MN-CR ISOTOPE SYSTEMATICS IN THE LL TYPE ORDINARY CHONDRITE ST. SÉVERIN.
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Introduction: The Mn-Cr analyses of several H chondrites including Forest Vale, Dimmitt, Ste Marguerite and Richardton [1-3], have all shown reasonable agreement between the obtained 'Mn-Cr ages' and the known Pb-Pb ages determined on phosphates. These studies imply that the best fit lines in the ^{53}Mn-^{53}Cr evolution plots for these meteorites are isochrons rather than mixing lines and that the slope of the lines correspond to the Mn-Cr closure times for these ordinary chondrites. Furthermore, the fact that a correlation exists between the degree of metamorphism and the Mn-Cr closing times for H chondrites (H chondrites with lower petrographic grade have older Mn-Cr ages) is only explainable if the Mn-Cr ages date metamorphic events on the H chondrite parent body.

In order to extend this work to include LL type ordinary chondrites we investigated the Mn-Cr isotope systematics of St. Séverin (SS). There are two essential conditions we have considered for selecting meteorites for Mn-Cr analysis: (i) a reliable and accurate U-Pb age must be available for the meteorite and (ii) the U-Pb age must be > 4550 Ma, because Mn-Cr is a relative chronometer and for closure times younger than 4550 Ma, the Mn-Cr age cannot be determined since the short lived ^{53}Mn (half-life ~ 3.7 Ma) would have completely decayed. Göpel and co-workers have determined accurate Pb-Pb ages for six different L type chondrites and three LL chondrites [4]. However, only one of these chondrites (St. Séverin, LL6) fulfills condition (ii).

Experimental Procedures: We have determined the Mn and Cr concentrations and the Cr isotopic abundances in three fractions of St. Séverin: bulk rock, silicates (Sil), and chromite-spinel (Chr). A 420 mg fragment of the bulk meteorite was crushed using a clean mortar and pestle. The grains were then thoroughly washed in acetone under ultrasonication. After washing, the dried bulk sample was re-weighed and dissolved in an HF/HNO_3 mixture under ultrasonication followed by concentrated HNO_3 and 4.5N HCl. Because chromite-spinels are highly resistant to dissolution in acids, these grains (< 1 mg) were separated and subsequently dissolved in an HF/HNO_3 mixture at elevated temperature (~185ºC) using a Teflon pressure bomb. The bulk rock solution was obtained by combining equal aliquots of the silicate and chromite-spinel solutions. The concentrations of Mn and Cr in each of these fractions were analyzed by ICP-OES. The separation and purification of Cr from other elements was achieved using a procedure similar to that of Birck and Allègre [5].

The isotopic analyses of Cr were made using a Micromass Sector 54 thermal ionization mass spectrometer in single-collector mode. Chromium samples (~700 ng) were loaded in a silica gel/boric acid mixture on pre-baked W filaments as previously described [2]. All chromium isotopes were normalized to ^{52}Cr and corrected for mass fractionation using the ^{50}Cr/^{52}Cr ratio as an internal standard. A second order fractionation correction using the ^{54}Cr/^{52}Cr ratio was applied as discussed in [2]. For each sample between 15-20 measurements of the chromium isotopic composition were performed and the results were averaged.

Results and Discussion: Table 1 shows the Mn and Cr abundances, Mn/Cr ratios, and ^{53}Cr excesses determined for the various fractions of SS. A plot of the data shown in Fig. 1 indicates that the ^{53}Cr excesses are correlated with the respective ^{55}Mn/^{52}Cr ratios and the data points for Chr, Bulk, and Sil form a straight line. If this line is interpreted as an isochron, its slope yields a ^{53}Mn/^{55}Mn ratio of $(6.87 \pm 1.0) \times 10^{-7}$ at the time of isotopic closure. Given that the ^{53}Mn/^{55}Mn ratio of the angrite LEW86010 (LEW) at the time of isotopic closure was measured to be $(1.25 \pm 0.07) \times 10^{-6}$ [6], the ^{53}Mn/^{55}Mn ratio for SS translates into an age relative to LEW of -3.2 ± 0.9 Ma. Since the Pb-Pb age of LEW has been precisely measured to be 4557.8 ± 0.5 Ma [6], we calculate an absolute 'Mn-Cr age' for SS of 4554.6 ± 1.4 Ma. Within experimental uncertainties, this Mn-Cr age is in agreement with the Pb-Pb age of 4553.6 ± 0.7 Ma previously reported for SS phosphates [4], where the primordial Pb isotopic composition from Tatsumoto et al. [7] was used to calculate the Pb-Pb age.

It is interesting to note that the I-Xe age of 4558 ± 4 Ma determined on SS feldspars [8] is about 3.4 Ma older than the Mn-Cr age, suggesting a small bias between the two chronometers. A systematic difference between the Mn-Cr and I-Xe ages for several H chondrites has also been found [9]. One possible explanation for this bias is that different meteorites were used to calibrate the systems: for Mn-Cr, the Pb-Pb age of the angrite LEW86010 was used to anchor the system, whereas for I-Xe, the Pb-Pb age of the primitive achondrite Acapulco was used [8]. However, if the I-Xe ages are also calibrated to LEW by anchoring the I-

Xe ages to the Mn-Cr age of Acapulco at 4555.1 Ma, this results in a younger I-Xe age for SS of 4556 ± 4 Ma. This revised I-Xe age is in much closer agreement with Mn-Cr and Pb-Pb ages for SS.

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Table 1. Mn and Cr concentrations, Mn/Cr ratios, and ^{53}Cr excesses in St. Séverin.

Sample	Mn (ppm)	Cr (ppm)	^{55}Mn/^{52}Cr (± 5%)	ε(53)*
Bulk	2803	3906	0.81	0.46 ± 0.04
Chr†	nd	nd	0.007	0.40 ± 0.04
Sil	2783	512	6.08	0.76 ± 0.05

† Mass of the chromite grains not determined.
* Uncertainties ($2\sigma_{mean}$) based on the standard deviation of the average value of 15-20 measurements. For ε see caption to Fig. 1.

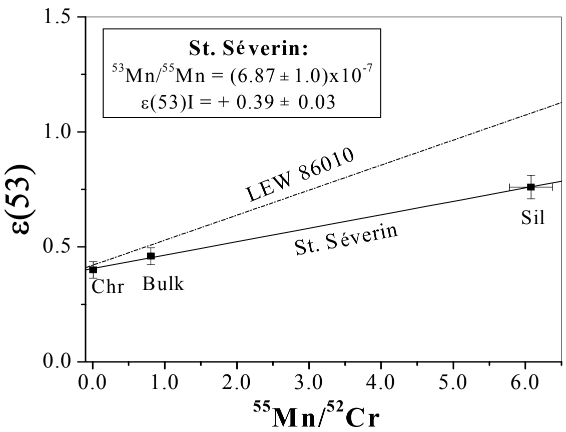

Fig. 1. ^{53}Mn-^{53}Cr systematics in the LL6 chondrite St. Séverin (SS). The ^{53}Cr/^{52}Cr ratios are expressed as the deviations from the average standard value in ε-units ($\varepsilon \equiv [(^{53}Cr/^{52}Cr)_{sample}/(^{53}Cr/^{52}Cr)_{standard} - 1] \times 10^4$) where $(^{53}Cr/^{52}Cr)_{standard} = 0.1134507$. The slope of the best fit line for the bulk rock (Bulk), silicate (Sil) and chromite (Chr) fractions of SS yields ^{53}Mn/^{55}Mn = (6.87 ± 1.0) x 10^{-7} and an initial ε(53)I = 0.39 ± 0.03. The isochron for the angrite LEW 86010 (LEW) taken from ref [6] is shown for comparison (dashed line). The calculated age of SS relative to LEW is – 3.2 ± 0.9 Ma and the absolute age is then 4554.6 ± 1.4 Ma. A spallation correction for cosmic ray produced ^{53}Cr was not necessary given the relatively short exposure age for SS [10].