RAPID COOLING OF THE IIIAB IRON METEORITE PARENT BODY INFERRED FROM Pd-Ag CHRONOMETRY. M. Matthes, M. Fischer-Gödde, T.S. Kruijver, I. Leya, T. Kleine, Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (max.matthes@uni-muenster.de), Physical Institute, Space Science and Planetology, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland.

Introduction: The short-lived $^{107}\text{Pd}^{107}\text{Ag}$ system ($t_{1/2} \sim 6.5$ Ma) is well-suited to investigate the accretion and cooling history of iron meteorite parent bodies [1-5]. Palladium is siderophile and has a relative high condensation temperature, $T_C$, of $\sim$1324 K. Silver, in contrast, is chalcophile and volatile with $T_C \sim 996$ K. Major processes fractionating Pd and Ag, therefore, are volatilization/condensation and metal-sulphide separation. For instance, most magmatic iron meteorites are depleted in volatile elements and, hence, are characterized by high Pd/Ag ratios and highly radiogenic Ag isotopic compositions. Moreover, many iron meteorites contain troilites, which are characterized by Pd/Ag~0. The strong Pd/Ag fractionations in iron meteorites make it possible to obtain high-precision Pd-Ag ages, but so far internal isochrons have been obtained for only very few magmatic iron meteorites, including Cape York and Grant (IIIAB) [1,4,5], as well as Gibeon and Muonionalusta (IVA) [2,3].

The interpretation of the Pd-Ag system in iron meteorites is complicated by cosmic ray-induced neutron capture (NC) reactions on Ag isotopes [6]. Dating iron meteorites with the Pd-Ag system, therefore, requires the quantification of these effects. However, the importance of NC-effects on Ag isotopes has only recently been recognized [6], and so none of the previous Pd-Ag studies had considered them.

We present a method for correcting NC-effects on $^{107}\text{Ag}/^{109}\text{Ag}$ using Pt isotopes (Fig. 1), which were recently shown to constitute a powerful neutron dosimeter for iron meteorites [7,8]. To test this model and to assess the magnitude and significance of the NC corrections, we obtained combined Pd-Ag and Pt isotope data for several samples of the IIIAB irons Cape York, Grant and Henbury. After successful NC corrections, these data are used to constrain the time scale of crystallization and cooling of the IIIAB core.

Analytical methods: All metal samples were cleaned with abrasives and leached in 6 M HCl prior to digestion in aqua regia. Aliquots were taken for the determination of Ag and Pd concentrations by isotope dilution, and for Pt isotope measurements. From the remaining sample solution, Ag was purified using ion exchange chromatography modified after [5,9]. Platinum was purified using anion exchange chromatography as in [7].

Isotope measurements were conducted on the ThermoScientific Neptune Plus MC-ICPMS at the University of Münster. Samples were introduced using an ESI Apex-Q (Ag) or a Cetac Aridus II (Pt) desolvating nebulizer. Measured Ag isotope ratios were corrected for instrumental mass fractionation using admixed Pd and were normalized to $^{108}\text{Pd}/^{106}\text{Pd} = 0.97237$ using the exponential law. The Ag isotope ratios are reported in $\epsilon^{107}\text{Ag}$ as the parts per 10$^6$ deviation from the $^{107}\text{Ag}/^{109}\text{Ag}$ obtained for the terrestrial standard (NIST SRM 978a). The external reproducibility of the $^{107}\text{Ag}/^{109}\text{Ag}$ measurements was $\pm 0.5 \epsilon^{107}\text{Ag}$ (2 s.d.). The Pt isotope measurements were normalized internally to $^{198}\text{Pt}/^{195}\text{Pt} = 0.2145$ using the exponential law, and are reported in $\epsilon^{196}\text{Pt}$ units as the parts per 10$^4$ deviation from the terrestrial $^{196}\text{Pt}/^{195}\text{Pt}$. The reproducibility of the Pt isotope measurements was $\pm 0.07 \epsilon^{196}\text{Pt}$ (2 s.d.). For the isotope dilution measurements, an ESI SIS spray chamber was used, and instrumental mass fractionation was corrected relative to bracketing standard runs.

Figure 1. Expected shifts in $\epsilon^{107}\text{Ag}$ due to neutron-capture. Results for Cape York (green), Grant (blue), and Henbury (red) are shown for comparison.

Results: The results of our NC model calculations together with Pd-Ag and Pt isotope data are shown in Fig. 1. For each sample, the $\epsilon^{107}\text{Ag}$ values are broadly correlated with $^{108}\text{Pd}/^{106}\text{Ag}$ (Fig. 2). Most metal samples show high $^{108}\text{Pd}/^{106}\text{Ag}$ ratios and large $^{107}\text{Ag}$ excesses of up to 140 $\epsilon^{107}\text{Ag}$ (Fig. 1), in good agreement with results of previous studies. The troilite samples generally have much lower $^{108}\text{Pd}/^{106}\text{Ag}$ and $\epsilon^{107}\text{Ag}$ than...
the metals, but one Henbury metal has a lower $\varepsilon^{107}\text{Ag}$ than its sulphide. This suggests the presence of unsupported radiogenic Ag in the Henbury sulphide, as has also been observed for other iron meteorites [1,3].

All the investigated Grant and Henbury samples exhibit Pt isotope anomalies, indicating significant neutron capture effects in these samples. The two Cape York samples, in contrast, show no resolved effects (Fig. 1), consistent with the near absence of secondary neutrons in this sample [10]. Overall the Pt isotope results are in good agreement with those of our previous study [7].

**Discussion: Effects of neutron capture.** The dominant neutron capture reaction affecting Ag isotopes is $^{108}\text{Pd}(n,\gamma)^{109}\text{Pd}(\beta^-)^{109}\text{Ag}$. Neutron capture, therefore, lowers $\varepsilon^{107}\text{Ag}$ and the magnitude of this effect depends on both $^{108}\text{Pd}/^{109}\text{Ag}$ and neutron fluence. The latter can be quantified using $\varepsilon^{106}\text{Pt}$. Our results indicate that NC-effects in Grant and Henbury are large, ranging up to $\sim 30 \varepsilon$, and are variable between different meteorites and also between different samples of a given iron meteorite (Fig. 1). This highlights the importance of determining the neutron fluence separately on each individual sample analyzed for Pd-Ag systematics, as is done in this study using Pt isotope measurements.

The importance of quantifying NC-effects for obtaining accurate Pd-Ag ages is further highlighted by considering the Henbury and Grant data in isochron diagrams (Fig. 2). Whereas the uncorrected metal samples of Grant and especially Henbury do not define an isochron, for both samples well-defined isochrons are obtained after correction for NC using our model.

**Pd-Ag ages.** After correction for NC-effects, the three investigated IIIAB iron samples have indistinguishable initial $^{107}\text{Pd}/^{108}\text{Pd}$, corresponding to Pd-Ag ages of $\sim 0.6$ to $\sim 0.9$ Ma after Gibeon [1]. Relative to a solar system initial $^{107}\text{Pd}/^{108}\text{Pd}$ of $\sim 2.8 \times 10^{-5}$, as inferred from the IVA iron Muonionalusta [3], the Pd-Ag ages of the IIIABs are $\sim 2$ Ma. They change to $\sim 9$ Ma, if a solar system initial $^{107}\text{Pd}/^{108}\text{Pd}$ of $\sim 5.9 \times 10^{-5}$ obtained from a chondrite whole-rock isochron [11] is used instead.

**Crystallization and cooling history.** Based on variations in Ir content, the three investigated IIIAB iron samples almost the entire crystallization sequence of the IIIAB core, with Henbury representing an early and Grant a late crystallized sample. Large parts of the IIIAB core, therefore, must have crystallized and cooled below Pd-Ag closure within at most $\sim 9$ Ma after CAI formation. Since the core probably crystallized inwards, late crystallized samples should be located at greater depths within the core than early crystallized samples. The Pd-Ag ages indicate that, in spite of their different burial depths, the three investigated IIIAB iron samples cooled below Pd-Ag closure within less than $\sim 1$ Ma of each other. Such a rapid cooling requires either a very small parent body or removal of the insulating silicate mantle by impact erosion. The latter would be consistent with evidence from IIIAB cooling rates, which also have been used to argue for exposure of the IIIAB core by impacts [12].


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**Figure 2.** Pd-Ag isochrons for Henbury, Cape York, and Grant. Uncorrected data shown with open, NC-corrected data with filled symbols. Regression calculated using IsoPlot.