WHAT IS THE ORIGIN OF ^{107}Ag AND ^{109}Ag IN NICKEL-RICH ATAXITES?

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The existence of Ag with an anomalous isotopic composition was discovered by Kelly and Wasserburg [1]. Later studies by Kaiser, Kelly and Wasserburg [2,3] confirmed the existence of ^{107}Ag excess (*) and showed that the ratios of $^{107}Ag/^{109}Ag$ were much higher than first reported due to contamination with terrestrial Ag. This $^{107}Ag^*$ is most plausibly the result of decay of extinct $^{107}Pd(\tau_{1/2} = 6.5$ m.y.) in the early solar system. The present study was undertaken to further clarify the origin of isotopically peculiar Ag. Ag and Pd have been measured in six ataxites (see Table 1) which are all found to contain anomalous Ag. The isotopic shifts are large. The meteorites are strongly depleted in Ag and show very small Ag/Pd (Table 2). In the present work our concern has been with more quantitative measurements of both $^{107}Ag/^{109}Ag$ and $^{108}Pd/^{109}Ag$ to test the validity of a possible isochron. This problem is rather formidable due to the low concentration of Ag. We have followed the procedures in [2] but used sufficiently large samples so that equal aliquots of the same sample solution could be used for composition and concentration runs. This will tend to eliminate scatter in $^{108}Pd/^{109}Ag$ and $^{107}Ag/^{109}Ag$ due to blanks and chemical yield and give superior analyses. To test the variability of $^{107}Ag/^{109}Ag$ found earlier in Piñon (compare #2B and D in Table 1), a piece adjacent to D (labelled D*) was analyzed. Data on D* show it to have a higher ratio of $^{107}Ag/^{109}Ag$ and a lower ^{109}Ag content than D. The analyses D* and 147.A.1 are on equal aliquots and may be considered superior. They show a $^{107}Ag/^{109}Ag$ ratio increasing with $^{108}Pd/^{109}Ag$ (Fig. 1). A line through the two superior Piñon data points passes close to the origin which requires a component of nearly pure ^{109}Ag. If the Ag in Piñon were a mixture of $^{107}Ag^*$ and normal Ag, the line should cross the ordinate at $^{107}Ag/^{109}Ag = 1.09$. Two superior analyses of Hoba are also presented. These also show a spread in $^{107}Ag/^{109}Ag$ and in $^{108}Pd/^{109}Ag$. A line through the data points H1, H2 passes close to normal $^{107}Ag/^{109}Ag$, which is compatible with an internal isochron (with normal Ag being one component) and with $^{107}Ag^*/^{108}Pd = 1.8\text{x}10^{-5}$. In general, it is not possible to prove that normal silver is not added to samples as a result of normal terrestrial contamination, although no evidence of this has been found in blank experiments which were run between every meteoritic sample and which did not reveal any variability of the blank larger than $\pm 6\text{x}10^{9}$ atoms ^{109}Ag which is included in the errors. In addition, it is possible that pure ^{109}Ag may be added as a result of laboratory contamination from tracer. However, after almost every spiked meteoritic sample, a Ag normal of comparable size was passed through the total separatory procedure and showed no evidence for enrichment in ^{109}Ag due to residual tracer. While it is reasonable to expect the initial $^{107}Ag/^{109}Ag$ in these meteorites to be greater than 1.09 due to the decay of ^{107}Pd in the parent body, it is not plausible that the initial solar silver should have been predominantly ^{109}Ag. With exception of the two data points on Piñon all of the data could be explained by normal Ag and ^{107}Ag from in situ decay of ^{107}Pd in the parent bodies if they were formed over a time interval of $\sim$ 30 m.y. Table 2 shows $^{107}Ag^*/$ $/^{108}Pd$ for these samples as well as $^{4}He/^{56}Fe$ from Villa, Huneke, and Wasserburg [4]. $^{4}He/^{56}Fe$ is a measure of the galactic cosmic ray (GCR) irradiation history and varies by a factor of $\sim$ 40. However, as shown in [4], there is no correlation of $^{107}Ag^*$ or ^{107}Ag with exposure to GCR particles as monitored by He, Ne and Ar. In addition, $^{109}Ag/^{108}Pd$ only varies by a factor of 3.2. While $^{107}Ag^*/^{108}Pd$ and $^{109}Ag/^{108}Pd$ show a limited variability, $^{107}Ag/^{108}Pd$ is almost constant. This suggests that all these meteorites may have a characteristic

ORIGIN OF ^{107}Ag AND ^{109}Ag

Kaiser, T. and Wasserburg, G. J.

$^{107}Ag/^{108}Pd$ ratio ($\sim 2.6\times10^{-5}$) which is independent of the ^{109}Ag content. Together with the results of Piñon, which indicate a varying component rich in ^{109}Ag, this suggests the presence of pure ^{107}Ag (from ^{107}Pd decay) and ^{109}Ag from another source.

A possible mechanism for production of essentially pure ^{109}Ag would be capture of slow neutrons by Pd. These neutrons could have been produced by GCR over the past 4.5 AE if the FeNi meteorites investigated spent $\sim$ 1 AE at a depth of a few meters below the surface of a rocky parent asteroidal body before the present meteorites were set free by sequential break-up. Material at a depth of 1-5 meters would possibly yield enough low energy neutrons to produce the ^{109}Ag effects without the hard primary component yielding abundant spallation products. With a resonance integral I = 250b for $^{108}Pd(n,\gamma)^{109}Pd$ (Mughabghab and Garber [5]) an epithermal neutron fluence of 10^{16}-10^{17} n/cm^2 would be required. After break-up of the asteroidal parent-body, all the meteorites would then have received their observed doses of hard GCR. Another means of producing Ag rich in ^{109}Ag may be an early irradiation of meter-sized planetesimals strongly depleted in volatile elements (shades of FGH) [6]. The required fluences of secondary neutrons to produce ^{109}Ag are comparable to those discussed above. A later melting stage of the aggregated planetesimals would be required to outgas any spallation He, Ne, Ar. A more intense irradiation (x10^2) and chemical fractionation would be necessary to produce both ^{107}Pd and ^{109}Ag in a solar system irradiation model. Isotopic effects on near-surface materials of other planetary bodies must be further evaluated.

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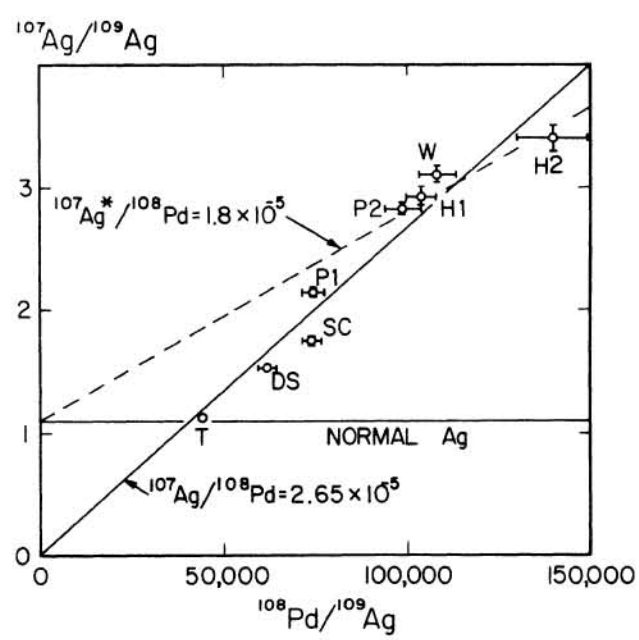

Fig.1: Ag-Pd evolution for different iron meteorites. Sample names are: DS: Deep Springs; H1: Hoba #60B; H2: Hoba #4213; P1: Piñon #D*; P2: Piñon #147.A.1; SC: Santa Clara #1060.1; T: Tlacotepec; W: Warburton Range. Distance P1-P2 and H1-H2: unknown. Sources of the samples: Courtesy Dr. C. Moore, The Arizona State University, Tempe, and Hoba #4213: Dr. Prinz, The American Museum of Natural History, New York.

ORIGIN OF ^{107}Ag AND ^{109}Ag

Kaiser, T. and Wasserburg, G.J.

Table 1. Ag Isotopic Ratio and Concentrations (C) before (I) and (II) after Correction for Blank for Different Nickel Rich Ataxites. (Errors 2σ)

Sample[a]	class	FeNi [g]	$^{107}Ag/^{109}Ag$[b] I[c]	$^{107}Ag/^{109}Ag$[b] II[d]	C[10^{11} atoms/g metal] ^{109}Ag I	^{109}Ag II[d]	$^{107}Ag^*$ calc.	Ref.
PIÑON	anom.							
(#2B)		2.44	2.10±0.04	2.46±0.19	2.8	2.1±0.2	2.9	2
(#D)		1.77	1.64±0.03	1.75±0.06	4.7	3.8±0.2	2.5	2
#D*[e]		2.64	2.03±0.02	2.14±0.02	2.8	2.5±0.06	2.6	this work
#147.A.1		5.32	2.65±0.03	2.83±0.04	2.1	1.9±0.05	3.3	2
SANTA CLARA	IVB							
(#9)		3.38	1.66±0.02	1.73±0.06	2.8	2.3±0.3	1.5	2
#1060.1		5.54	1.68±0.01	1.76±0.02	2.1	1.9±0.1	1.3	2
HOBA	IVB							
#60B		2.94	2.64±0.04	2.92±0.09	1.2	1.0±0.05	1.8	3
#4213		6.28	2.94±0.05	3.4±0.1	0.9	0.74±0.04	1.7	this work
TLACOTEPEC	IVB							
#113ax		2.70	1.11±0.01	1.11±0.01	2.3	2.2±0.08	0.05	3
WARBURTON RANGE	IVB							
#923		2.29	2.89±0.04	3.11±0.06	1.8	1.6±0.05	3.3	this work
DEEP SPRINGS	anom.							
#357.1		3.49	1.46±0.01	1.52±0.02	1.2	1.05±0.04	0.45	this work
NORMAL								
NBS 978		--	--	1.089±0.005		--	--	

a) Samples listed are central metal pieces, after removing a layer of ~ 1mm thickness from the surface (see in [2]). b) Detector: el. Multiplier. c) Errors include mass spectrometric analysis. d) Errors as in c) plus scattering of total procedural blank. e) Sample D* is adjacent to sample D analyzed earlier (see text). () Parentheses indicate early experimental work with Ag concentrations done on small analyzed aliquots and large uncertainties.

Table 2. Comparison of Ag/Pd Ratios for Different Samples. (Errors[a] 2σ)

Sample	$^{107}Ag/^{108}Pd$	$^{107}Ag^*/^{108}Pd$	$^{109}Ag/^{108}Pd$	^{4}He (Ref.4) [10^{-6} cc STP/g]
Piñon #D*	$2.9\pm0.1\times10^{-5}$	$1.4\pm0.1\times10^{-5}$	$1.34\pm0.05\times10^{-5}$	15
Piñon #147.A.1	$2.9\pm0.1\times10^{-5}$	$1.8\pm0.1\times10^{-5}$	$1.01\pm0.05\times10^{-5}$	--
Santa Clara #1060.1	$2.4\pm0.1\times10^{-5}$	$9.0\pm0.3\times10^{-6}$	$1.35\pm0.05\times10^{-5}$	16
Hoba #60B	$2.8\pm0.1\times10^{-5}$	$1.8\pm0.1\times10^{-5}$	$9.6\pm0.5\times10^{-6}$	1.3
Hoba #4213	$2.4\pm0.1\times10^{-5}$	$1.7\pm0.1\times10^{-5}$	$7.1\pm0.4\times10^{-6}$	--
Tlacotepec #113ax	$2.5\pm0.1\times10^{-5}$	$5\pm3\times10^{-7}$	$2.3\pm0.1\times10^{-5}$	21
Warburton Range #923	$2.9\pm0.1\times10^{-5}$	$1.9\pm0.1\times10^{-5}$	$9.2\pm0.5\times10^{-6}$	26
Deep Springs #357.1	$2.5\pm0.1\times10^{-5}$	$7.0\pm0.4\times10^{-6}$	$1.61\pm0.07\times10^{-5}$	51

a) The errors include contributions from Pd concentration determination, Ag isotopic composition measurement, Ag concentration measurement and Ag procedural blank.

Ref: [1] Geophys. Res. Lett. 5(1978)1079; [2] ibid. 7(1980)271; [3] Meteoritics 15(1980) in press; [4] submitted to Earth Planet. Sci. Lett.; [5] Report BNL 325, 3rd ed., V.1(1973); [6] Geoph.J. 6(1962)148. Div. Contr. #3552(378).