

THE OSMIUM ISOTOPIC COMPOSITION OF TAGISH LAKE AND OTHER CHONDRITES, IMPLICATIONS FOR LATE TERRESTRIAL PLANETARY ACCRETION. A. D. Brandon¹, ¹SR/NASA Johnson Space Center, Texas 77058, alan.d.brandon1@jsc.nasa.gov.

Introduction: The prevailing models for terrestrial planet origin and differentiation call upon magma oceans generally concurrent with core formation very early during differentiation. Tungsten isotope measurements of Earth and Mars materials are consistent with core formation occurring in terrestrial planets within 30 m.y. or less after the onset of condensation of the solar system [1-4].

In such models, extraction of the core likely leaves the silicate portions of the Earth and Mars strongly depleted in the highly siderophile elements (HSE), consisting of Re, Os, Ir, Rh, Ru, Pt, Pd, and Au [5-8]. In addition, magma ocean development and other processes occurring during early accretion and differentiation would result in strong degassing, and would leave early interiors of Earth and Mars relatively volatile depleted [9]. A result of such processes is that late accretion of materials subsequent to core formation and magma ocean development is may be necessary to replenish both volatiles and HSE to their estimated and measured bulk silicate Earth and Mars concentrations [5-10].

A question that is crucial for constraining early Earth and Mars differentiation is thus, was an acquisition of volatiles and highly siderophile elements during late accretionary processes coupled? If the abundances of these two elemental groups are coupled, then materials must have existed that are volatile-rich, and have the requisite HSE abundances and Os isotopic compositions that would signify that one type of material could be the supplier.

Alternatively, materials that are strongly HSE depleted but volatile-rich, and vice versa, could have both contributed, or the mechanisms of volatile and HSE replenishment are decoupled. Each of these scenarios has important consequences to the earliest history of terrestrial planetary differentiation and implications for the types of materials present in the inner solar system during those events.

There are drawbacks to having late accretion material with elevated HSE that is volatile-rich. The relatively volatile-rich carbonaceous (C) chondrites have present day Os isotopic compositions that are too low to explain the proposed Earth's primitive upper mantle (EPUM), reflecting a time-integrated lower Re/Os [11]. However, the Tagish Lake C-chondrite may be material that could fulfill these requirements. Brown et al. [12] measured concentrations for Re, Os, and Pt for one aliquot of Tagish Lake. The calculated Re/Os

and Pt/Os of this aliquot are 0.122 ± 0.013 , and 2.65 ± 0.22 , respectively. Friedrich et al. [13], obtained concentrations for Re, Ir, and Pt for 3 different aliquots. Taking Os/Ir of Brown et al. [12], these aliquots would have a Re/Os of 0.115 ± 0.004 , and a Pt/Os of 2.00 ± 0.06 . If these ratios are indicative of the time-integrated Re/Os and Pt/Os of the Tagish Lake material, it would evolve to a higher $^{187}\text{Os}/^{188}\text{Os}$ and $^{186}\text{Os}/^{188}\text{Os}$ than other C-chondrites which have lower Re/Os of up to 0.084 and Pt/Os ratios of up to 1.88 [11,14]. Hence, if such material was part of a volatile-rich late accretion material, then a coupling between volatile and HSE budgets might have occurred.

The goals of this investigation are twofold. First, obtain high-precision Os isotope measurements of Tagish Lake and other chondrites by TIMS. Second, measure Re, Os, Pt, and other HSE concentrations by isotope dilution using TIMS and ICPMS. These measurements will determine whether this meteorite does in fact represent C-chondrite material with time-integrated elevated Re/Os and Pt/Os with the implications to late accretion material characteristics.

Results: Two different aliquots of the pristine portions of the 0.5 kg mass of frozen Tagish Lake [15] present at JSC, and one aliquot of homogenized Allende (CV3) obtained from the Smithsonian Institution (for comparison to Walker et al. data [11]) were spiked and measured for $^{187}\text{Os}/^{188}\text{Os}$. The HSE concentrations of these aliquots will be measured by the time of this meeting. One of the aliquots of pristine Tagish Lake was the carbonate-poor (C-P) lithology, while the other was the carbonate-rich (C-R) lithology [15]. The aliquot of Allende measured at JSC has a $^{187}\text{Os}/^{188}\text{Os}$ of 0.12596 ± 0.00001 , similar to the 4 different aliquots previously measured [11] with $^{187}\text{Os}/^{188}\text{Os}$ from 0.12614 ± 0.00004 to 0.12643 ± 0.00004 . Tagish Lake C-P has a $^{187}\text{Os}/^{188}\text{Os}$ of 0.12801 ± 0.00002 , and Tagish Lake C-R has a $^{187}\text{Os}/^{188}\text{Os}$ of 0.12718 ± 0.00002 . Thus, Tagish Lake has the most radiogenic $^{187}\text{Os}/^{188}\text{Os}$ of C-chondrites measured to date, and falls just outside of the range of 0.12596 ± 0.00131 measured by Walker et al. [11]. The $^{187}\text{Os}/^{188}\text{Os}$ for the C-P and C-R lithologies reflect time-integrated $^{187}\text{Re}/^{188}\text{Os}$ of 0.4145 (Re/Os = 0.0860) and $^{187}\text{Re}/^{188}\text{Os}$ of 0.4039 (Re/Os = 0.0838), respectively, assuming no disturbance since 4.558 Ga (i.e. conforming to the IIIAB isochron Fig. 1). This long term Re/Os is significantly lower than the Re/Os measured and inferred from data in Brown et al. [12] and Friedrich et al. [13].

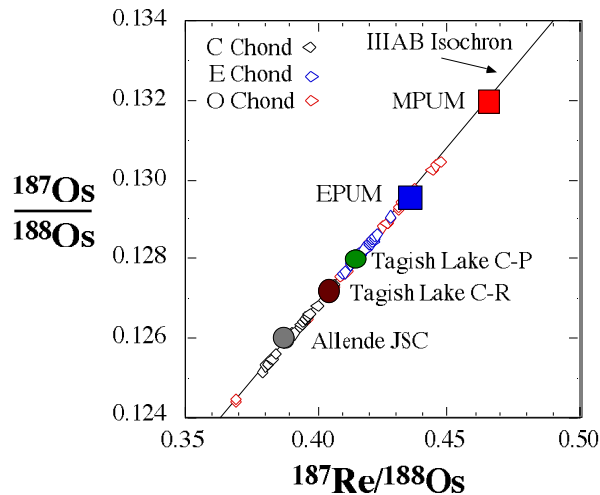


Fig. 1. The calculated $^{187}\text{Re}/^{188}\text{Os}$ vs. measured $^{187}\text{Os}/^{188}\text{Os}$ for chondrites (this study, [11]).

Aliquots of Allende, Chainpur (LL3.4), and Indarch (EH4) were dissolved unspiked for high precision Os isotopic measurements [19,20]. Replicate measurements for the unspiked aliquot of Allende gave $^{187}\text{Os}/^{188}\text{Os} = 0.1260575 \pm 0.0000013$, and $^{186}\text{Os}/^{188}\text{Os} = 0.1198353 \pm 0.0000007$ ($n=4$, 2SM), for Chainpur gave $^{187}\text{Os}/^{188}\text{Os} = 0.1289815 \pm 0.0000010$ ($n=3$) and $^{186}\text{Os}/^{188}\text{Os} = 0.1198369 \pm 0.0000011$, and for Indarch gave $^{187}\text{Os}/^{188}\text{Os} = 0.1282215 \pm 0.0000005$ and $^{186}\text{Os}/^{188}\text{Os} = 0.1198325 \pm 0.0000005$ ($n=3$). Additional unspiked aliquots of chondrites will be measured.

Discussion: The Earth and Mars primitive upper mantles have been estimated to have HSE concentrations within a similar range, approximately 0.002 to 0.007 times relative to CI chondrites [5-8,16,17]. The HSE ratios are estimated to be generally chondritic. Approximately 0.5 to 1% of chondritic late accretion that is mixed into the Earth's mantle could account for these HSE characteristics [8].

The $^{187}\text{Os}/^{188}\text{Os}$ for EPUM is estimated to be 0.1296 ± 0.0008 [18], reflecting a time-integrated evolution with a $^{187}\text{Re}/^{188}\text{Os}$ of 0.4346 (Fig.1). This $^{187}\text{Os}/^{188}\text{Os}$ is more radiogenic than those for C chondrites including Tagish Lake, but falls within the upper range of both enstatite (E) and ordinary (O) chondrites [11]. The $^{186}\text{Os}/^{188}\text{Os}$ for EPUM has been estimated at 0.1198343 ± 0.0000009 [19,20], and falls within the range of $^{186}\text{Os}/^{188}\text{Os}$ measured for all three chondrites measured in this study. Therefore, the Os isotope data to present are consistent with a late accretion on Earth of materials with time-integrated Re/Os and Pt/Os ratios similar to relatively low volatile E- and O-chondrites rather than relatively volatile rich C-chondrites.

The present day $^{187}\text{Os}/^{188}\text{Os}$ of the Martian primitive upper mantle (MPUM) has been estimated at

0.132 ± 0.001 (Fig.1) based on the isotopic composition of the SNC lherzolites (LEW 88516, ALHA 77005, Y793605), which have chondritic $^{182}\text{W}/^{184}\text{W}$ and $^{142}\text{Nd}/^{144}\text{Nd}$ isotopic compositions [21]. This estimate of the present day $^{187}\text{Os}/^{188}\text{Os}$ of MPUM reflects the time-integrated evolution of a reservoir with a $^{187}\text{Re}/^{188}\text{Os}$ of 0.4651. If these values represent the HSE characteristics of late accretion material on Mars, then no bulk chondritic material analyzed to date has the necessary characteristics. The maximum $^{187}\text{Os}/^{188}\text{Os}$ measured on a bulk chondrite to date is 0.13045 on Avanhandava H5 [11].

Conclusions: The new measurements on Tagish Lake indicate that similar C-chondrite material cannot explain the present day $^{187}\text{Os}/^{188}\text{Os}$ of EPUM or MPUM by late accretion. These data, and the new high precision $^{186}\text{Os}/^{188}\text{Os}$ data confirm that materials similar to some E- and O-chondrites are the only samples measured to date that can be considered late accretion candidates from an HSE perspective. No chondrites measured to date can explain the estimated $^{187}\text{Os}/^{188}\text{Os}$ of MPUM if such reflects late accretion materials. Instead, late accretion on Mars would have consisted of materials with a higher Re/Os in this scenario, unlike those that bombarded Earth. In addition, these data imply that the acquisition of volatiles after core formation and outgassing is decoupled from HSE inheritance, resulting from different mechanisms or from materials that are decoupled in these elements, such as rock-depleted comets and rock-rich asteroids.

References: [1] D.-C. Lee and A.N. Halliday (1997), *Nature* 388, 854-857. [2] Q. Yin et al. (2002), *Nature* 418, 949-952. [3] T. Kleine et al. (2002), *Nature* 418, 952-955. [4] Schoenberg et al. (2002), *GCA* 66, 3151-3160. [5] C.-L. Chou (1978), *LPS IX*, 219-230. [6] J.W. Morgan (1985), *Nature* 317, 703-705. [7] J.W. Morgan (1986), *JGR* 91, 12375-12387. [8] J.W. Morgan et al. (2001), *MAPS* 36, 1257-1275. [9] D. Porcelli and R.O. Pepin (2000), In: *Origin of the Earth and Moon*, 435-458, Univ. Ariz. Press, Tucson. [10] K. Righter et al. (2000), In: *Origin of the Earth and Moon*, 291-322, Univ. Ariz. Press, Tucson. [11] R.J. Walker et al. (2002), *GCA* 66, 4187-4201. [12] P.G. Brown et al. (2000), *Science* 290, 320-325. [13] J.M. Friedrich et al. (2002), *MAPS* 37, 677-686. [14] M.F. Horan and R.J. Walker (2000), *LPS XXXI*, #1375. [15] M.E. Zolensky et al. (2002), *MAPS* 37, 737-761. [16] H.E. Newsom and K.W.W. Sims (1991), *Science* 252, 926-933. [17] P.H. Warren et al. (1999), *GCA* 63, 2105-2122. [18] T. Meisel (2001), *GCA* 65, 1311-1323. [19] A.D. Brandon et al. (2000), *EPSL* 177, 319-335. [20] R.J. Walker et al. (1997), *GCA* 61, 4799-4808. [21] A.D. Brandon et al. (2000), *GCA* 23, 4083-4095.