RADIOGENIC ^{26}Mg IN STE MARGUERITE AND FOREST VALE PLAGIOCLASE: CAN ^{26}Al BE USED AS CHRONOMETER?

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Introduction: Evidence for the initial presence of the short-lived radioisotope ^{26}Al in CAIs [1] raised two important questions: can ^{26}Al serve as heat source for the melting of small asteroids [2] and can it serve as a fine-scale chronometer for early-solar-system events? A positive answer to these questions requires that ^{26}Al be uniformly distributed in early-solar-system matter, with the ^{26}Al presumably produced by a stellar source [3]. However, most of the evidence for the presence of ^{26}Al in the early solar system comes from measurements on CAIs. Recently, Shu and coworkers [4, 5] proposed a model according to which ^{26}Al was produced by particle irradiation in the X-wind region of the early sun and only CAIs had high ^{26}Al/^{27}Al ratios, i.e., ^{26}Al was *not* widely distributed. This model was strengthened by evidence for ^{10}Be in CAIs [e.g., 6]. A way to test whether ^{26}Al can be used as a chronometer is to measure the Al-Mg system in objects of different ages according to other, independent, chronometers. Such measurements in plagioclase grains from the H4 chondrites Ste. Marguerite and Forest Vale [7, 8] yielded inferred ^{26}Al/^{27}Al ratios that, if compared with the canonical ratio of 5×10^{-5} in CAIs, result in time differences that are in agreement with those obtained by Pb/Pb measurements [9, 10]. A temporal interpretation of the results on the H4 feldspars implies that they are of metamorphic origin. However, the Al-Mg measurements were made on grains from mineral separates and the petrographic context of the plagioclase is unknown. We therefore started an ion microprobe study of the Al-Mg system in plagioclase located in polished sections of Ste. Marguerite (SM) and Forest Vale (FV) and are reporting here the first results.

Experimental: Plagioclase in H4 chondrites is quite rare and we used automatic EDX imaging of the elements Mg, Al, Si and Ca in the SEM to locate grains of this mineral with sizes suitable for ion probe analysis. We measured one plagioclase from FV and three grains from SM. The crystal from FV is ~300µm in length (Fig. 1). It is a xenolith, located in the matrix, without any obvious relationship to any other mineral components. It is apparently a fragment of an even larger crystal. On its right part one can see inclusions of original residual liquid, separated from the plagioclase by a sharp, straight line. The three plagioclase grains from SM were found within larger Mg-rich chondrules. They are smaller (30-50µm) than the FV grain. All grains are quite albitic; the FV grain is An_{48}, SM grain #9 An_{44}, and grains #6 and #8 only An_{14} and An_{10}, respectively.

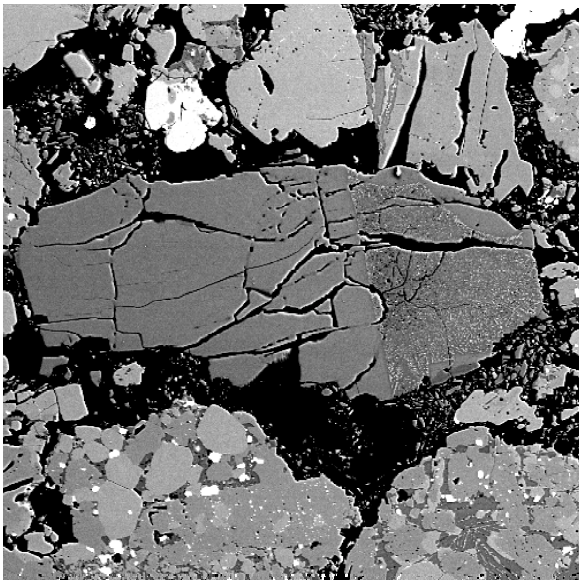

Figure 1

The Al-Mg measurements were made with the NanoSIMS ion microprobe at the MPI Mainz. This instrument, with its high transmission [11] at the mass resolution of ~3000 required for Mg isotopic measurements, is well suited for the analysis of H4 plagioclase grains with their extremely low Mg concentrations. The Mg isotopes were measured in a peak jumping mode with the first small electron multiplier, while the Al^+ signal was detected with the adjacent Faraday cup. Al^+ signals produced by a primary O^- beam of ~1nA were typically 4×10^7 counts/sec. The presence of many tiny Mg-rich grains in the plagioclase complicated the analysis. For this reason it would be desirable to make these measurements in multidetection mode in order to minimize the sample volume consumed during analysis. However, so far we could achieve a precision of 1‰ only in peak jumping mode. Al-Mg ratios were obtained from calibration measurements on a terrestrial anorthite standard.

Results and discussion: Al-Mg plots of the measured samples are shown in Figs. 2 and 3. On the large FV crystal we could perform many measurements. The data points lie within analytical errors on a straight line with an inferred ^{26}Al/^{27}Al ratios of 1.6×10^{-7}. This is in agreement with the ratio previously obtained from three isolated FV plagioclase grains [8]. The data for SM grain #8 are consistent with the FV line. However, those for grains #6 and #9 clearly lie above this line. The best-fit line for the ratios of these two grains has a slope of 8×10^{-7} (Fig. 3). This is almost three times the value of 2.8×10^{-7} previously obtained from isolated SM grains [7]. There might be two different types of plagioclase crystals in SM, the large grains with high Al/Mg represented by the samples obtained from mineral separates and by the FV grain of this study, and smaller grains with smaller Al/Mg ratios residing inside of larger chondrules.

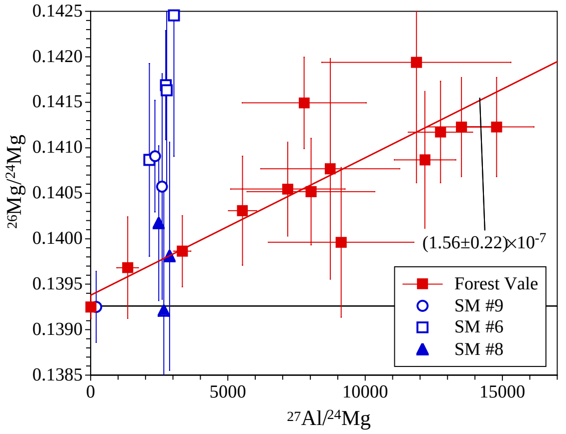

Figure 2

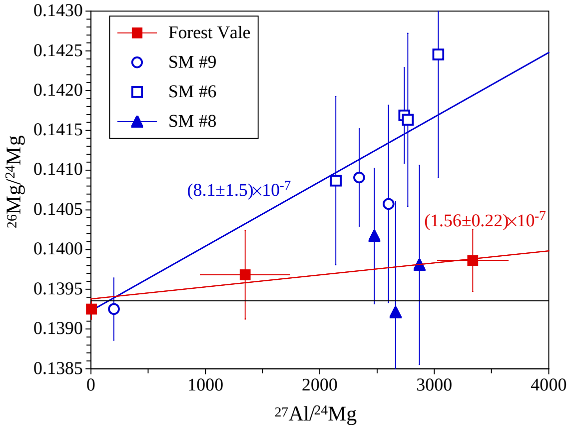

Figure 3

With a ^{26}Al/^{27}Al ratios of 8×10^{-7} for SM the relative Al-Mg ages for CAIs, SM and FV agree with the Pb/Pb ages, obtained on phosphates, even better than before. However, the latter, especially for CIAs, are in conflict with ages derived from the ^{53}Mn chronometer [12]. Figure 4 shows a comparison of ages based on the U-Pb, Mn-Cr, and I-Xe systems [10, 13, 14]. Only the first provides absolute ages, the others have been anchored to the Pb/Pb ages of the angrites and of Acapulco, respectively. According to the Mn-Cr system, Kaidun carbonates [15] are older than CAIs (Pb/Pb ages), raising doubts about the primary signature of the latter [12]. We have plotted relative Al-Mg ages of CAIs, SM and FV so that CIAs are 1Ma older than Kaidun carbonates. With such a choice for the CAI age, the Mg-Al age of SM agrees well with its Mn-Cr and I-Xe ages. The difference between FV ages may be related to different metamorphic effects on chondrule and matrix. Nevertheless, the data require that ^{26}Al was widely distributed in the early solar system and at the time of CAI formation it was not mostly present in CAIs as the X-wind model for the production of ^{26}Al and the formation of CAIs postulates.

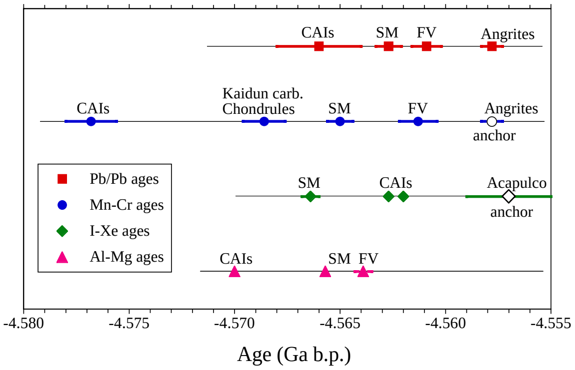

Figure 4

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