THE CONCORDANCY OF URANIUM-LEAD AGES IN METEORITES. J. H. Chen[1] and D. A. Papanastassiou[2], [1,2]Science Division, [1]M/S 183-601, [2]M/S 183-335, Jet Propulsion Laboratory, Caltech, 4800 Oak Grove Dr., Pasadena, CA 91109-8099 (James.H.Chen@jpl.nasa.gov).

Introduction: Recent improvements of Pb analytical techniques (high precision, high ionization efficiency, and lower blanks) [1] allow analysis of much smaller samples with high precision. However, terrestrial Pb contamination, which is difficult to remove, even with stepwise or intense acid leaching, still hampers the attempts to obtain reliable U-Pb or ^{207}Pb-^{206}Pb ages. In the presence of complex U-Pb systematics, caused in part by potential differential U-Pb leaching, there has been a tendency to rely on just Pb-Pb ages to date chronological events, the age of the solar system, or as benchmarks for anchoring extinct nuclide chronometries. The key issue is under which, if any, circumstances Pb-Pb model ages reflect a simple, single-stage evolution, with high precision and reliability and with better than 1 Ma time resolution. In this report, we assess U-Pb data, in the literature, from some chondrites, using the conventional U-Pb diagrams.

Chondrites: Previously we analyzed the U-Pb systematics of Allende CAIs and reported a single stage ^{207}Pb-^{206}Pb model age of 4.565 ± 0.004 Ga [2]. In constructing this diagram, we assumed the initial Pb for Allende was the same as that determined in Canyon Diablo troilite (PAT) [3]. Therefore, the ^{207}Pb-^{206}Pb isochron is essentially a "primary single stage Pb-Pb isochron". In a concordia diagram, the Allende data define a chord which intersects the concordia curve at 4.568±0.087 and 0.28±0.2 Ga. Our previous Allende ^{207}Pb-^{206}Pb age is indistinguishable from the new results of 4.5662±0.0025 Ga [4] or 4.568±0.0094 Ga [5] for Allende CAIs. The lower age intercept is not well-defined, but is critical in assessing the validity of a simple, single-stage evolution, and the calculation of a meaningful ^{207}Pb-^{206}Pb model age. In a U-Pb evolution diagram (Fig. 1) our previous Allende data array (uncorrected for initial Pb) yields an initial ^{207}Pb/^{206}Pb value of 1.10±0.05, which is indistinguishable from primordial Pb (PAT). In this diagram, uncontaminated and undisturbed samples should fall on a line (A) connecting PAT and a pure radiogenic point on the concordia curve (at T=4.56 Ga) [6,7]. Terrestrial contamination would pull the data points down and rotate the data array counterclockwise (cf. line B), intersecting with concordia at an older age. However, the low precision of our previous data prevented precise assessment of the U-Pb systematics.

Using greatly improved U-Pb analytical techniques, Amelin et al. [8] reported high precision U-Pb data on Acfer 059 (CR chondrite) and on CAIs in Efremovka (CV). They claimed that the ^{207}Pb-^{206}Pb

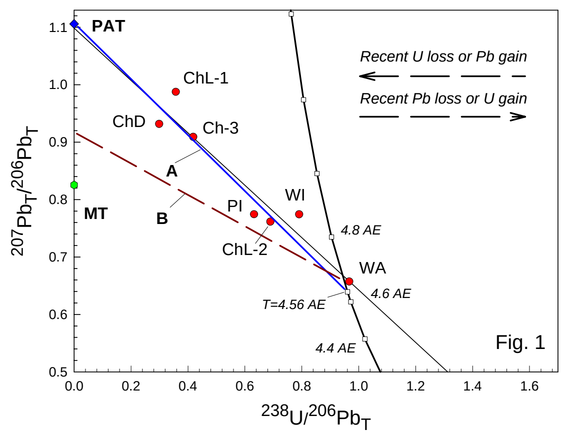


Fig. 1

ages of these two meteorites (Acfer 059: 4564.7±0.6 Ma and Efremovka: 4567.2±0.6 Ma) give an interval of 2.5±1.2 Ma between formation of the CV CAIs and the CR chondrules. These new U-Pb data allow more accurate assessment of the U-Pb systematics. We plotted their data for Acfer on a conventional U-Pb concordia diagram (Fig. 2). All samples were acid-washed, except Chondrule 1 and the matrix, which are the most discordant. Their U-Pb data show a wide range of ratios, but also seem to define a linear array which points toward a near-zero lower intersect "age" on the concordia curve. The upper intercept age (4560.5±2.7 Ma) for Acfer was close to the Pb-Pb age of this meteorite. It seems that this is a special case for the U-Pb system, which is applicable only if all disturbances are at "zero" age (the present). It is clear, however, that leaching can produce artifacts (U-Pb fractionation) and prevent critical evaluation of U-Pb ages. In this case, their strong leaching removed 85-98% of the total lead. The U-Pb data for Efremovka CAI E49 also display a zero lower intersect age and define a

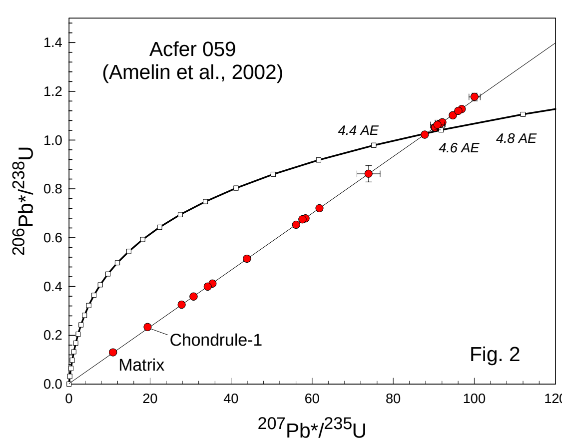
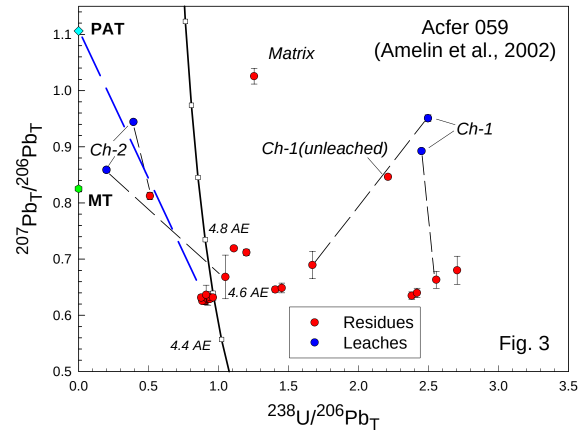


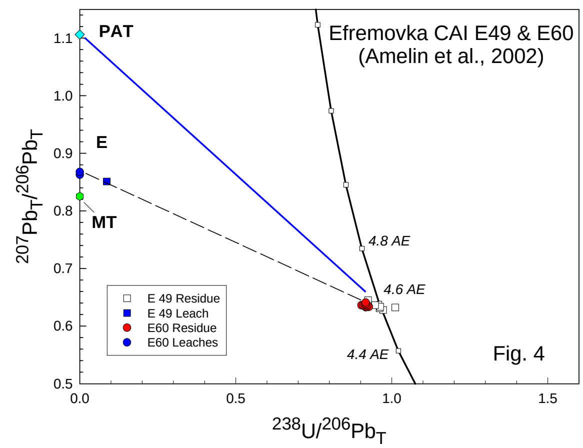
Fig. 2

4566.6±0.7 Ma concordia upper intersect age. However, all samples from E60 yield discordant ^{206}Pb-^{238}U ages, from 4.65-4.73 Ga.

Discussion: In a U-Pb evolution diagram (Fig. 3), the Acfer samples show a complicated pattern. U-Pb data were reported on only 4 leaches. The reported leach and residue data for the same samples are connected with tie lines. The severe leaching has quantitatively removed significant amounts of radiogenic and non-radiogenic Pb and produced U/Pb fractionation. For example, for Chondrule-2, the U/Pb ratios decrease in the leaches relative to the residues. For Chondrule-1, three analyses show that the U/Pb ratios increase and decrease in leaches relative to the respective residues. The data also show that the sampled aliquots of Chondrule-1 were very heterogeneous. Only leaches and residues of Chondrule-2 seem to fall on the line connecting PAT and the radiogenic component on the concordia. All other data, including the unleached Chondrule-1 and matrix are not consistent with the simple U-Pb model as shown in Fig. 2. The U-Pb data for the Efremovka CAIs are plotted in Fig 4. These samples seem to fall on a line connecting the radiogenic component on the concordia and an "exotic" component (E), $(^{207}Pb/^{206}Pb)_E$=0.865±0.002, which is also much less than PAT. In summary, most samples from Acfer and Efremovka are not consistent with a simple, single stage evolution model, with PAT as the initial Pb, but, instead, require multiple stage evolution. Therefore, the reported ^{207}Pb-^{206}Pb isochron ages for Acfer and Efremovka CAIs are not primary, single-stage isochron ages. The leaching clearly fractionates U/Pb and could have produced artifacts in the ages (discordancies). Because the initial Pb in these meteorites might not be PAT, then the calculation of radiogenic Pb and the construction of the concordia diagram (cf. Fig. 2) may not be correct. Since, every meteorite may have evolved from parent bodies having different initial Pb (equal to or different than PAT), the practice of combining data sets from different meteorites or the selective regression of data sets [5] to determine the age of the Solar System is strictly incorrect and may lead to weakly supported conclusions.

In addition, the difficulty in determining a precise U-Pb age for a disturbed system for the early solar system is inherent in the nature of the concordia diagram. For fine-time resolution, related to events mostly at T>4.53 Ga, the curvature in the U–Pb concordia curve is so subtle that a cord connecting two points in that age region is tangential to the curve and the cord and curve may be practically unresolvable [7]. Part of the problem is that the analytical errors for U/Pb ratios are too large compared with errors for the $^{207}Pb/^{206}Pb$ ratios. Therefore, as demonstrated previously on chon-





drite phosphates, a series of disturbed U-Pb systems for samples formed and recrystallized early in the solar system (>4.53 Ga) would appear strictly concordant, but could yield 'false' single-stage ages [7].

In conclusion, the current practice of severe leaching steps seems to remove a large fraction of contaminant Pb, but it also produces artifacts in the U-Pb systematics. It is premature to use the Pb-Pb ages based on leached residues to establish the age of the Solar System or to anchor the timing of short-lived chronometers. The apparent high precision of ^{207}Pb-^{206}Pb model ages is always very enticing, but may be misleading.

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