VERY HIGH TRACK-DENSITIES IN FOREST VALE (H4) MERRILLITES: WAS CM248 ALIVE IN THE EARLY SOLAR SYSTEM? P. Pelies, C. Perron, M. Bourot-Denise, C. Fiéni, M. Ghelis, Laboratoire de Mineralogie du Musée and CNRS, 61 rue Buffon, 75005 Paris (France) and G. Crozaz, McDonnell Center for the Space Sciences and Earth and Planetary Sciences Department, Washington University, St. Louis, MO 63130, USA.

In the course of fission-track studies of phosphates undertaken to decipher the early thermal histories of H chondrites, very high track densities were measured in merrillites of Forest Vale (FV) H4 chondrite.

FV is apparently an unshocked object described by Noonan et al. (1) who noted that the metal was subjected to a rapid cooling. Our mineralogical study also indicates a very fast cooling rate (>1000 K/Ma). An Ar40-Ar39 age for FV of 4.52 ± 0.03 Ga, with no evidence of Ar loss, is the oldest age reported by Turner et al. (2) for a set of 15 chondrites.

Phosphates separate from two samples (USNM 4052) consist of apatites and merrillites in about equal proportions that are often intergrown. In spite of the long exposure age (>1.80 Ga) (3), the cosmic-ray track densities of FV pyroxenes are low (<10^5/cm²), indicative of a large pre-atmospheric meteoroid (R ≥ 30 cm, mass ≥ 400 kg).

The total track densities measured by SEM in 41 merrillites range from 0.4 to 1.5x10^8/cm² and are the largest observed so far in chondritic merrillites, exceeding by a factor of 2 to 22 those observed in other chondrites. The track densities of apatites range from 8 to 60x10^9/cm² and are typical of chondritic apatites. If the tracks in merrillite are fission tracks, track excesses in apatite (within 5 µm of the merrillite-apatite contact) are expected to be 10-20% of the track density in merrillite (4). In all cases in these two FV subsamples the track excesses are much lower (<1%) (Fig.1a). For comparison, similar measurements were made in the Ste Marguerite (SM) H4 chondrite. Like FV, SM chondrite cooled rapidly and has intergrown merrillite andapatite; however, track excesses in apatites are 1% (Fig.1b), i.e., the expected fission track densities. SIMS measurements of REE patterns and abundances in individual grains of both phosphates of FV are in agreement with previous observations (8,9). The Nd concentration in merrillite is ~110 ppm.

What could be the origin(s) of these very high track densities?

1) Cosmic-ray tracks can be ruled out due to the low track densities in pyroxene. A spontaneous U238 fission origin appears implausible as it would require an unreasonable high U content in merrillites (>100 ppm). Induced fissions of U+Th by protons and secondary particles can account for less than 3x10^3 tr/cm², assuming a normal U content (200 ppb) of merrillites and a Th/U ratio of 10 (5). The contribution of neutron-induced fission of U235 is still lower by one order of magnitude. In addition, confusing dislocations for tracks can be discarded for 2 reasons: a) the very high dislocation densities would have to be present only in merrillites and not in the adjacent apatites; b) annealing experiments (460°C for 2 h.) reduce track densities in merrillites to 0~80x10^6/cm², a behavior consistent with tracks and not with dislocations.

2) Spallation-recoil tracks should be considered in the case of long exposure in space (6). There is, however, no correlation between track densities and Ti, V, Cr and Fe contents of merrillites (SIMS analyses). Moreover, assuming a spallation track production rate of 1.7x10^8/cm², a maximum of 1.5x10^8 tr/cm² can be attributed to this source. Furthermore, annealing experiments were performed (250°C, 5 h.) that should erase the major part of the spallation tracks (6), without affecting to any large extent the fission tracks in both types of phosphates (according to our unpublished results, >95% of the fission tracks will be lost; see also (7)). After thermal treatment, the track densities in 12 merrillites decreased to 0.35-0.75x10^9/cm², indicating that most tracks are not due to spallation. It should be noted that, in spite of this annealing, track excesses in FV apatite in contact with merrillite are still lower than expected (Fig.1c), while in SM (Fig.1d) the values are again within the expected range. 3) Excess tracks in chondritic merrillite are usually attributed to the decay of Pu244. A Pu track density of 5.5x10^9/cm² (after 5 h. annealing at 250°C) requires ~70 ppb of Pu and a Pu/Nd ratio in merrillite of ~6x10^-1, i.e., ~4 times larger than the ratio measured in St. Séverin and Nadasabonid merrillites (10). Such a Pu enrichment cannot be due to a chronological effect as it would imply an unlikely formation age > 4.68 Ga. Although, one could invoke an inhomogeneous...
distribution of Pu among merrillites, there is a major objection to attributing excess tracks to the decay of Pu, namely the absence of Pu fission tracks in apatite contacts. If the majority of tracks in merrillite were produced by Pu decay, a heating event must have occurred that erased fission tracks in apatites, but not in merrillites, some 2 half-lives after the formation of FV. In addition, this heating event should not have been accompanied by any Ar loss. We consider this scenario rather unlikely. 4) An alternative and far-reaching explanation would be to assume the presence of Cm248 (1/2 = 3.4 x 10^7 y) in these FV merrillites. If this was the case, the implications are the following: A) About 0.5 ppb of Cm248 is needed to account for the tracks in merrillite (above an assumed track-density background of 3 x 10^8/cm^2 due to Pu-fission). The near absence of tracks in the margins of adjacent apatites requires that at least 3 Cm248 half-lives elapsed between track retention in merrillites and apatites. This corresponds to a cooling rate of 100 K/Ma in the temperature interval 420-340 K. Above 420 K the cooling rate must have been much faster (>1500 K/Ma, a rate compatible with our metallographic results) so that Cm248-decay did not produce a large amount of fission xenon, with its characteristic mass spectrum (12). B) A last minute synthesis of actinide nuclei would have contaminated some fractions of pre-solar material within one to two half-lives of Cm248 before tracks were retained in FV merrillites. This would imply an extremely fast condensation and accretion of chondritic bodies followed by efficient heating (metamorphic temperatures required to produce petrologic type(s) 4) and then cooling. The isotope Cm247 would have been produced at about the same rate as Cm248 (13) and its decay would have affected the U238/U235 ratio in merrillites, in conflict with the results (10,11). Although a maximum value of 0.3 ppb of Cm247 (and by extension of Cm248) would be consistent with the U238/U235 ratio measured in Nadiabondi merrillites (10), it is conceivable that Cm was inhomogeneously distributed. In this context, we note that track-densities in merrillites from a second sample of FV (Paris MNHN 3347) range between 5 and 6 x 10^8/cm^2 and might be for the most explained by Pu fission and spallation recoil tracks, as it could also be the case for the SM merrillites. To settle the question, fission xenon measurements of phosphates of FV are in progress.