THE REGOLITH EXPOSURE HISTORY AND EXTREMELY SHORT TRANSIT TIMES OF TWO ANTARCTIC H CHONDRITES, MAC 02630 AND 02740. K. C. Welten[1], K. Nishiizumi[1], M. W. Caffee[2], M. M. M. Meier[3] and R. Wieler[3]. [1]Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA (E-mail: kcwelten@berkeley.edu), [2]Department of Physics, Purdue University, West Lafayette, IN 47907, USA. [3]Isotope Geology and Mineral Resources, ETH Zürich, CH-8092 Zürich, Switzerland.

Introduction: During our ongoing ^{36}Cl terrestrial age survey of Antarctic meteorites [1], we found very low ^{36}Cl concentrations of 1.0-1.3 dpm/kg in the metal phase of two H chondrites: MacAlpine Hills (MAC) 02630 and 02740. Although the low ^{36}Cl concentration in MAC 02630 was initially attributed to a long terrestrial age (~1.25 Myr [1]), it can also be due to irradiation in a large object (R>2 m) or a very short cosmic-ray exposure (CRE) age (<0.1 Myr). We therefore measured cosmogenic ^{10}Be (half-life =1.36 Myr) and ^{26}Al (0.705 Myr) in the metal phase and noble gases in bulk samples of MAC 02630 and 02740 to distinguish between these three scenarios.

Fig. 1. Investigated samples of MAC 02630 (,6) and MAC 02740 (,4). Photo courtesy of NASA Johnson Space Center, Houston.

Samples and Experimental Methods: MAC 02630 (H5, 133 g) and 02740 (H, 281 g) are two of the ~300 ordinary chondrites (>100 g), that were randomly selected for the terrestrial age survey. Although MAC 02740 was initially classified as an L chondrite, its metal composition (0.48 wt% Co) suggests that it is probably an H-chondrite. Hand specimens of the two meteorites (Fig. 1) show a variety of clasts, indicating they are H-chondrite breccias.

Radionuclide analysis. We crushed ~2.5 g of each sample and separated the metal fraction. After cleaning the metal with 0.2N HCl and concentrated HF, 80.8 and 85.7 mg of clean metal was dissolved for radionuclide analysis, along with a carrier solution containing a few mg of Be, Al, Cl and Ca. All AMS measurements were performed at PRIME lab, Purdue University [2]. Results are listed in Table 1.

Noble gas analysis. One or several small chips wrapped in Al foil were heated to 1750 °C for 30 min. to extract He, Ne and Ar in a single step. Gases were analysed using procedures described previously [3]. Results are given in Table 2.

Results and Discussion. Assuming typical production rates in the metal phase of ~5 dpm/kg for ^{10}Be, ~3.5 dpm/kg for ^{26}Al and ~22 dpm/kg for ^{36}Cl, the measured ^{10}Be and ^{36}Cl concentrations yield CRE ages of 0.027±0.003 Myr for MAC 02630 and 0.020±0.002 Myr for MAC 02740 (Fig. 2). The extremely short CRE ages provide strong evidence that these two H-chondrites are paired.

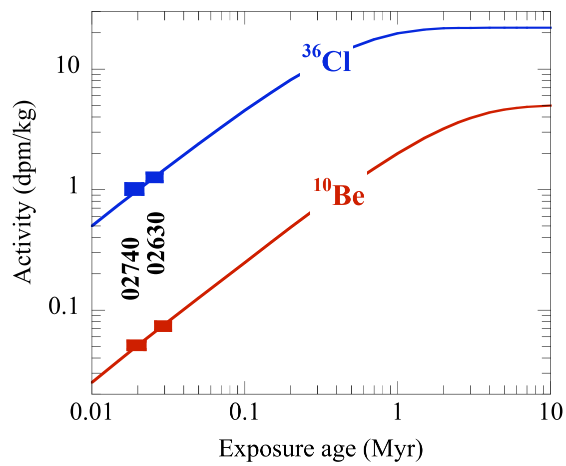

Fig. 2. Concentrations of ^{10}Be and ^{36}Cl in the metal phase of MAC 02630 and 02740, compared with expected values as a function of exposure age (solid curves).

These ages are 2-3 orders of magnitude lower than typical CRE ages of ordinary chondrites, which are in the range of 1-50 Myr [4]. However, they are not unique, as three other ordinary chondrites with CRE ages <0.1 Myr have previously been reported;

Farmington (L5) with an age of 0.032±0.003 Myr, Galim (LL6) with an age of 0.033±0.007 Myr and GRV 98004 (H5) with an age of 0.052±0.008 Myr [5, 6]. It is intriguing that four ordinary chondrites show CRE ages of 0.02-0.06 Myr, while ages <0.5 Myr are otherwise rare. It has been suggested that the short CRE ages reflect the short delivery times of meteoroids ejected from Earth-crossing Apollo objects [7]. The noble gases in both MAC samples are dominated by solar gases, with roughly a factor of 10 higher concentrations in MAC 02630 than in MAC 02740. Although the high solar gas contents inhibit the determination of cosmogenic He and Ar, ^{21}Ne shows a clear cosmogenic signal.

Neon. The trapped neon component shows ^{20}Ne/^{22}Ne ratios of 11.0-11.5, consistent with implantation fractionated solar wind. We derive cosmogenic ^{21}Ne concentrations of ~0.32 and ~0.89 x 10^{-8} cm^3 STP/g (Table 2). These cosmogenic Ne contents are much higher than the estimated amount of ~0.01 x 10^{-8} cm^3 STP/g based on the radionuclide CRE age. We thus conclude that the cosmogenic Ne component was produced almost entirely during 2π exposure on the parent body, most likely during GCR/SCR irradiation of the individual components in the regolith. Assuming a maximum ^{21}Ne production rate of ~0.16 x 10^{-8} cm^3 STP/g/Myr for 2π exposure at a depth of ~50 g/cm^2 [8], we derive minimum 2π exposure ages of 2.0 and 5.5 Myr for MAC 02740 and 02630, respectively. The ratio of $^{21}Ne_{cos}$ produced during 2π exposure to trapped solar ^{20}Ne in MAC 02630/02740 is similar to the respective value derived for solar-gas-rich matrix samples of the Fayetteville H-chondrite breccia [9]. This indicates a similar regolith mixing dynamics on their parent bodies and can also be used to derive a rough estimate of 2-3 AU for their semimajor axes [9]. Finally, we note that MAC 02630/02740 is not paired with a previously reported regolith breccia, MAC 87302, which has a ^{21}Ne CRE age of ~27 Myr [10].

Argon & Helium. The measured ^{36}Ar/^{38}Ar ratios of 5.78-5.92 are significantly higher than the accepted solar wind value of ~5.5 [11,12] and even higher than the expected fractionated SW values of 5.1-5.3 observed in most solar-gas rich meteorites. Although some of the "excess" ^{36}Ar may be due to decay of neutron-capture produced ^{36}Cl during exposure in the regolith, it seems unlikely that this accounts for 5-10% of the total ^{36}Ar. The upper limit of 0.69x10^{-8} cm^3 STP/g of $^3He_{cos}$ for MAC 02740 corresponds to a ^{3}He/^{21}Ne ratio <2.1, indicating significant loss of cosmogenic He.

The very short transit time to Earth allows to constrain when the regolith irradiation of MAC 02360 and 02740 occurred. Because all radionuclides – in particular ^{10}Be – which must have been produced during the regolith exposure essentially have decayed completely, this exposure must have terminated at least 10 Myr prior to the fall of the meteorite to Earth. The two meteorites can thus not have been ejected from near-surface locations on their parent body by the event which initiated the 4π exposure, and the solar wind "antiquity" of the paired meteorites is at least ~10 Myr. A similar conclusion has been made for the Kapoeta howardite [13].

Conclusions. The low concentrations of cosmogenic radionuclides in MAC 02630 and 02740 indicate that these paired H-chondrites had a transit time of 0.02-0.03 Myr from their parent body to Earth. Based on the extremely short transit time and high concentrations of solar gases, we conclude that MAC 02630/02740 represents a unique regolith breccia with an almost pure regolith noble gas record.

Acknowledgments: This work was supported by NASA grant NNG06GF22G and the Swiss National Science Foundation.

References: [1] Welten K. C. et al. (2007) *LPSC XXXVIII,* CD-ROM, #2345. [2] Sharma P. et al. (2000) *NIM*, B172, 112-123. [3] Wieler R. et al. (1989) *GCA 53,* 1449-1459. [4] Marti K. and Graf Th. (1992) *Ann. Rev. Earth Planet. Sci. 20,* 221-243. [5] Patzer A. et al. (1999) *LPSC XXX,* CD-ROM, #1145. [6] Lorenzetti S. et al. (2003) *MAPS 38,* 1243-1253. [7] Gladman B. et al. (1997) Science 277, 197-201. [8] Leya I. et al. (2001) *MAPS 36,* 1547-1561. [9] Wieler R. et al. (1989) *GCA 53,* 1441-1448. [10] Welzenbach L. et al. (2005) LPSC XXXVI, CD-ROM, #1425. [11] Meshik A. et al., (2007) *Science 318,* 433-435. [12] Heber V. S. et al. (2008) *LPSC XXXIX,* this conference. [13] Caffee M. W. and Nishiizumi K. (2001) *MAPS 36,* 429-437.

Table 1. Concentrations of cosmogenic radionuclides (in dpm/kg) in metal phase of MAC 02630 and 02740.

MAC	^{10}Be	^{26}Al	^{36}Cl
02630	0.075±0.006	0.092±0.012	1.25±0.06
02740	0.050±0.006	–	1.00±0.09

Table 2. Noble gas concentrations[1] (in 10^{-8} cm^3 STP/g) in bulk samples of MAC 02630 and 02740.

MAC	Mass (mg)	^{3}He	^{4}He	^{20}Ne	^{21}Ne	^{22}Ne	$^{21}Ne_{cos}$	^{36}Ar	^{38}Ar	^{40}Ar	^{36}Ar/^{38}Ar
02630	46.2	24.4	69750	968	3.46	88.4	0.887±0.052	76.3	12.9	9490	5.92
02740	86.3	0.69	1971	101	0.570	8.74	0.315±0.009	7.96	1.38	2867	5.78

[1]Uncertainties: 2% for concentrations, 0.5% for isotopic ratios.