PB-PB ISOTOPE DATING OF ORDINARY CHONDRITES A. Bouvier[1], J. Blichert-Toft[1], J. Vervoort[2] and F. Albarède[1], [1] Ecole Normale Supérieure de Lyon, 46 Allée d'Italie, 69364 Lyon Cedex 07, France, [2] Washington State University, Pullman 99164-2812, WA, USA. <abouvier@ens-lyon.fr>

Introduction: The precision of the Pb-Pb chronology of the early Solar System has benefited recently from new developments in mass spectrometry and low-blank separation techniques. Here we report Pb isotopic data on chondrule separates from ordinary chondrites (OC) analysed by MC-ICP-MS at ENS Lyon. We selected exclusively fall-observed OC of different types (H, L, and LL 4 or 5) and with S1 or S2 shock levels.

Preparation and data acquisition: The OC samples were obtained from the Museum in Paris and the Laboratory of Meteoritics in Moscow. 0.4 to 1 g of chondrules were hand-picked in the WSU clean lab from 10 to 25 g samples using stainless steel tweezers and an agate mortar.

Pb was separated in the clean lab at ENS Lyon. The samples were leached sequentially in acetic acid and HCl. Samples > 800 mg were first dissolved in HF-HNO_3 in a Savillex beaker. The residue (and the bulk of the small samples) were then transferred into steel-jacketed PTFE bombs and digested in HF-HNO_3 for one week at 150°C. The Pb fraction was separated by HBr and HNO_3 on teflon micro-columns filled with 180µl of AG1-X8 resin (200-400 mesh).

The Pb isotopic compositions were determined on the Plasma 54 in Lyon using an Aridus desolvater. The measured isotope ratios were corrected for mass bias by the Tl doping and standard braketing method [1].

Total procedural blanks from leaching to mass spectrometry were 160 pg for 1 g of chondrules and 15 pg for the leachates. The blank represents 0.01 to 0.9 % of the total Pb contents of the various samples.

Results: All calculations were made in $^{207}Pb/^{206}Pb$-$^{204}Pb/^{206}Pb$ space, which minimizes noise-induced correlations between variables. The data were first corrected for the blank contribution. We then assumed that the sample is a mixture of radiogenic (*) and common lead and used the intercept of the residue-leachate array in the $^{207}Pb/^{206}Pb$-$^{204}Pb/^{206}Pb$ plot to estimate the $^{207}Pb^*/^{206}Pb^*$ ratios. Full error propagation inclusive of blank contribution required the development of a specific correction scheme. For $^{206}Pb/^{204}Pb$ > 30 and sample/blank ratios > 100, typical errors on ages vary between 400 ky and 1.2 My.

We found that whole-rocks yield ages clearly less reliable than those of chondrules. Chondrules from Ste Marguerite (H4) give an age of 4563.4 ± 0.6 Ma indistinguishable from the phosphate age of 4562.7± 0.7 Ma [2]. These values are also indistinguishable from the age of the chondrules from Nadiabondi (H5) (4562.5 ± 0.9 Ma), whereas the phosphates give a younger age of 4555.6 ± 3.4 Ma [2]. The oldest age is obtained for Forest City (H5; 4567.8± 0.7 Ma).

On average, the ages of the L chondrites are younger. The age of Elenovka (L5; 4480 ± 47 Ma) is consistent with the phosphate age of 4535 ± 1 Ma [3], but is too imprecise to be useful. Ausson (L5) gives an age of 4555.6 ± 0.5 Ma, which is older than the phosphate age of 4526.8 ± 0.9 Ma [2]. The chondrules from Tuxtuac (LL5) are 4559.9 ± 0.5 Ma old, again older than the phosphates (4543.6 ± 2.1 Ma) [2].

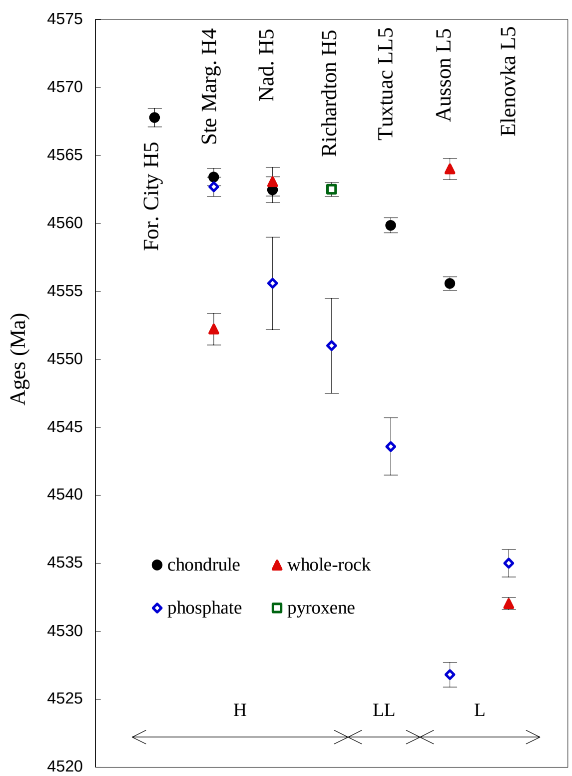

Figure 1: Comparison of Pb-Pb ages for chondrules, whole-rocks, phosphates, and pyroxenes from different studies. Filled circles and triangles: our study; diamonds and squares: [2], [3] and [4].

Meteorite	Element	Weight g [a]	$^{206}Pb/^{204}Pb$ [b]	$^{207}Pb/^{206}Pb^{*}$ [c]	2σ	$^{207}Pb^{*}/^{206}Pb^{*}$ Age, Ma [c, d]	2σ
Sainte-Marguerite	Chondrules	1.0842	35.83	0.623359	0.000275	4563.5	0.6
H4	Whole-rock	0.9390	41.66	0.618567	0.000497	4552.2	1.2
Forest City	Chondrules	0.4226	42.92	0.625247	0.000292	4567.8	0.7
H5	Whole-rock	1.1562	21.42	0.668474	0.000673	4664.4	0.4
Nadiabondi	Chondrules	1.2534	129.1	0.622954	0.000412	4562.5	0.9
H5	Whole-rock	0.9579	62.25	0.623212	0.000455	4563.1	1.1
Tuxtuac	Chondrules	0.6301	49.27	0.621831	0.000234	4559.9	0.5
LL5	Whole-rock	0.9801	21.45	0.626355	0.000172	4570.4	0.4
Ausson	Chondrules	1.0728	24.67	0.619999	0.000208	4555.6	0.5
L5	Whole-rock	1.0658	24.40	0.623618	0.000342	4564.0	0.8
Elenovka	Chondrules	1.0541	181.8	0.588676	0.019654	4480.3	47
L5	Whole-rock	1.0042	156.2	0.610021	0.000283	4532.1	0.5

Table 1: Pb isotope data for chondrules from ordinary chondrites (this study). [a] Before leaching. [b] Corrected for mass bias and blank. [c] Radiogenic Pb isotope ratios calculated by leaching interpolation. [d] Ages calculated assuming $^{235}U/^{238}U$=1/137.88 and Steiger and Jäger (1977) decay constant values of ^{235}U and ^{238}U.

Two whole-rock ages at 4564.0 ± 0.8 Ma (Ausson) and 4563.0 ± 1.1 Ma (Nadiabondi) seem meaningful, whereas other whole-rock ages clearly are perturbed or may not satisfy our simple two-component assumption.

When the most precise of the ages of chondrules, phosphates, and pyroxenes are compiled, we obtain for the ages of H, L, and LL chondrites a range of ~9 My (Fig. 1). This compilation excludes the older Forest City, as well as Elenovka which seems to have experienced a protracted thermal history. Cooling rates may be estimated using the data of [5] on Pb diffusion in rock-forming minerals: for a similar grain size the closure temperature is some 300°C lower in phosphates than in pyroxenes, which probably represent the main Pb carrier in chondrules. A fast cooling rate (~300°C/My) may be inferred for Ste Marguerite (H4). Nadiabondi (H5; ~40°C/My) and Ausson (L5; 10°C/My) appear to have cooled much more slowly. The age of Ste Marguerite is therefore the closest to the temperature peak (4563.5 ± 0.6 Ma). Assuming that the dominant heat source was ^{60}Fe ($T_{1/2}$ = 1.5 My), this places the age of the protoplanet at 4567 ± 1 Ma.

References: [1] Albarède et al. (2004), GCA 68 (12), [2] Göpel et al. (1994), EPSL 121, [3] Amelin (2000) LPSC 1201, [4] Amelin et al. (2001) LPSC, 1389, [5] Cherniak et al. (1991) GCA 55(6).