Mössbauer spectroscopy of the Colony meteorite

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Summary. — The CO3 carbonaceous chondrite Colony, a 1975 find, was examined by ^{57}Fe Mössbauer spectroscopy. In agreement with the literature this well-weathered meteorite showed a prominent quadrupole doublet consistent with paramagnetic Fe^{3+} phases as well as a doublet for olivine and at least one ferromagnetic sextet. The ratio of Fe^{3+} to total Fe is consistent with a terrestrial age of 4×10^4 years.

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Colony, a 1975 find in Washita County, Oklahoma, is of particular interest as one of the least metamorphosed members of the CO3 carbonaceous chondrite group [1]. It is extremely weathered, but to our knowledge no estimate of its terrestrial age has been made. ^{57}Fe Mössbauer spectroscopy can provide an approximate ratio of Fe^{3+}/Fe^{2+} ions, a value that often correlates well with terrestrial age determined by isotope ratio methods [2-4]. This study aimed to corroborate some of the chemical analysis results [1] and also estimate the terrestrial age for this meteorite.

A 10.3 g sample of Colony was obtained from the dealer David New, Anacortes, WA 98221. Random samples were ground to powder in an agate mortar, and 200 mg portions were mixed with epoxy resin and formed in a mold into a wafer. Spectra were taken at room temperature for 100 mg/cm^2 of sample with a ^{57}Co source in a Rh matrix with transmission geometry at constant acceleration between $\pm$ 8 mm/s. Spectra were fitted by a Levenberg-Marquardt least-squares routine to Lorentzian peaks and calibrated for velocity with a metallic iron foil. The fitting program was constrained for equal linewidth and area under the peak for each quadrupole-split pair and for equal outer line spacings for magnetic sextets.

A sample of ground Colony was separated with a hand magnet into magnetic and non-magnetic fractions. Figure 1 compares the ^{57}Fe Mössbauer spectrum for the unfractionated sample of Colony with the magnetic and non-magnetic parts. Figure 1c presents the magnetic fraction fitted by computer to two quadrupole doublets and one sextet. As might be expected from the weathered nature of the meteorite, the most prominent feature is a doublet in the isomer shift and quadrupole splitting range for

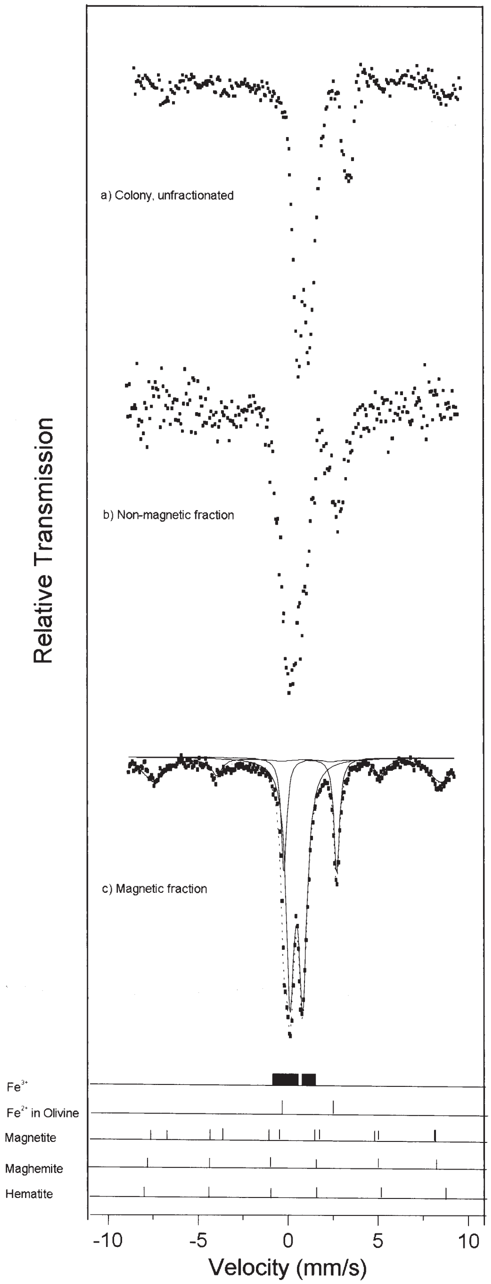

Fig. 1. – Mössbauer spectrum for Colony. References for standard peak positions are as in table I. a) Unfractionated sample; b) non-magnetic fraction; c) magnetic fraction fitted by computer to a sextet and two doublets.

Fe^{3+} ion in silicate or oxide minerals [5]. Its linewidth, greater than the 0.35 mm/s usual for Fe^{3+} paramagnetic phases in meteorites [5], suggests a mixture of such

TABLE I. – *Phases apparent in the* ^{57}Fe-*Mössbauer spectrum of the Colony meteorite and values for known minerals (italics).*

Phase	Formula	IS (mm/s)	QS (mm/s)	LW (mm/s)	H_{int} (Koe)	% Area
Fe^{3+} doublet		0.39	0.70	0.54		63
Fe^{3+} in silicates and oxides [5]		*0.1–0.5*	*0.2–2.0*			
Fe^{2+} doublet		1.14	2.92	0.73		21
Olivine [5]	$[Mg, Fe]_2SiO_4$	*1.16*	*2.81*			
Sextet		0.59		1.59	500	25
Magnetite [6]	Fe_3O_4	*0.26*	*– 0.02*		*490*	
		0.67	*0.00*		*460*	
Maghemite [6]	γ-Fe_2O_3	*0.32*	*0.02*		*499*	
Hematite [6]	α-Fe_2O_3	*0.37*	*– 0.20*		*517*	
Kamacite	$Fe_{1-x}Ni_x$	*0.00*			*330*	

components. Another doublet partially overlaps the deeper one and is consistent with the spectrum of Fe^{2+} in the silicate mineral olivine [5]. Finally, a sextet of broad line width overlying the two doublets appears enriched in the magnetic fraction. Table I gives the parameters calculated for the fitted curves with literature values for comparison.

The sextet is in the range for the magnetic iron oxides magnetite, maghemite and hematite (table I). The large linewidth suggests that more than one oxide phase is present, and some metallic Fe contribution as kamacite is also likely, judging from published mineralogical and chemical analysis [1]. The same authors [1] reported analyses of single olivine and low-Ca pyroxene grains showing an average of 13.5 wt.% FeO in olivine grains, but only 2.3 wt.% in pyroxene, another silicate mineral common in meteorites. The lack of a Mössbauer doublet for pyroxene is thus not surprising, although the large linewidth suggests some pyroxene contribution. The possibility of magnetite is puzzling, however; none was found by Rubin *et al.* "despite a search" [1]. They do not mention other iron oxides, but Colony is a breccia, and our sample could possibly differ from theirs.

The area under the peak gives an estimate of the relative concentration of the phase (assuming equal recoil-free fractions), so the amount of Fe^{3+} material in Colony and its terrestrial age may be estimated. Bland and co-workers [7] have plotted percent oxidation as determined this way against ^{14}C terrestrial age for a number of meteorites found in arid terrain. The 63% Fe^{3+} shown by Colony (table I) would correspond to about 4×10^4 years on earth, assuming desert-like conditions. Since Oklahoma, where Colony was found, is not quite so dry, this figure would be an estimate of the upper limit for terrestrial age.

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