Air and Space this Week

Item of the Week

THREE IMPORTANT METEORS/METEORITES

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Twenty years ago, I built out the National Air and Space Museum's Discovery Learning Station about Meteors, Meteorites, and Why They are Important. In it, I consider meteorites to be "Ambassadors of Science," giving us a LOT of information about our Solar System and the formation of the Earth.

Three important meteorite falls have anniversaries in the next ten days; two of them are good "round number" events: Sikhote-Alin (2/12/1947), Allende (2/8/1969), and Chelyabinsk (2/15/2013).

INTRODUCTION

The realization that rocks actually can fall from the sky is only 220 years old. A large fall of stones was observed by a large number of people in and around the village of L'Aigle, France on April 6, 1803. Too many "reputable" folks reported the same thing for a hoax to be likely, so the French scientific community investigated, and confirmed the sighting, and collected some of the stones observed to fall. For more on this event, see here.

Astronomers quickly realized the scientific value of actually being able to examine "rocks from Space" in detail! Observations would confirm that most meteors have trajectories that link them to specific comets or the asteroid belt in general (recall that the first asteroid was identified but three years previous). The research continues to this day.

The rocks observed to fall over the ensuing years showed a considerable diversity of composition. Most were rocky, some were metallic (an iron/nickel alloy), and a few had characteristics of both, including beautiful examples of a metal body studded with crystals of olivine (peridot).

Most of the meteorites reaching Earth are stony, but they weather quickly and become difficult to identify long after their fall; many are recovered after being observed to fall. Iron meteorites, on the other hand, are radically different from most naturally-occurring outcrops, so finding them long after the fall is much more common. When the Antarctic ice cap was found to be a good collector of all meteorites falling on it, we got a better handle on the relative proportions of the types of meteorites.

Reminder: The terminology for natural objects falling from Space is a bit awkward. Falling stars were originally thought to be an atmospheric (only) phenomenon, hence the same root word for weather-related stuff, "meteor," was used for them. The "falling star" part is called a "meteor," but if the object reaches the ground without burning up completely, it's called a "meteorite." If it's still out in Space, it's a "meteoroid," and don't ask me the difference between "meteoroid," "asteroid," and "planetoid!"

Meteorites are almost always given the name of the nearest town (or geological/geographical feature) to the impact site.

SIKHOTE-ALIN

A mass of iron-nickel fell in Russia's Sikhote-Alin Mountains on the morning of February 12, 1947, 75 years ago this week. It was widely observed by everyone around, because it was as bright or brighter than the Sun, left a persistent smoke trail, and the sound of its impact carried hundreds of miles. A number of people, including scientists, came to the impact site, and a great amount of material was collected.

The mass of the Sikhote-Alin meteoroid ("S-A") was estimated to be on the order of 100,000 kg and its size was on the order of 25 m across. Soviet scientists estimated that 20-25% of the mass of S-A made it to the ground. For you experts in meteoritics, S-A is classed as a Group IIAB octahedrite, and its composition is 93% iron, 5.9% nickel, 0.48% phosphorus, and traces of sulfur, germanium, and iridium. A number of iron-nickel minerals are present, including taenite and kamacite, which produce a distinctive "Widmanstätten" pattern of interconnecting metal crystals when the meteorite is cut and polished.

Solid iron would resist the extreme aerodynamic forces the S-A body experienced, but iron meteorites usually have a lot of internal flaws that cause the meteor to spall off pieces on the way down, and S-A was no exception. Meteoritic debris was strewn over an area of about half a square mile. The biggest crater produced was about 25 m across and 6 m deep; there were a number of smaller craters nearby.

An artist who witnessed the smoke trail and impact painted what he saw; on the tenth anniversary of the impact the USSR issued a postage stamp bearing the painting.

Other large iron meteorites are known; most famously those associated with Meteor Crater in Arizona and the "Tucson Ring" Meteorite now on display next to the Hope Diamond in the National Museum of Natural History (see here for how the Smithsonian acquired it). Asteroid 16 Psyche appears to be (mostly) iron, too; we have a mission of that name launching in October to investigate.

So where could a large mass of essentially-pure iron come from? Like meteorites on Earth, most are rocky, but some, like Psyche are mostly metal (and it's quite large – over 100 miles across!). The only place reasonable is that they were once part of the core of a asteroid/planet large enough to be hot enough inside for long enough for differentiation to occur, where denser materials (iron) sink to the middle and lighter stuff (rock) floats up to the surface (a raft of rock floats well on a sea of liquid steel!). After differentiation, the parent body was hit by another, fragmenting both. Rocks from the original mantle and crust become rocky meteoroids, and bits from the original core become iron meteoroids. We can learn a lot about Earth's core by studying the composition of iron meteorites!

Twenty-thousand kilograms of iron is a lot of metal! Several large pieces are on display in Russia, and a lot of S-A material has ended up in labs and in private collections.

ALLENDE

An iron meteorite, like Sikhote-Alin, was once part of a body that had active internal geology going on after its formation. That's good for comparing it to what Earth's core might be like, but not so good for helping planetologists understand the composition of the nebula from which the Solar System condensed – too much has happened to the irons since the Solar System was initially created. What is needed to understand the earliest phase of Solar System formation are meteorites that have not changed since they condensed. Fortunately, there are such things, a class of meteorites known as carbonaceous chondrites (meaning they contain carbon (organic but not biological!) and chondrules, spherical crystalline bits).

On the early afternoon of February 8, 1969, a fireball came in and hit near the small village of Pueblo de Allende, in Chihuahua, Mexico. By 1969, the U.S. had established a network of automated night sky observing telescopes, images from which allowed astronomers to quickly establish that Allende meteorite came from the outmost part of the Solar System, and hence was unlikely to have been part of a significantly-larger body, one that had differentiated. It was left-over debris from the formation of the Solar System, and was, hence, a good measure of the proto-solar nebula's initial composition. Fortuitously, the Lunar Receiving Laboratory was just coming on line to handle the lunar materials that would be coming from Apollo missions starting later that year. Here was a perfect opportunity to test-drive the LRL on a scientifically-important project!

A number of books, and many scientific papers about the Allende meteorite and its provenance resulted. Now that collectors are competing with scientists for meteorites, bits of Allende can be rather expensive. But I liked using Allende in the NASM "Touch a Falling Star" learning station, because I could engage the visitors with confidence in the truth when I told them they were holding the "oldest rock you will EVER touch!"

CHELYABINSK

A large meteor appeared over the Russian town of Chelyabinsk Oblast on February 15, 2013, ten years ago next week. Its appearance was a total surprise; its approach was masked by the Sun. Fortunately, damage was minimal and most of the ~1500 injuries incurred were relatively minor, and fortunately, the car insurance situation in Russia meant that many cars out at the time had dash cams. Data from them helped astronomers work out its trajectory, hence orbit. Needless to say, the event caused considerable panic and concern.

Chelyabinsk was about 20 m across when it hit Earth's atmosphere, making it the largest impact event since Tunguska in 1908. It's classed as an LL Chondrite, a rare kind of stony meteorite. It came from the Asteroid Belt, and likely it's seen more geological activity than did Allende.

We acquired a sample of Chelyabinsk for the afore-mentioned NASM learning station; I liked to be able to let someone touch a meteorite that had been in the news so recently. I especially liked it when I had a multi-generation group of visitors when I operated the station. I'd watch the faces of the "Children of Apollo" in the audience, those who could personally remember the early 1960s. Tensions were so high in the 1962-63 time-frame that both sides were worried that the other might overreact over their ongoing lunar and planetary launches that they let each other know what they might expect to see that was not related to geopolitics. Then I'd point out that Chelyabinsk fell almost 50 years exactly after the Bay of Pigs and the Cuban Missile Crisis. Then I'd mention that Chelyabinsk is about 930 miles from Moscow and about 590 miles from the Baikonur Launch Complex in Kazakhstan. Fifty years in time, and less than a thousand miles of distance are miniscule in the grand cosmic scheme of things. The look on their faces when I asked what might have happened had Chelyabinsk happened fifty years prior and a few hundred miles from where it did hit was – well, interesting.

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Norton, O. Richard (2008), *Field Guide to Meteors and Meteorites*, part of Springer's Patrick Moore Practical Astronomy Series, ASIN: B003RRX21K

NASA: https://solarsystem.nasa.gov/asteroids-comets-and-meteors/meteors-and-meteorites/in-depth

National Geographic: https://education.nationalgeographic.org/resource/meteorite

The Meteoritical Society: https://meteoritical.org

Smithsonian's National Meteorite Collection: https://naturalhistory.si.edu/research/mineral-sciences/collections-overview

Field Museum: https://meteorites.fieldmuseum.org/home

Arizona State University's Buseck Center for Meteorite Studies: https://meteorites.asu.edu

University of New Mexico Institute of Meteoritics: http://meteorite.unm.edu

Nature Portfolio: https://www.nature.com/subjects/meteoritics

Meteor Crater, Arizona: https://meteorcrater.com

A problem with meteorites is that many/most of the websites with information about them are commercial and are trying to sell you meteorites.

NOTE to Caregivers: Arizona State University has on-line meteorite resources to engage and support K-12 learning; see: https://meteorites.asu.edu/news/k-12

Sikhote-Alin

Meteoritical Bulletin Database: https://www.lpi.usra.edu/meteor/metbull.php?code=23593

Wikipedia: https://en.wikipedia.org/wiki/Sikhote-Alin_meteorite

Allende

ASU's Allende 50th Anniversary: https://meteorites.asu.edu/news/allende50

UC Berkeley: https://news.berkeley.edu/2011/03/03/reading-the-life-history-of-a-4-5-billion-year-old-meteorite

Smithsonian Magazine: https://www.smithsonianmag.com/smithsonian-institution/oldest-material-smithsonian-institution-came-outer-space-180971017

Smithsonian Archives: https://siarchives.si.edu/collections/siris_sic_13852

Analysis of the Allende Meteorite Reference Sample: https://repository.si.edu/bitstream/handle/10088/813/SCES-0027.pdf?sequence=1

Nine new minerals were found in Allende: https://www.sci.news/geology/article00424.html

Wikipedia: https://en.wikipedia.org/wiki/Allende_meteorite

Chelyabinsk

NASA: https://web.archive.org/web/20130430164941/http://neo.jpl.nasa.gov/news/fireball_130301.html and https://www.nasa.gov/content/nasa-and-international-researchers-collect-clues-to-meteoroid-science/#.U_vfLlfvmlA

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Damage Assessment: http://cams.seti.org/Popova2013-ms.pdf

Physics Today: https://physicstoday.scitation.org/doi/10.1063/PT.3.2515

Wikipedia: https://en.wikipedia.org/wiki/Chelyabinsk_meteor

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NASA YouTube: Asteroid Initiative Workshop: https://www.youtube.com/watch?v=BNkS1uHUbq8&ab_channel=NASA

Recent Meteoritics Research

Meteorites Reveal Likely Origin of Earth's Volatile Chemicals: https://www.sciencedaily.com/releases/2023/01/230127131132.htm

Solar System Formed from “Poorly Mixed Cake Batter,” Isotope Research Shows: https://www.sciencedaily.com/releases/2023/01/230126161919.htm

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