^{182}Hf-^{182}W Chronometry and an Early Differentiation in the Parent Body of Ureilites. D-C. Lee[1], A. N. Halliday[2], S. J. Singletary[3], and T. L. Grove[4], [1]Inst. of Earth Sciences, Academia Sinica, Nankang, Taipei 115, Taiwan (dclee@earth.sinica.edu.tw); [2]Dept. of Earth Sciences, Oxford University, Oxford OX1 3PR, UK; [3]Lunar and Planetary Laboratory, U. of Arozona, Tucson, AZ 85712, USA. [4]Dept. of Earth, Atmospheric & Planetary Sciences, MIT, Cambridge, MA 02139, USA.

Ureilites are primitive achondrites that are composed mainly of olivine and pyroxenes with abundant interstitial and crosscutting carbon polymorphs, Fe-Ni metal, sulfides, and silicates. Studies of ureilites indicate that the parent body went through a series of igneous processes, while, at the same time, ureilites contain features that can only be explained by mixing of primitive nebular materials [1]. Several models have been proposed to explain the origin of ureilites, and these include multi-stage igneous cumulate processes [2], residues of partial melting [3], collision of primitive planetesimals [4], and most recently smelting of an olivine-rich parent body [5]. Despite the difficulty of finding a single model to satisfy all the chemical and physical observations, there is little doubt that ureilites represent the silicate portion of a differentiated body. In this study, we present the first ^{182}Hf-^{182}W ($t_{1/2}$ ~ 9 myrs) data for a suite of ureilites in order to further constrain the nature and the timing of this partial melting/smelting event.

A total of eight ureilites, including ALHA77257, Dhofar132, EET87517, EET96042, EET96293, GRA95205, GRO95575, and PCA82506, covering a significant portion of the chemical variations observed in ureilites, have been studied with the ^{182}Hf-^{182}W isotope system [6]. All eight ureilites show significant ^{182}W deficits relative to that of the terrestrial W standard. All eight samples show sub-condritic ε_w [7,8], varies from -4 to -2.7, despite that their ^{180}Hf/^{184}W ratios vary from sub-chondritic to slightly above chondritic (0.07 to 1.6). There appears no apparent relationship between the W isotopic compositions and the respective ^{180}Hf/^{184}W ratios. In fact, these ureilites have W isotopic compositions comparable to that of early metals extracted from ordinary and enstatite chondrites and iron meteorites [9,10], in contrast to other basaltic achondrites all of which have positive to chondritic ε_w [11,12].

The unradiogenic ε_w observed in all the ureilites provides evidence that its parent body differentiated early, consistent with the recent ^{53}Mn-^{53}Cr data [13], and comparable to the differentiation timescales for the HED parent body [11,12,14]. The unradiogenic ε_w in these ureilites predominantly reflects their sub-chondritic Hf/W ratios. The only exception is EET96263, which has a slightly above chondritic Hf/W, yet it has a sub-chondritic ε_w at -3, suggesting that this sample may have been disturbed and that some of the Hf has been added at a later time.

In addition to the predominantly sub-chondritic Hf/W and ε_w, the eight ureilites studied here all have sub-chondritic Hf and W contents. Altogether these characteristics require the simultaneous removal of both Hf and W at an extremely early stage, probably within 1 to 2 myrs since the solar system formed, in contrast to a conventional core formation model followed by silicate melting that has been used to model the HED parent body with great success. Alternatively, a smelting event of an olivine-rich ureilite parent body predicts the simultaneous removal of metal and silicate melt as the smelting reaction progresses [15]. Such a smelting origin for the ureilite parent body provides a simple yet quantitative mechanism to remove both Hf and W, without the need of complex partial melting regimes [2,3]. The fact that all the ureilites studied here have sub-chondritic W provides further constraints about the timescale of this smelting event, if it indeed happen, to within a few myrs since the start of the solar system.

Despite that these eight ureilites do not represent the entire chemical and petrographic types of the ureilite families, the Hf-W data are quite consistent among these eight ureilites. It seems clear that the ureilite parent body must have differentiated early, and melting events that can remove both Hf and W simultaneously, such as the smelting reaction [15], are necessary to explain the observed Hf-W data.

References:

[1] Goodrich C. A. (1992) *Meteoritics, 27,* 327-352. [2] Goodrich C. A. et al. (1987) *Geochim. Cosmochim. Acta 51,* 2255-2273. [3] Warren P. H. and Kallemeyn G. W. (1989) *Meteoritics, 24,* 233-246. [4] Takeda H. (1987) *Earth Planet. Sci. Lett. 81*, 358-370. [5] Walker D. and Grove T. L. (1993) *Meteoritics, 28,* 629-636. [6] Lee D-C. et al. (2002) *Earth Planet. Sci. Lett. 198,* 267-274. [7] Yin Q-Z. et al. (2002) *Nature 418*, 949-952. [8] Kleine T. (2002) *Nature 418*, 952-955. [9] Horan M. F. et al. (1998) *Geochim. Cosmochim. Acta 62*, 545-554. [10] Lee D-C. and Halliday A. N. (2000) *Science 288,* 1629-

1631. [11] Lee D-C. and Halliday A. N. (1997) *Nature 388*, 854-857. [12] Quitté G. et al. (2000) *Earth Planet. Sci. Lett. 184*, 83-94. [13] Goodrich C. A. (2002) *Meteoritics & Planet. Sci., 37*, A54. [14] Lugmair G. W. and Shukolyukov A. (1998) *Geochim. Cosmochim. Acta 62*, 2863-2886. [15] Singletary S. J. and Grove T. L. (2003) *Meteoritics & Planet. Sci. 38*, 95-108.