

REEVALUATION OF THE ^{53}Mn - ^{53}Cr SYSTEMATIC IN THE BASALTIC ACHONDRITES. A. Trinquier, J.L. Birck and C.J. Allègre. Laboratoire de Géochimie et Cosmochimie, Institut de Physique du Globe, 4 place Jussieu, 75252 Paris cedex 05, France (trinquier@ipgp.jussieu.fr).

Introduction: Previous chromium isotopic work has shown the presence of live ^{53}Mn in the early solar system [1,2] in the source of basaltic achondrites and therefrom a magmatic activity which was very short and early on their parent body [3,4]. The details of the history and the absolute time scale are still debated. The discovery of a homogeneous ^{54}Cr deficit in the HED meteorites [5] (see companion ^{54}Cr abstract) requires that the ^{53}Cr isotopic effects related to ^{53}Mn decay to be reevaluated. During Cr isotopic measurement, after exponential mass fractionation correction using ^{50}Cr and ^{52}Cr residual random second order variations are present in the $^{54}\text{Cr}/^{52}\text{Cr}$ and $^{53}\text{Cr}/^{52}\text{Cr}$ ratios. Lugmair and Shukolyukov [4] used the correlation between the two fluctuations to correct $^{53}\text{Cr}/^{52}\text{Cr}$ ratios for this second order dispersion. They assumed that $^{54}\text{Cr}/^{52}\text{Cr}$ is equal to terrestrial when the measured ratios are close to the Cr laboratory standard. This way high precision at the 5 ppm level have been obtained, in particular for the ^{53}Mn - ^{53}Cr study of the HED meteorites. Nevertheless this assumes that the $^{54}\text{Cr}/^{52}\text{Cr}$ is exactly terrestrial. If small ^{54}Cr anomalies are present in the samples this procedure may introduce a bias in the $^{53}\text{Cr}/^{52}\text{Cr}$ ratios. With the evidence of a ^{54}Cr deficit of $0.72 \pm 0.02 \text{ ‰}$ in basaltic achondrites, it is necessary to reevaluate the ^{53}Cr isotopic effects as well. Our experimental procedure does not require a second order fractionation correction to obtain a few ppm level of precision in the measurement of the $^{53}\text{Cr}/^{52}\text{Cr}$ ratios.

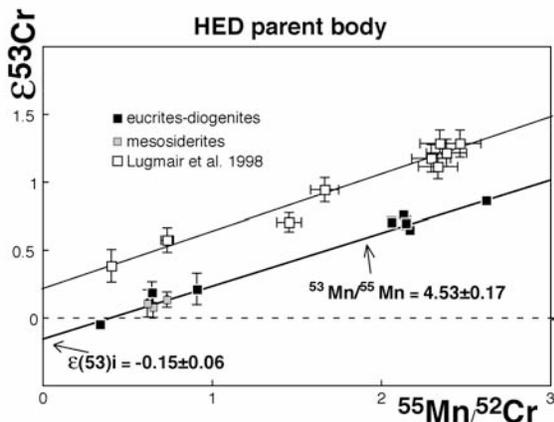


Fig. 1. ^{53}Mn - ^{53}Cr systematic of the basaltic achondrites. $\text{‰}^{53}\text{Cr}$ represents a $^{53}\text{Cr}/^{52}\text{Cr}$ ratio in ‰ -unit (fractional deviation in 10^{-4} relative to the laboratory standards). All uncertainties are 2‰ .

Results: Fig. 1 displays the ^{53}Cr isotopic results in an isochron diagram together with the former results of Lugmair and Shukolyukov [4]. ^{53}Cr variations in eucrites, diogenites and mesosiderites are correlated with their chemical Mn/Cr ratio and define an isochron. As expected from a correction with constant ^{54}Cr offset the slope of the two data sets are identical within error. $^{53}\text{Mn}/^{55}\text{Mn} = (4.5 \pm 0.17) \times 10^{-6}$ at the time of the last Cr isotopic reequilibration during melting. At the reverse, the $^{53}\text{Cr}/^{52}\text{Cr}$ initial ratio that defines the Cr isotopic composition of the reservoir at the time of differentiation, changes significantly to a value lower by 0.4 ‰ .

Discussion: Fig. 2 displays the ^{53}Cr isotopic evolution diagram versus time. In this diagram the coordinates of each point are the slope and initial ratios obtained from isochron diagrams like Fig. 1. At the opposite of Lugmair and Shukolyukov our discussion assumes that with the exception of Allende's inclusions the solar system is homogeneous with regard to $^{53}\text{Mn}/^{55}\text{Mn}$ [3]. This allows the $^{53}\text{Mn}/^{55}\text{Mn}$ axis to be seen as a time scale. This assumption relies on the observation that large up to 250 ‰ mineral scale ^{54}Cr variation found in carbonaceous chondrites do not correlate with ^{53}Cr variations. The ^{53}Cr variations found in C1 chondrites are about two orders of magnitude smaller and correlate with Mn/Cr, which in our opinion indicates solely a ^{53}Mn decay effect and an absence of evidence for other nucleosynthetic effects on ^{53}Cr .

In Fig.2 the evolution of closed reservoirs versus Mn-Cr exchanges plot as straight lines and the slope of $^{53}\text{Cr}/^{52}\text{Cr}$ evolution is proportional to the Mn/Cr elemental ratio. In the model developed earlier (Model1) [3] the average solar system composition was equivalent to the CI chondrite and has a Mn/Cr ratio of 0.72. This leads to a present day composition of $\text{‰}_{53} = 0.45 \text{‰}$. The updated value of the HED parent body plots well below this evolution line. This implies that the materials constituting this body have evolved a significant time with a lower than solar Mn/Cr after extraction from the solar nebula. As Mn is more volatile than Cr in nebular processes, the volatile depleted nature of the basaltic achondrite source is confirmed in agreement with trace element data as for the Earth and Moon.

Updated data of chondrites from various classes are also displayed in Fig.2. A general trend is noticeable and most samples plot on the best fit line

within error including Allende's refractory Inclusions. It is tempting to consider this line as the evolution of the bulk solar system (Model 2). A Mn/Cr of 0.53 is deduced from the slope.

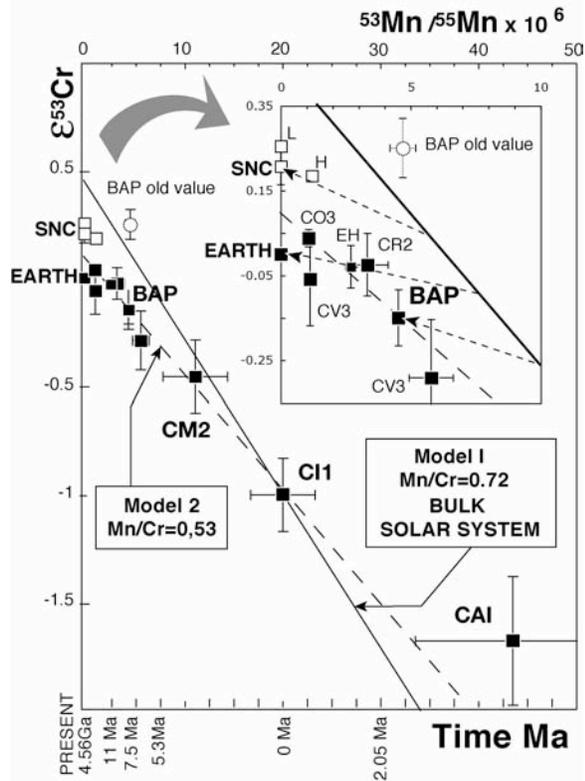


Fig. 2. ^{53}Cr isotopic evolution versus the $^{53}\text{Mn}/^{55}\text{Mn}$ which is equivalent to a time scale as far as the Mn isotopic ratio is homogeneous in the solar system. BAP stands for basaltic achondrite parent body. BAP old value, EH, H, L [4]; CI, CM2 [3]; CAI [1].

Such a model does not match some other observations. The Mn/Cr measured in C1 [6] is significantly higher than the model 2 solar ratio implying that C1 are enriched in Mn relative to the average parent material. This is in disagreement with photospheric observation. On the other hand there is no evidence for extra enrichment of other volatile elements in CIs relative to the Sun. When assumed the model 2 evolution for the solar nebula, it follows that most planetary bodies separate from the solar nebula without large chemical Mn-Cr fractionation or without spending significant time in a secondary reservoir. This is also difficult to reconcile with interelemental chemical fractionation related to volatility, which is observed for other couples like e.g. Rb/Sr or U/Pb, and (or) with the requirement for some duration to build up large bodies like the Earth or Mars. Our preferred interpretation is model 1 [3]. The bulk solar system evolves with a composition

close to CI chondrites from which the materials constituting the planetary bodies are extracted. The Mn/Cr fractionation at formation time can be deduced from their composition and Cr isotopic systematic [3]. In this model the values of C1 chondrites have a critical importance.

With regard to the lower $^{53}\text{Cr}/^{52}\text{Cr}$ for HED meteorites as previously thought, the possibility of a past gradient in $^{53}\text{Mn}/^{55}\text{Mn}$ with heliocentric distance exists no more as an alternative to a sole control of the $^{53}\text{Cr}/^{52}\text{Cr}$ by the Mn/Cr ratio directly connected to the volatility of the two elements. This in agreement with the dynamical calculations of the chemical mixing in the inner solar system. [7] But with respect to dynamical mixing we have a new problem with $^{54}\text{Cr}/^{52}\text{Cr}$, which is now appearing more heterogeneous than previously thought. [5]

Time scales are not significantly changing with the new data sets for basaltic achondrites which are formed in a short time scale of about 9-11 Myr after inclusions in agreement with Sr isotopic data [8] and Hf-W systematics of chondrites [9].

Conclusion:

HED meteorites formed less than 11 Myr after the first condensates. Its history can be connected to that of other meteorite group using ^{53}Mn - ^{53}Cr systematic. The Cr isotopic evolution is controlled by the relative volatility of the two elements Mn and Cr in nebular processes.

References: [1] Birck J.L. and Allègre C.J. (1985) *Geophys. Res. Lett.* 12, 745-748. [2] Birck J.L. and Allègre C.J. (1988) *Nature* 331, 579-584. [3] Birck J.L. et al. (1999) *GCA* 63, 4111-4117. [4] Lugmair, G.W. and Shukolyukov A. (1998) *GCA* 62, 2863-2886. [5] Trinquier A. et al. (2003) *Geophys. Res.* Abstract #05916 [6] Anders E. and Grevesse N. (1989) *GCA* 53, 197-214. [7] Chambers J.E. and Wetherill G.W. (1998) *Icarus* 136, 304-327 *LPS XXXIV*, Abstract #1279. [8] Papanastassiou D A and Wasserburg G.J. (1969) *EPSL* 5, 361-376. [9] Quitté G. and Birck J.L. (2004) *EPSL* 219, 201-207.