TERRESTRIAL AGE DETERMINATION OF AN ACHONDRITE FROM RIO CUARTO, ARGENTINA.

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Introduction: We have used accelerator mass spectrometry of ^{26}Al, ^{36}Cl, and ^{41}Ca to determine the terrestrial age of an achondrite meteorite found near Río Cuarto, Argentina. The achondrite, tentatively designated Río Cuarto 001, was collected by [1] from an oblong depression approximately 4 km long and 0.6 km wide, at 32°52.3' S, 64°13.4' W. A formal description of this achondrite, which appears to be a brecciated eucrite, has been submitted. Bland et al. [1] placed a lower limit of 52 ka on the terrestrial age of this meteorite from their failure to detect live cosmogenic ^{14}C. The survival of a meteorite for such a long time is remarkable in a place like Río Cuarto, whose average annual precipitation is 815 mm [2], much greater than at other localities known for yielding long-lived meteorite finds. Our investigation of three relatively slowly decaying cosmogenic nuclides from this specimen allows us to explore the range of possible preatmospheric sizes of the meteoroid, depths within that body of the recovered sample, and its residence time on Earth. Stronger constraints on the terrestrial age of this meteorite are important for assessing the value of the Río Cuarto area for the preservation of ancient meteorites.

The Río Cuarto area in particular, and the Argentine Pampas region in general, have retained evidence of multiple meteorite impacts in the last ~500 ka, including suites of impact glasses of different ages and several meteorites [3,4,5,1]. Terrestrial ages of the meteorites are necessary to evaluate possible associations among them, between any of the meteorites and the other impactites, or with the curious depressions in which they have been found [4].

Sample Preparation: A ~4 g chip of the achondrite was provided by P. Bland, and approximately half the sample was ground into a fine powder. Al, Cl, and Ca separates from two aliquots, each representing 500 mg of powdered meteorite, were isolated at the TANDAR Laboratory in Buenos Aires, following the technique of [6] with slight modifications. The meteorite powder, along with Cl carrier, was disaggregated in a 3:1 mixture of 40% HF and 70% HNO_3 using a high-pressure digestion bomb. After separating the insoluble fluorides and nitrides from the supernatant solution, Cl, in the form of AgCl, was precipitated from the solution by the addition of 0.1 M $AgNO_3$. Once the Cl had been removed, the remaining liquid was recombined with the initial insolubles and boiled away, leaving the residues to be attacked by boiling with HNO_3 and HCl, and finally with HCl alone. The residues were picked up in 10 N HCl and passed through a 15 mL column of Dowex 1X8 anion exchange resin. Al and Ca were both eluted in the first 20 mL of 10 N HCl, and then separated from one another by successive precipitations. Al, in the form of $Al(OH)_3$ was precipitated upon neutralization of the acid solution with NH_3 and then removed; Ca was precipitated when the solution was re-acidified, seeded with 2% $NH_4C_2O_4$, and re-neutralized. The $Al(OH)_3$ was oxidized to Al_2O_3 in a 900 °C furnace, and the CaC_2O_4 was redissoved in HCl and then precipitated as CaF_2 upon the addition of 40% HF. The purified, washed, and dried AgCl, Al_2O_3, and CaF_2 were loaded into cathodes for accelerator mass spectrometry.

Accelerator Mass Spectrometry: Here we present preliminary analysis and interpretation of data acquired by accelerator mass spectrometry.

Aluminum-26. ^{26}Al/^{27}Al ratios were measured at the VERA Laboratory in Vienna. Any Mg which remained in the sample was strongly suppressed by the extraction of Al^- ions from the cathode, as the isobarically interfering Mg^- ion is unstable. We infer a ^{26}Al/^{27}Al ratio for the meteorite of $(2.65 \pm 0.04) \times 10^{-11}$, corresponding to a ^{26}Al activity of 75.5 ± 1.1 dpm/kg. Blanks, including terrestrial rocks which underwent the same chemical preparation as the meteorite, had ^{26}Al/^{27}Al ratios $< 3 \times 10^{-15}$.

Chlorine-36. The concentration of ^{36}Cl in the achondrite was measured using the tandem accelerator at the Technical University of Munich. Isobaric suppression of ^{36}S was achieved using the GAMS gas-filled magnet [7]. Chlorine is the only element we examined for which we needed to use a carrier during the chemical preparation, and our analysis is unfortunately complicated by the possibility, still under investigation, that our Cl carrier contained ^{36}Cl. Our data appear to favor a ^{36}Cl activity of 5.4 ± 0.4 dpm/kg of meteorite. Any contamination of ^{36}Cl, whether from the laboratory or the environment, would render this value an upper limit on the ^{36}Cl activity in the meteorite. The principal sources of ^{36}Cl in the meteorite are assumed to be spallation of Fe and Ca; we have neglected any production of ^{36}Cl by neutron capture reactions.

Calcium-41. The concentrations of ^{41}Ca was measured in the VERA Laboratory. Any ^{41}K that survived the chemical purification of the Ca sample was distinguished from ^{41}Ca at the detector, a high energy resolution ionization chamber with foil covering the entry window, in which differential energy losses of ^{41}K and ^{41}Ca were measured. Concentrations of ^{41}Ca/^{40}Ca as low a few parts in 10^{14} can be identified with this apparatus. However, measurements of geological blanks, prepared using the same chemical process as the meteorite samples, necessitated a relatively large and uncertain background correction to be made to the meteorite data. We find a ^{41}Ca/^{40}Ca ratio in the meteorite of $(3.4 \pm 1.5) \times 10^{-13}$, corresponding to an activity of 4±2 dpm/kg.

Results and Discussion: The production of cosmogenic ^{26}Al and ^{36}Cl in stony meteorites was modeled by [8]. Production of ^{41}Ca in HED meteorites, by both neutron capture and spallation reactions, has been considered by [9]. All of these production rates vary with the size of the preatmospheric meteoroid, the depth within that body at which the surviving fragment was situated, and the chemical composition. The abundances of major elements in the meteorite were measured by energy dispersive x-ray spectrometry at the University of Chicago (Table 1). For different depths within pre-atmospheric meteoroids of radii 5-100 cm, we computed the saturation concentrations of ^{26}Al, ^{36}Cl and ^{41}Ca predicted by [8,9] for a meteorite with the composition of Río Cuarto 01, and we modeled the decay of each isotope as a function of the terrestrial age of the meteorite. We find agreement between our measurements and the models of [8,9] only for a preatmospheric radius of 40-50 cm and a terrestrial age of 435-495 ka (confidence intervals approximately 1σ). We have assumed that the meteoroid was exposed in space for long enough to become saturated with the three measured cosmogenic species.

The terrestrial age is very sensitive to the measurement of ^{36}Cl, because the saturation concentrations developed by [8] for stony meteoroids of all sizes (up to 120 cm in radius) are in the range 8-17 dpm/kg. Thus our measurement of only 5.3 ± 0.4 dpm/kg requires the meteorite to have been shielded from cosmogenic sources for a time comparable to the half-life of ^{36}Cl (301 ka). The presence of any detectable ^{41}Ca (half life 103 ka) in a meteorite this old implies that the specimen came from relatively deep within the preatmospheric meteoroid, where a relatively high flux of thermalized neutrons efficiently creates ^{41}Ca by neutron capture.

If our measurements are correct, they raise questions about the special conditions of preservation which must have characterized the environmental of the Río Cuarto area through the last ~500 ka, and they suggest that the region might retain other meteorites that fell to Earth over this period.

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Element	mg/g
Na	5.8
Mg	51.5
Al	68.2
Si	235.2
S	1.9
K	0.5
Ca	66.2
Ti	3.1
Cr	2.7
Mn	4.1
Fe	126.4

Table 1: Major-element composition of Río Cuarto 01, determined by energy-dispersive x-ray spectrometry.