THERMAL HISTORIES OF ORDINARY CHONDRITE PARENT ASTEROIDS. P. Pellas and C. Fiéni, Lab. de Minéralogie du Muséum, 61 rue Buffon, 75005 Paris, France.

In order to explain an apparent lack of correlation between metallographic cooling rates (MTCR) and petrologic types along with very large variations of MTCRs (1 to > 1000K/Ma) found in various clasts of surficial breccias of OCs, Taylor et al. (1) claim that H- and L asteroids "were disrupted and reassembled before they had cooled below 500°C." Here, we would like to point out that early thermal histories of OCs retraced by absolute (Pb-Pb, Rb-Sr, Ar-Ar) and relative (244Pu-Xe_f-fission tracks) clocks agree rather well for H and LL materials and do not require any catastrophic disruption. For the L body many data indicate that around 4.45 Ga a huge impact event must have modified the internal structure, deeply perturbing all chronometers (2,3). A later event, ∿500 Ma ago has added more perturbations which render difficult any chronological interpretation. Therefore the L body will not be discussed here. Note also that the most unshocked and homogeneous OCs were selected for this work.

I) Differential "ages" obtained from the starting time of absolute clocks in a given object allows to define an approximate time interval during which cooling has taken place between closure temperatures of Pb-Pb (∿1150K) and Ar-Ar (∿600K) systems. For St. Séverin (LL6) and Guarena (H6), with Pb-Pb ages of 4.55 ±0.01 (4,5), and Ar-Ar ages of 4.42-4.38 and 4.44 (±0.03) Ga respectively (6,7), cooling rates of ∿3 and ∿5K/Ma are derived. With the same thermal conductivity for H and LL materials a larger size is inferred for the LL- (R_o: 130-150 km) than for the H-body (80-100 km).

II) In Fig.1 are shown the U+Pu fission track densities (FTDs) in phosphates of 11 H chondrites arranged according to petrologic types (and with exposure ages ranging from ∿2 to ∿80 Ma). For whitlockites (WHTs), FTDs (essentially Pu) are indicated by mean values. It is clear that for 10 (out of 11) objects a progressive FTD increase is observed from $50\times10^6/cm^2$ up to $690\times10^6/cm^2$ (Forest Vale). In the latter object a possible fission contribution of 248Cm ($T_{1/2}$: 0.34 Ma) might have increased the FTDs by a factor of ∿2 (8), which apparently seems not to be the case for B.Creek and Ste Marguerite. With an original abundance of ∿25 ppb in Guarena WHTs (as found by extrapolating PuFTDs through OLV- and OPX contacts up to Xe_f retention temperature of ∿900K), a Xe_f-track interval of ∿160Ma is found for Guarena leading to a PuFTCR of ∿3K/Ma within 900-380K, and of ∿4.5K/Ma between 1150 and 380K, in excellent agreement with the value obtained in paragraph I. This is the lowest cooling rate obtained for an equilibrated H object. An interesting exception is Mt Browne which shows (Fig.1) a very high PuFTD for a H6 sample. Its FTCR is also quite fast (>30K/Ma for 670-400K). The high Pu content (44ppb) and very high Pu/Nd ratio (4.6×10^{-4})(9) suggest that a peak metamorphic temperature (∿1150) of very short duration (10^3-10^6yr) was sufficient to establish the equilibration observed to-day in Mt Browne. If this was the case, the original Mt Browne material must have been extracted -still hot- before the accretion of the H asteroid was over, thus alleviating the difficulty of taking out materials from large depths, and invalidating an apparently strong argument presented in (1). Similar results are observed for LL OCs. For instance, a very low PuFTD of ∿$35\times10^6/cm^2$ has been found for ALHA 84027, a LL7 object (10), while for Soko-Banja (LL4) the FTD is $310\times10^6/cm^2$. Therefore (assuming the same Pu content) the time difference between track retentions in both WHTs would correspond to ∿260 Ma, leading to a FTCR of ∿2.5K/Ma for this LL7 sample (1150-360K).

Thus PuFT thermometry indicates a long (∿160Ma) metamorphic time for most H6 objects, and even longer for a LL7 stone. On the other hand, many H4 samples (Fig. 1) cooled down very fast within a very short metamorphism interval (possibly $<10^6$yr). In between these two extremes numerous H4-H5 samples are grouped. This kind of stratification amazingly resembles the onion-shell structure which corresponds also to the simplest accretional process. With minor modifications, a similar layered structure is implied by early thermal histories of many LL objects for which there are significant chronological data and of which the pristine character has been preserved.

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III) Such internal structures and size differences are confirmed by Ar-Ar ages of OCs. In Fig.2 a significant difference emerges between H and LL OCs : i) for 11 (out of 12) H objects the ages overlap and cluster (whatever the petrologic type) at 4.48± 0.04 Ga. This tells us that the H-body was a rather small asteroid (R_o < 100km) in which the Ar closure temperatures of all materials were achieved at an early time within a spread of ∿80Ma. The Ar-Ar method is not sensitive enough indeed (±30Ma) to disentangle petrologic types in a rather small asteroid; ii) this is no more true for LL materials : there is a clearcut difference between LL3-LL5 and LL6 OCs, with almost no overlapping. That is what is expected for samples located near the surface (types 3-5) and at significantly greater depths (LL6) in a rather large asteroid (R : 130-150 km), assuming canonical parameters for thermal evolution (11). An insulating regolith would accordingly decrease the radius (12). An interesting confirmation of this trend would be to obtain a still lower Ar-Ar age (4.30 Ga?) for the LL7 sample (ALHA 84027). For L materials, not enough analyzed samples exist for unmodified objects to get definite conclusions. In short, contrary to what is argued in (1) Ar-Ar ages do not disagree at all with onion-shell structures for OCs asteroids.

It is hoped that the above facts and clarifications will help to dismiss an imaginative model which does not seem applicable to the H- and LL asteroids.

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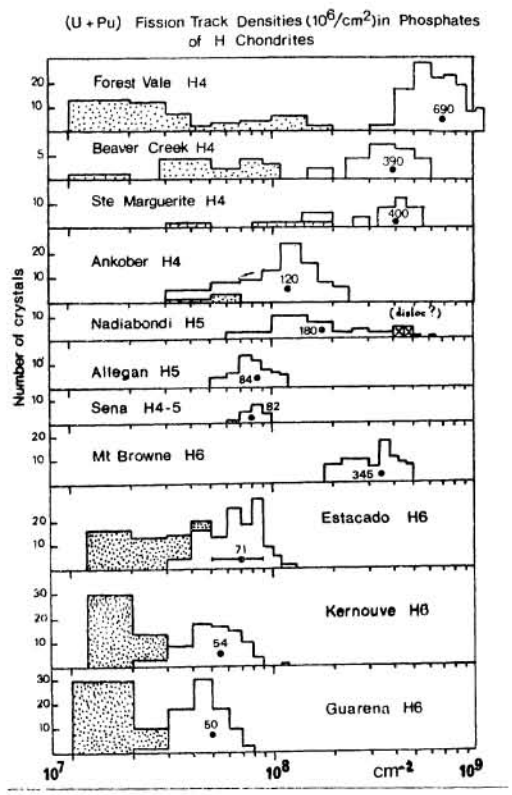

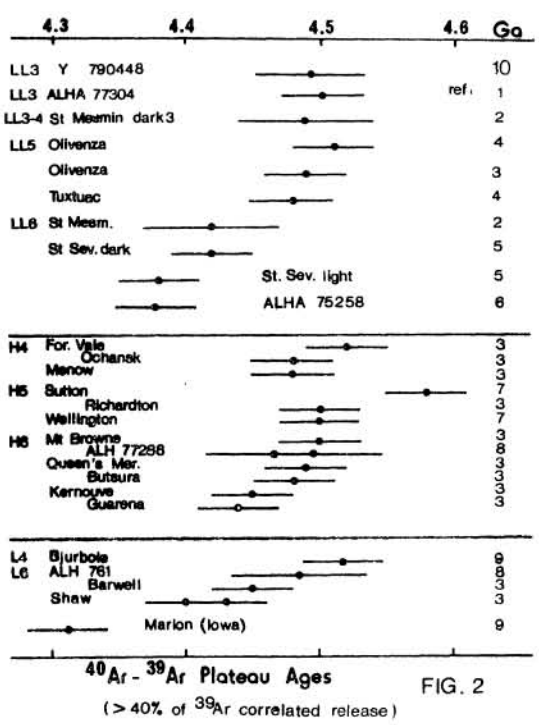

FIG. 2