PLANETARY SCIENCE RESEARCH
PSRD Discoveries

Headline Article

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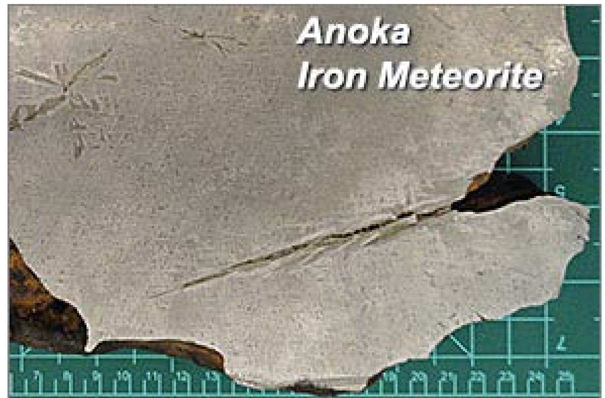
Archaeology, Artifacts, and Cosmochemistry

--- Iron beads, identified as pieces of the Anoka meteorite, are among a small handful of artifacts made from material from the birth of the Solar System.



University of Minnesota Meteorite Collection

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PSRD covers research that ascertains the content, formation, and evolution of our Solar System and planetary systems in general. Our archives are full of sample-based studies of extraterrestrial materials that relate to the building of planets, moons, and minor bodies. Rarely do we cover the cosmochemistry of artifacts, but the importance of cosmochemistry is abundantly clear in this story of artisan iron beads of archaeological significance and the quest to find the source meteorite.

Twenty-two meteoritic iron beads, recovered from mounds in Havana, Illinois of the Hopewell people and culture, have been identified as pieces of the Anoka iron meteorite, according to work by Timothy McCoy (National Museum of Natural History, Smithsonian Institution), Amy Marquardt (undergraduate intern at the NMNH/SI and now at the University of Colorado at Boulder), John Wasson (UCLA), Richard Ash (University of Maryland), and Edward Vicenzi (SI).

Reference:

- McCoy, T. J., Marquardt, A. E., Wasson, J. T., Ash, R. D., and Vicenzi, E. P. J. (2017) The Anoka, Minnesota Iron Meteorite as Parent to Hopewell Meteoritic Metal Beads from Havana, Illinois, *Journal of Archaeological Science,* v. 81, p. 13-22, doi: 10.1016/j.jas.2017.03.003. [**article**]
- **PSRDpresents:** Archaeology, Artifacts, and Cosmochemistry -- **Short Slide Summary** (with accompanying notes).

An Archaeological Find

Hopewell describes the prehistoric people and culture, encompassing many tribes, who shared a trading network in the North American Mississippi and Ohio Valleys. Their artifacts, including constructed earthworks and burial mounds, form what's known to archaeologists as the cultural Hopewell horizon spanning the years 400 BCE (Before Common Era) to 400 CE (Common Era, which begins at year 1 of the Gregorian calendar) within the Middle Woodland period in Eastern North America. Exotic materials found in the early 19th century in Hopewell mounds in present-day Ohio included iron metal beads, which were ultimately identified in 1969 as pieces of the Brenham **pallasite** [Data link from the **Meteoritical Database**] through trace element analysis. Other excavation efforts in 1945 of one of the burial mounds located near the present town of Havana, Illinois revealed a string of

22 **meteoritic** iron beads along with over 1000 shell and pearl beads. (Wood from this mound was dated at 2,336 ± 250 years old.) Since the Hopewell Havana find, scientists have wanted to match these beads with a known **iron meteorite** that supplied the raw material. McCoy and colleagues set out to collect the data needed to make the match.

The meteoritic iron beads are shaped from rolled tubes. Natural **weathering** altered the outside of the beads and filled the original holes with iron oxide (rust). The **Widmanstätten pattern** of the iron is still visible in a cut face, though it was deformed and folded during manufacture of the bead, discussed later.

Hopewell Meteoritic Metal Beads from Havana, Illinois

(McCoy *et al.*, 2017, *J. Archaeol. Sci.*, doi: 10.1016/j.jas.2017.03.003.)

Two meteoritic iron beads from Havana, Illinois are shown with a 1 centimeter cube for scale. The bead on the left was cut perpendicular to the central hole. It shows how the central hole has been filled and the bead itself has been altered by natural weathering. The bead on the right was cut parallel to the central hole. It shows the concentrically deformed Widmanstätten pattern.

Metallic Building Blocks

Iron meteorites are divided into 13 chemical groups of, theoretically, 13 separate parent bodies. A banded structure within iron meteorites is visible when a cut, polished surface is etched in acid. The nickel-rich (taenite) metallic phase and the nickel-poor (kamacite) metallic phase create the banded Widmanstätten structure (**see this example**) The band widths give additional information about cooling rates and diffusion of nickel that are responsible for chemical zonation in the mineral grains. (See this **PSRD animation of the development of nickel zonation**.) Cooling-rate details of iron meteorites are important in the big picture of deciphering the size of meteorite parent bodies.

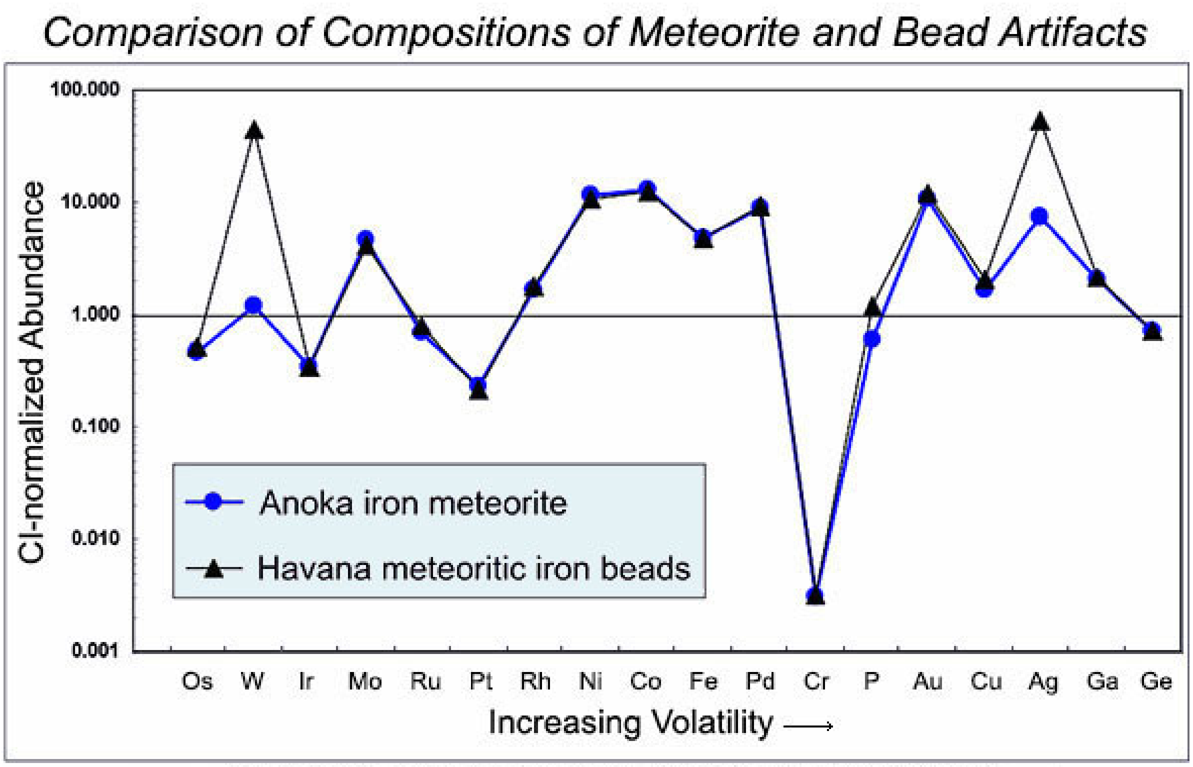
Cosmochemical studies and dynamical modeling of protoplanets in the early Solar System support the idea that early large impact events and hit-and-run collisions led to distributed debris-chains of metal-rich fragments and bodies (see **PSRD** articles: **Hit-and-Run as Planets Formed** and **When Worlds Really Did Collide**. Most iron meteorites [Data link from the **Meteoritical Database**] are the residual debris of protoplanetary impacts and collisions between differentiated bodies that had metallic cores. They are composed almost entirely of iron and nickel.

The Chemical Match with Anoka Meteorite

As early as the 1970s, researchers identified three likely meteorite-contenders for a bead match. The Carlton iron found in Texas [Data link from the **Meteoritical Database**], the Edmonton (Kentucky) iron found in Kentucky [Data link from the **Meteoritical Database**], and the Anoka iron found in Minnesota [Data link from the **Meteoritical Database**] are chemically similar to the Hopewell Havana beads, but none of the original meteorites showed evidence of having pieces broken off for any reason, let alone for making beads. Fortunately, another piece of the Anoka meteorite was discovered in 1983 across the Mississippi River, indicating a likely shower of meteorite pieces were strewn across the area. When the newer find was available for study, McCoy and colleagues re-examined the Anoka meteorite sample to compare it with three Havana meteoritic iron beads and to reconsider if a piece of Anoka meteorite had served as the source material for the beads.

The research team used a variety of laboratory techniques, including electron probe microscopy, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), and instrumental neutron-activation analysis (INAA) to determine the metallography, major and minor element compositions, trace element abundances, and bulk chemical compositions of the beads and Anoka meteorite. The detailed metallographic and compositional data are reported in the literature, and summarized below. The table shows major element chemical compositions determined using the electron probe microanalyzer at the Smithsonian Institution (**see the SI facility**). The graph shows trace element abundances determined by LA-ICP-MS using the laboratory at the University of Maryland, Department of Geology (**see the UMD Plasma Laboratory**).

COMPARISON OF COMPOSITIONS				
	iron (wt%)	nickel (wt%)	phosphorus (wt%)	cobalt (wt%)
Havana Hopewell Beads (avg.)	86.0	11.4	0.12	0.64
Anoka Meteorite	86.8	11.3	0.04	0.64



(McCoy *et al.*, 2017, *J. Archaeol. Sci.*, doi: 10.1016/j.jas.2017.03.003.)

Anoka belongs to the low-Au, medium-Ni subgroup (sLM) of the iron IAB complex. This graph compares the elemental abundances of the Anoka iron meteorite to the Hopewell Havana meteoritic iron beads determined by LA-ICP-MS and normalized to CI chondrites. The data are consistent with the hypothesis that a piece from the Anoka iron meteorite shower was the source material used to make the Hopewell Havana metal beads.

McCoy and coauthors attribute the difference in abundances of phosphorus (P) and possibly tungsten (W) and silver (Ag) to the abundance of the phosphorus-bearing mineral schreibersite. Any one chip of the meteorite could contain more or less schreibersite as it is unevenly distributed throughout the meteorite (see photo below) and is discussed again in the next section.

Anoka Iron Meteorite

(McCoy *et al.*, 2017, *J. Archaeol. Sci.*, doi: 10.1016/j.jas.2017.03.003.)

This cut slice of the Anoka meteorite shows a fine Widmanstätten pattern as well as relatively long, thin schreibersite crystals, one of which cuts across the upper-right corner of the sample. For scale: the longest dimension of this piece of meteorite is 26 centimeters.

Fashioning an Iron Meteorite into a Bead

2,000 years ago, how would an artisan break off a piece of an iron meteorite? McCoy and colleagues surmise that the schreibersite crystals, which are more brittle than the surrounding metal, were used as fracture planes. To get a better understanding of the basic manufacturing process, Tim McCoy experimented with making a bead from a piece of Anoka meteorite. A **Smithsonian Insider article** includes a photograph of McCoy making a bead and describes the method of repeated cycles of heating and cold-working the metal to make a flattened, thin plate that was then rolled to make a bead similar to the Havana artifacts.

These reflected light photomicrographs compare the cut faces of two meteoritic metal beads. [Left] Cross-section of a Hopewell Havana artifact showing Widmanstätten pattern deformed and folded around the center of the bead. The black splotches are iron oxides, products of 2,000 years of natural weathering. [Right] Cross-section of a bead with a large central hole made from a piece of Anoka meteorite during the modern science investigation. It shows the deformed Widmanstätten pattern caused by repeated cycles of heating and flattening during bead manufacture, a pattern which closely mimics the Hopewell beads.

The Hopewell Havana metal beads, identified as pieces of the Anoka meteorite, are among a small handful of artifacts made from material from the birth of the Solar System. Cosmochemistry has made it possible to connect earth and sky in this story of 2000-year-old beads and an even-older iron meteorite, giving an intriguing glimpse of a dynamic people who lived long ago.

Additional Resources

Links open in a new window.

- **PSRDpresents:** Archaeology, Artifacts, and Cosmochemistry --**Short Slide Summary** (with accompanying notes).

- Buchwald, V. F. (1976) Handbook of Iron Meteorites, University of California Press, Berkeley, 1426 pages. [**Online eBook**] and [**Appendix 6: Listing of Twenty-six Venerated Iron Meteorites**]

- Daley, J. (2017) Beads made from Meteorite Reveal Ancient Trade Network, *Smithsonian Magazine*. [**news article**]

- Donahue, M. Z. (2017) Ancient Native American Beads Traced to Otherworldly Source: An Iron Meteorite, *Smithsonian Insider*. [**news article**]

- McCoy, T. J., Marquardt, A. E., Vicenzi, E. P., Ash, R. D., and Wasson, J. T. (2008) Meteoritic Metal Beads from the Havana, Illinois, Hopewell Mounds: A Source in Minnesota and Implacations for Trade and

Manufacture, *Lunar and Planetary Science Conference XXXIX*, abstract 1984. [**abstract**]

- McCoy, T. J., Marquardt, A. E., Wasson, J. T., Ash, R. D., and Vicenzi, E. P. J. (2017) The Anoka, Minnesota Iron Meteorite as Parent to Hopewell Meteoritic Metal Beads from Havana, Illinois, *Journal of Archaeological Science,* v. 81, p. 13-22, doi: 10.1016/j.jas.2017.03.003. [**article**]

- Wasson, J. T., Sedwick, S. P. (1969) Possible Sources of Meteoritic Material from Hopewell Indian Burial Mounds, *Nature,* v. 222, p. 22-24.

- Watson, T. (2017) Beads Made from Meteorite Reveal Prehistoric Culture's Reach, *Nature,* doi: 10.1038/nature.2017.21990. [**news article**]

- NOTE: The Hopewell Havana meteoritic beads, now identified as pieces of the Anoka iron meteorite, were originally added to the Meteoritical Database as "Havana," see the **Data link**.

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