shen *et al.* [1] have reported on analytical techniques which yield replicate analyses of Re-Os which are in good agreement, within ±2.5‰ (2σ). For whole samples of iron meteorites the results show a well defined correlation line on a ^{187}Re-^{187}Os evolution diagram for iron meteorites from groups IA, IIA, IIIA, IVA, and IVB, taken together [1]. This correlation line yields a slope of 0.07848 ± 0.00018 (2σ) and initial $^{187}Os/^{188}Os$ = 0.09563 ∓ 0.00011 (2σ). The corresponding age is 4.61±0.01 AE using $\lambda(^{187}Re = 1.64\times10^{-11}\ a^{-1})$. Re-Os data on sulphides from two iron meteorites (Group IA) show that the sulphides are extremely depleted in Re and Os. These workers concluded that sulphide formation and segregation, in the presence of FeNi, does not affect the Re-Os system (except as a diluent) and that sulphide is not useful for the possible determination of internal isochrons [1,2].

We have pursued the evidence that massive schreibersite contains low but significant levels of Re and Os, with highly enriched Re/Os. We have obtained additional schreibersite data from two IA and one IID iron meteorites. The purpose is a) to investigate the use Re-Os in schreibersite for age determinations; b) to address the thermal evolution of iron meteorites; and c) to provide a comparison between metallographic cooling rates based on Ni diffusion profiles and on Re-Os systematics. We have also measured metal slivers adjacent to schreibersite inclusions, in order to check for possible preserved gradients in Re and Os and their possible chronologic implications. We show the analytical data in Table 1. We present new data for FeNi (away from massive schreibersite) for Bischtübe (Group IA) and Wallapai (Group IID). These data fall precisely on and are consistent with the previously determined whole rock isochron for all iron meteorites [1]. The schreibersite data show that Os and Re are depleted in schreibersite relative to FeNi by factors of 29-54 and 5-15, respectively (Table 2). The differential depletion of Re and Os results in large fractionation in Re/Os in schreibersite, by factors from 2.7 to 8.1; the $^{187}Os/^{188}Os$ ratios in schreibersite are also much more radiogenic than the ratios for the corresponding FeNi. Re-Os model ages for the schreibersites (Table 1) range from 4.47±0.02 AE for Wallapai to 3.48±0.07 for Bischtübe. For Canyon Diablo and for Wallapai we have cut two 1 mm-thick pieces of FeNi, adjacent to the measured schreibersite inclusions, in sequence (labelled 1-mm and 3-mm, with a curf loss of ~0.75 mm between the two FeNi slivers) for each meteorite. For the pieces adjacent to the scheibersite (1-mm) we abraided, mildly, with SiC, the small amounts of adhering schreibersite. The data for the Canyon Diablo and Wallapai show substantial enrichments in the FeNi slivers (1-mm) in Os by 18% and 39% (respectively) and in Re by 5% and 26% (respectively) relative to the concentrations in the FeNi away from massive schreibersite inclusions. These Os and Re enrichments are not simply due to adhering schreibersite. The slivers (3-mm) further away from the schreibersite show definite but smaller enrichments in Os (7% and 12%) and enrichments in Re of 7% and 12%, relative to the FeNi away from massive schreibersite inclusions. These data are consistent with Os and, to a lesser extent, Re becoming excluded from the schreibersite during the formation of the schreibersite by solid state diffusion and precipitation, as P becomes less soluble in FeNi at lower temperatures [3]. These data also indicate that significant gradients in Re and in Os in FeNi have been preserved, and that diffusion of Re and Os is comparable to the diffusion of Ni and much slower than the diffusion of P. The $^{187}Os/^{188}Os$ ratios in these FeNi slivers near the massive schreibersite correlate with the $^{187}Re/^{188}Os$ ratios. A best fit line (York fit) for the Canyon Diablo data yields a slope of 0.07191±0.0030 and $(^{187}Os/^{188}Os)_I$=0.09848±0.0062;for Wallapai, slope=0.07570±0.0025 and $(^{187}Os/^{188}Os)_I$ = 0.09626± 0.0025. The corresponding ages are 4.23±0.17 AE for Canyon Diablo, and 4.45±0.15 AE for Wallapai. We note (Fig. 1) that there are deviations from the best fit lines, by up to 1%, that are larger than the data uncertainties. The data on the schreibersites indicate substantial differences in the times of formation or sub-

sequent disturbance of the Re-Os systems in schreibersites. If we use the Re-Os ages obtained and a cooling interval of several hundred degrees, through which the schreibersites can continue to grow [3], the data are also indicative of slow cooling rates (0.5 and 1 °C/my for Wallapai and for Canyon Diablo and Tres Castillos and lower yet for Bischtübe). For Wallapai and Canyon Diablo, this requires burial on a planet to a depth of only 7-10 km, under a regolith blanket ($\kappa=10^{-4}$ cm^2/s).

Based on the preservation of the observed enrichments of Os and Re next to the schreibersite, we calculate a time interval for diffusion of about 30 Ma, if we use diffusion coefficients of 10^{-17} cm^2/s, about an order of magnitude lower than for Ni in the ternary Fe-Ni-P system [4]. This time interval is comparable to the cooling intervals obtained from Ni diffusion profiles and metallographic studies for Group I irons [5], but much shorter than the Re-Os age differences observed, based on schreibersites. This apparent discrepancy requires further investigation, although, as yet, metallographic cooling rates and Re-Os systematics have not yet been determined on the same iron meteorites.

Table 1. Os and Re Analytical Results

Sample	Sample mg	Os ppb	Re ppb	$^{187}Re/^{188}Os$	$^{187}Os/^{188}Os$	Model Age AE
Bischtübe (IA)						
FeNi	466	2,536	211.9	0.4023±1	0.12730±2	
Schr	92	76.8	18.52	1.168±5	0.1646±3	3.48±0.07
Canyon Diablo (IA)						
FeNi	385	1,982	209.7	0.5103±7	0.13561±4	
FeNi-1 mm	116	2,340	220.4	0.4538±6	0.13093±4	
FeNi-3 mm	151	2,113	225.2	0.5139±6	0.13514±7	
Schr	89	45.46	29.92	3.27±1	0.3302±8	4.24±0.08
	97	43.78	28.32	3.20±1	0.3320±8	4.35±0.08
Tres Castillos (IIIA)						
FeNi	1519	164	20.88	0.6135±6	0.14371±4	
Schr	966	5.65	1.89	1.63±2	0.2146±13	4.30±0.07
Wallapai (IID)						
FeNi	202	3,697	377.2	0.4918±2	0.13428±8	
FeNi-1 mm	154	5,141	474.6	0.445±1	0.12948±14	
FeNi-3 mm	188	4,123	420.8	0.492±1	0.13319±15	
Schr	108	69.1	25.7	1.816±2	0.2337±8	4.47±0.02

Uncertainties are 2σ. Model ages calculated for schreibersites (Schr), using the initial value $^{187}Os/^{188}Os = 0.09563$, and $\lambda(^{187}Re) = 1.64 \times 10^{-11}\ a^{-1}$.

Table 2. Re and Os Partition Coefficients in Sulphide and Schreibersite

Sample	$C^{Re}_{FeNi}/C^{Re}_{FeS}$	$C^{Os}_{FeNi}/C^{Os}_{FeS}$	$C^{Re}_{FeNi}/C^{Re}_{Pb}$	$C^{Os}_{FeNi}/C^{Os}_{Pb}$
Bischtübe (IA)	–	–	11.3	33.0
Canyon Diablo (IA)	380	150	4.6	43.5
			7.4	45.3
Odessa (IA)	224	1300	–	–
Tres Castillos (IIIA)	–	–	11.1	29.0
Wallapai (IID)	–	–	14.7	53.5

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