

OVERVIEW OF SHORT-LIVED NUCLIDES: THE ELUSIVE ROAD TO CONSISTENCY.

D. A. Papanastassiou, Science Division, Jet Propulsion Laboratory, Caltech, M/S 183-335, 4800 Oak Grove Drive, Pasadena, CA 91109-8099 (Dimitri.A.Papanastassiou@jpl.nasa.gov).

This workshop has been organized with planned, detailed presentations of specific parent-daughter systems, as well as with serious attempts to correlate the chronology extracted from individual systems, with the general aim of achieving a self-consistent chronology for the early solar system. There is a parallel effort to establish a set of consistent stellar production mechanisms and sources, to account for the introduction in the solar system of short-lived nuclides. However, there is a sufficiently wide range in mean lives among the various short-lived nuclides, that exponential decay intervals can wreak havoc with the implied production ratios and required number of diverse stellar sources.

The purpose of an introduction is to recognize the advances in the field as well as to remind us of the complexities of the individual parent-daughter systems. A driving force has been the attempt to define a consistent chronology. This driving force can be taken to extremes, where the desire for different systems to be concordant results in minimizing the importance of the complexities of individual systems and of limitations of specific data or of data on specific samples.

It is clear from a plethora of robust data that many short-lived parent nuclides were introduced (live) in the early solar system and that evidence for their existence has been preserved. It is less clear that a specific parent-daughter, short-lived system provides a well-defined chronology and it is much less clear that chronologies from different systems are correlated or can be considered to be consistent or “forced” into being consistent with judicious, rather than arbitrary choices.

The primary considerations are: a) Did the radioactive parent(s) get mixed uniformly, within the early solar system, prior to solid body formation, or at least in the regions of the solar system from where samples that are being dated originate? and b) Were the requirements met for internal isochron determinations, for individual parent-daughter systems and specific samples?

To a large extent, the answer to (a) is the last thing to determine, based on whether consistent chronologies can be defined. The requirements for (b) are an initial state of uniform isotopic compositions among coexisting mineral phases, with sufficient (chemical) dispersion in parent-daughter ratios. For multistage evolution, there may also be a correlation of initial isotopic

compositions and time. If the analytical techniques involve leaching, the key question is whether the parent-daughter ratios of the leaches and/or residues preserve the parent daughter ratios of the mineral phases. If, for specific parent-daughter systems, there are only two minerals that dominate, then establishing the distinction between an internal isochron and a mixing line, with no time significance, becomes a serious concern, and especially so when leaching is used.

When it comes to leaching, the case of the U-Pb system is of paramount importance. This system allows the precise calculation of $^{207}\text{Pb}/^{206}\text{Pb}$ model ages as well the determination of more complex evolution. However, if all samples have to be leached to remove potential terrestrial contamination, the question becomes whether U-Pb ages on the residual samples are compromised. For example, if leaching removes 98% of the terrestrial contamination and 25% of the natural/radiogenic Pb, can a sensible age be obtained? If such ages are compromised, then the ability to establish concordant U-Pb ages becomes inherently limited. Should Pb-Pb ages be viewed as true ages, with the extremely high precision inherent in determining a model age, based on the intermediate mean life of ^{235}U , if U-Pb ages are not concordant? What processes would allow Pb-Pb ages to give a precise age (or ages) for refractory inclusions, when we know that the long-lived Sm-Nd and Rb-Sr systems are significantly disturbed? Clearly, a zero-age (very recent) disturbance for the U-Pb system is allowed, but the nature of the disturbance for meteorites observed to be falls is unclear as it is unclear why we should be so lucky.

When it comes to other systems, for refractory inclusions, we know (from ion microprobe work) that, for ^{26}Al - ^{26}Mg individual mineral plagioclase grains show disturbances. What then is the meaning of the “canonical” $^{26}\text{Al}/^{27}\text{Al}$ initial ratio or of “super-canonical” ratios, obtained on bulk mineral separates? We also know that for ^{53}Mn - ^{53}Cr , in Allende, the system is disturbed and that there is no correlation between Al-Mg and Mn-Cr ages. We also know that for individual inclusions when a ^{53}Mn - ^{53}Cr age can be determined from coexisting spinel and pyroxene, the $^{54}\text{Cr}/^{52}\text{Cr}$ ratios of the same coexisting minerals are not uniform. This implies migration of Mn, Cr (and Fe) and would invalidate any internal isochron determination. For this system, the limitation of the measurements to only two mineral phases can definitely lead to mixing lines

which are not valid as isochrons. Similarly, for the Al-Mg system, because only limited attention has been paid to obtaining data on melilites, with sufficient precision, the internal isochrons are not necessarily robust. One should keep in mind that mixtures of two minerals can generally give collinear data and do not resolve the issue of a mixing line vs. an isochron with age significance.

These are but few of the considerations to keep in mind during the workshop and beyond. Such considerations may also help us temper the push for data and sample selection towards a consistent chronology for the early solar system.

And finally, a statement of caution about new and old techniques, when modern analytical improvements appear to result in highly improved precision at the ppm level. At this level, many interferences and artifacts that could be safely neglected at the 100 ppm (1 part in 10^4) level may become dominant. Similarly, chemical separation techniques which are adequate for thermal ionization techniques (with selective ionization conditions, for individual elements) may become totally inadequate for plasma ionization, with uniformly high ionization efficiency. These analytical issues reflect the importance and danger of living in "interesting times".