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Arkansas Meteorites and "Meteor-wrongs" -

Extraterrestrial Rocks and Terrestrial Rocks Often Mistaken for Them

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Arkansas Meteorites and "Meteor-wrongs" – An Overview of Extraterrestrial Rocks and the Terrestrial Rocks Often Mistaken for Them

By

William L. Prior, Corbin G. Cannon II, and J. Michael Howard

Introduction

Meteorites are greatly prized by scientists and the public because of their rarity and origin. Since a meteorite is a stony or metallic body that has fallen to the earth from outer space, it is valuable. Even though the chance of finding a meteorite is exceedingly small, we receive many requests hoping for the positive identification of one. This publication is meant to provide a summary of meteorites with examples of material that could be mistaken as meteorites.

Having not formed on Earth, meteorites are not like the rocks usually found on our planet. Most meteorites are believed to be the leftovers from the formation of our solar system some 4.6 billion years ago. Before they reach Earth's surface, they are known as meteors and commonly called "shooting stars" or "fireballs". Age dating indicates that meteorites are some of the oldest objects ever studied, even older than the oldest rocks found on earth.

Certain meteorites have a composition and texture indicating that it was once part of a larger body, possibly a "planetesimal" or protoplanet, that later shattered. Most meteorites are fragments of asteroids, however, rare meteorites can originate from comets, moons, or planets. These form from large surface impacts when debris is blasted into space, and then may orbit in the solar system for millions of years before being pulled to Earth by gravity. A meteorite can land virtually anywhere in the world. However, due to the varied terrain on Earth, most are discovered in areas with little or no vegetation, such as deserts and ice caps where it is easier to spot them.

It is recommended that any material suspected to be a meteorite be taken to a local university or geological survey to have a definitive identification made. If you suspect an object to be a meteorite, <u>**do**</u> <u>**not**</u> hammer it or try to break it in any way. Also, <u>**do**</u> <u>**not**</u> alter it in any way by using chemicals or heating it. <u>Any man-made changes to the object's structure will greatly reduce its value, both financially and scientifically</u>. It is through analysis of a meteorite's composition and structure that the most information can be learned.

If one is determined to examine the suspected meteorite before bringing it for expert identification, the best method is to grind a small spot on it with an emery cloth or carborundum grinding wheel to a depth of ¼ inch. This should be deep enough to get through the outer crust. The exposed surface can be examined to determine if there are any small irregular grains of steel-gray metal within a rocky structure or if it is made entirely of metal. There are many natural and man-made materials that can be confused with meteorites. These objects are sometimes referred to as "meteor-wrongs." It may take an expert to determine if an object is a meteorite. A small fragment of the object may need to be donated for a detailed analysis.

Steps for Initial Identification of a Meteorite

Below is a series of steps that can help to identify a possible meteorite:

1. Is a **magnet** attracted to it? Yes or No
2. Is it **heavier** than most other rocks of the same size? Yes or No
3. Does it have a **thin dark crust** on the outside? Yes or No
4. Without trying to break it open, can you tell if it has a **lighter color on the inside** compared with the outside? Yes or No
5. After sanding down a small spot to a depth of a ¼ inch, does the interior look metallic like steel? Yes or No
6. Does it have thumb-like impressions (**regmaglypts**) on the surface? Yes or No

If you have said yes to all the above, or yes to all except number 1, you may have a meteorite. For further verification call the Office of the State Geologist (OSG) at (501) 296-1877 or contact us by email at osg@arkansas.gov.

General Description of Meteorites

Meteorites in general have some features that help distinguish them from most terrestrial rocks and man-made materials. Externally, meteorites tend to have a black to dark brown **fusion crust** that is one to four millimeters thick (Figure 1). This crust is created by friction as the meteor passes through the atmosphere. Friction generates heat which melts the surface and can create depressions that look like thumb prints (**regmaglypts**) (Figure 2). These depressions occur only on the surface and are not holes that pass through the rock.

Most meteorites contain iron-nickel metal so they can typically be distinguished from Earth rocks as being heavier for a given size. Iron-nickel metal is magnetic, meaning most meteorites will attract a magnet.

Figure 1 - Canyon Diablo Meteorite, Arizona. Notice the dark brown to black fusion crust along the top of the specimen (magnetic). From University of Arkansas, Little Rock, collection.

Figure 2 - Iron meteorite from Russia with "thumb print"-like regmaglypts on the outer surface (magnetic). From University of Arkansas, Little Rock, collection.

Classification of Meteorites

Modern classification of meteorites began in the 19th century. Scientists recognized that there are different compositions and structures, relative to rocks formed on Earth, reflecting the differing origin of meteorites. Currently the only meteorite samples we have to compare meteorites collected on the Earth with are those collected during the Apollo missions to the moon in the 1960s and 1970s.

Recently, two asteroids were sampled: Samples taken from the Ryugu asteroid by the Japan Aerospace Exploration Agency (JAXA) were recovered in December of 2021. Samples taken from the Bennu asteroid by the National Aeronautics and Space Administration (NASA) are scheduled to be recovered in September 2023. Classification nomenclature will continue to evolve as further extraterrestrial samples are studied. As samples from other planetary bodies in our solar system are recovered and analyzed, categorization of meteorites will likely expand.

The classification of meteorites has become very complex. Meteorites have been found to have many overlapping features and compositions that make classification difficult and require detailed laboratory analysis. This section will give a general overview of the basic terms used and is by no means comprehensive. More advanced terms are used to describe specific meteorites to give geologists a quick snapshot of their origins. These advanced terms are beyond the scope of this publication. Therefore, it is suggested for the interested reader to read about meteorite classification to better understand the type of information a scientist can infer from terminology.

Meteorites are divided into two broad categories: **undifferentiated, called chondrites** and **differentiated, called achondrites**. Beyond these broad categories, the most widely used classification is based on the composition, dividing them into **irons, stony-irons, and stony** meteorites.

Chondrites are made of leftover matter from the formation of the solar system and are considered primitive in that they represent the building blocks of planetary bodies. They did not come from a larger parent body such as a planet or moon. A particular type of chondrite, carbonaceous chondrites (Fig. 3), are thought to be some of the oldest known meteorites yet discovered, dating as far back as the formation of the solar system.

Figure 3 - Carbonaceous chondrite from Algeria. From University of Arkansas, Little Rock, collection.

The most common type of meteorites found are chondrites which are often called ordinary chondrites (Fig. 4). They contain distinct rounded grains, called chondrules, that range in size from a few micrometers to over a centimeter. Chondrules appear as rounded balls of material in the rocky matrix of a meteorite.

A sub-category of chondrites are **stony meteorites** (Fig. 5). They contain the smallest percentage of metallic, or native iron of all the meteorites. Native iron is extremely rare on Earth but is present in almost all meteorites. See the Arkansas Meteorite Minerals section for more on native iron.

Figure 4 - Delaware meteorite, from Arkansas, an ordinary chondrite (slightly magnetic). From University of Arkansas, Little Rock, collection.

Figure 5 - Stony meteorite from northwest Africa (magnetic). From the author's collection.

Achondrites are differentiated meteorites that consist of fragments of larger bodies such as planets or moons that were subsequently blasted back into space by large impacts.

Iron and stony-iron meteorites are generally classified as achondrites. **Iron** meteorites (Fig. 6) are commonly differentiated from terrestrial rocks due to their higher density, being composed mostly of metallic iron and nickel. Metallic iron has a gray metallic appearance and when a cut polished surface is treated with acid, it frequently shows the Widmanstätten line patterns of iron crystals (Fig.7). These crystals are visible because each one has a different orientation according to the amount of nickel which ranges from 5-10 percent. The presence of Widmanstätten patterning and nickel are key indicators that a specimen could be a meteorite.

Stony-iron meteorites (Fig. 8 and 9), as the name implies, have a composition that includes flakes of metallic iron embedded in a rocky matrix. Suspected lunar and Mars meteorites are generally classified in this group. A more specific classification of stoney-iron meteorites that contain mostly olivine crystals are called pallasites. They are presumed to be from the mantle of a planetary body. The Newport meteorite is classified as a pallasite.

Figure 6 - Iron meteorite from Russia (note magnets). From University of Arkansas, Little Rock, collection.

Figure 7 - Iron meteorite with Widmanstätten (crystal structure) pattern. From University of Arkansas, Little Rock, collection.

Figure 8 - Stony-iron meteorite (magnetic). From University of Arkansas, Little Rock, collection.

Figure 9 – Pallasite, a type of stony-iron meteorite, from Argentina that contains crystals of olivine in iron-nickel matrix (magnetic). From the author's collection.

Arkansas Meteorites

Because Arkansas experiences abundant precipitation annually, most of the state is covered by vegetation and there are few areas of barren ground. This makes it difficult to find meteorites. However, there have been 15 confirmed meteorites (Table 1) found in Arkansas. Of these, six have been recovered from **witnessed falls**. The term "fall" refers to an eye-witness event of the passage of a fireball (meteor) in the sky and subsequent recovery of the associated meteorite. Most Arkansas meteorites are named after the location where they were discovered. Figure 10 shows locations of all meteorites recovered in Arkansas.

Table 1 - Fifteen confirmed Arkansas meteorites. (Fall) indicates the specimen was collected after an observed fall. Each meteorite is characterized as to sub-type if applicable.

Name	Location(County)		Date Found	Weight (lb)	Type
Cabin Creek	Johnson	(Fall)	1886	107	Iron
Calico Rock	Izard		1838	16	Iron
Delaware	Johnson		2002	18.4	Chondrite
Fayetteville	Washington	(Fall)	1934	4.95 & 0.24	Chondrite
Hatfield	Polk		1941	unknown	Iron
Hope	Hempstead		1955	15	Iron
Joe Wright Mtn.	Independence		1884	94	Iron
Miller	Cleburne	(Fall)	1930	36.7	Stony
Newport	Jackson		1923	12.3	Stony-Iron
Norfork	Baxter	(Fall)	1918	2.3	Iron
Paragould	Greene	(Fall)	1930	80 & 820	Stony
Sandtown	Independence		1938	7.15	Iron
Slovak	Prairie		1960s	18.1	Chondrite
Success	Clay	(Fall)	1924	7.7	chondrite
Western AR	Montgomery		1890	3.83	Iron

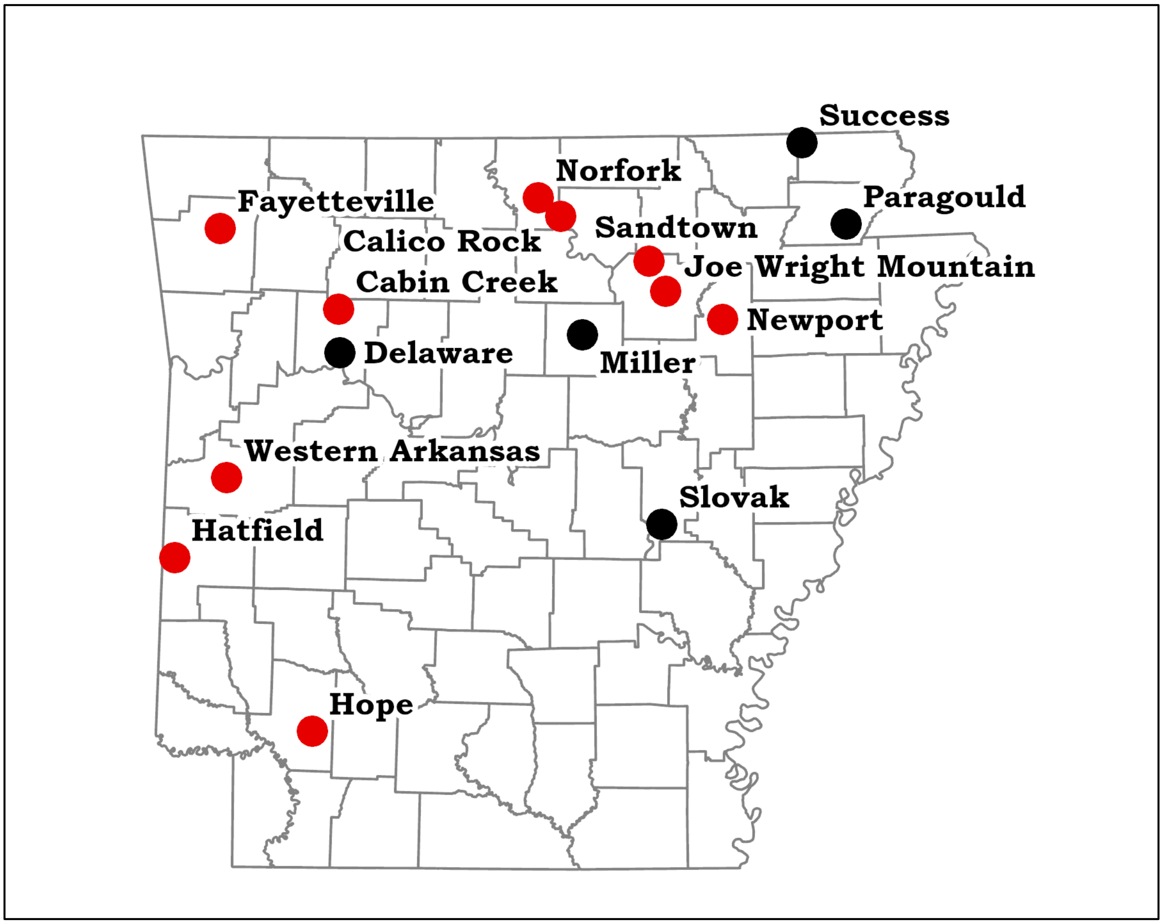

Figure 10 - Locations of recovered Arkansas meteorites. Red dots indicate recovery from an observed fall

Arkansas Meteorite Minerals

Fourteen minerals have been recognized in Arkansas meteorites. They are listed below in alphabetical order. Some meteorite classifications contain these mineral names to provide additional information about their origin.

Bronzite
Bronzite has been renamed ferrosilite. See ferrosilite (below).

Carlsbergite
Carlsbergite is a chromium nitride. It is extremely hard and rare but is present as microscopic metallic grains found in the Norfork Meteorite.

Cliftonite
Cliftonite is a form of carbon, like graphite and diamonds, and is present as microscopic grains in the Hope Meteorite. Physical properties include a hardness of 2.5 and specific gravity of 2.12.

Cohenite
Cohenite is an iron-nickel cobalt carbide found in iron meteorites. It is magnetic, tin-white in color, has a hardness of 5.5-6, and a specific gravity of 7.20-7.65. It can be seen in polished sections of the Hope Meteorite.

Daubréelite
Daubréelite is a ferrous iron chromium sulfide occurring in iron meteorites. It is black in color and is non-magnetitic. It can be seen in platy aggregates in the Western Arkansas Meteorite. Specific gravity is 3.81.

Enstatite
Enstatite is a magnesium ferrous iron silicate found in chondrites. Enstatite has variable color ranging from colorless to gray to yellow-green, and white to olive-green. It has been found in the Slovak meteorite. Specific gravity is 3.2-3.9.

Feldspar Group
Feldspar is a group term for a series of aluminum silicate minerals that are found in the matrix of stony or stony-iron meteorites. Feldspar Group minerals have been reported in the Miller and Paragould meteorites.

Ferrosilite
Ferrosilite is an iron-rich member of the Pyroxene Mineral Group. Pyroxenes are silicate minerals that are common in many terrestrial rocks. They are usually a dark color and are somewhat heavy due to their high iron and magnesium content. They are also part of the matrix in stony meteorites. Pyroxenes are reported as a common component in the stony meteorites from Arkansas. Specific gravity is 3.6-4.0.

Hypersthene
See ferrosilite (above).

Iron (native)
Native iron is typically present in almost all meteorites. It has a gray metallic appearance and when a cut polished surface is treated with acid, it frequently shows the Widmanstätten line patterns. Specific gravity is 7.3-7.87.

Kamacite
Kamacite is a natural alloy of iron and nickel with nickel content ranging from 4 to 7.5 percent. A natural alloy is a metallic substance composed of two or more elements.

Lawrencite
Lawrencite is a ferrous iron-nickel chloride. It has a green to brown color and is present in fracture fillings of the Newport meteorite. Specific gravity is 3.16.

Olivine Group
The Olivine Group consists of magnesium iron silicates that are common in terrestrial rocks. These minerals are most often observed in meteorites as yellow to green glassy crystals embedded in a metallic iron matrix such as a pallasite, which is a type of stony-iron meteorite (Fig. 9). Olivine has been found in several Arkansas meteorites including the Fayetteville, Miller, Newport, Paragould, Slovak, and the Success. Specific gravity is 3.275-4.39.

Schreibersite
Schreibersite is an iron-nickel phosphide with metallic luster, a specific gravity of 7.0-7.3, and a hardness from 6.5-7.8. It has been found in several of the iron and olivine rich iron meteorites from Arkansas.

Taenite

Taenite is an alloy of iron that contains about 32 percent nickel. It has a metallic luster and color varies from silver to gray white. It is strongly magnetic and is present in the iron meteorites found in Arkansas. Specific gravity is no data.

Troilite

Troilite is an iron sulfide with a metallic luster and is light grayish to brown in color. It forms nodules in iron meteorites. Specific gravity is 4.67-4.79.

Photos of Arkansas Meteorites

The following section is a photographic gallery of Arkansas meteorites displayed in various locations

Figure 11 - The Cabin Creek iron meteorite (magnetic) has large shallow pits and is deeply indented with regmaglypts on display in the Vienna Museum. Photo from Creative Commons Attribution-ShareAlike 3.0 Unported ,https://commons.wikimedia.org/wiki/User:HeMei.

Figure 12 - The Miller meteorite is a stony meteorite on display at the American Museum of Natural History in New York City.

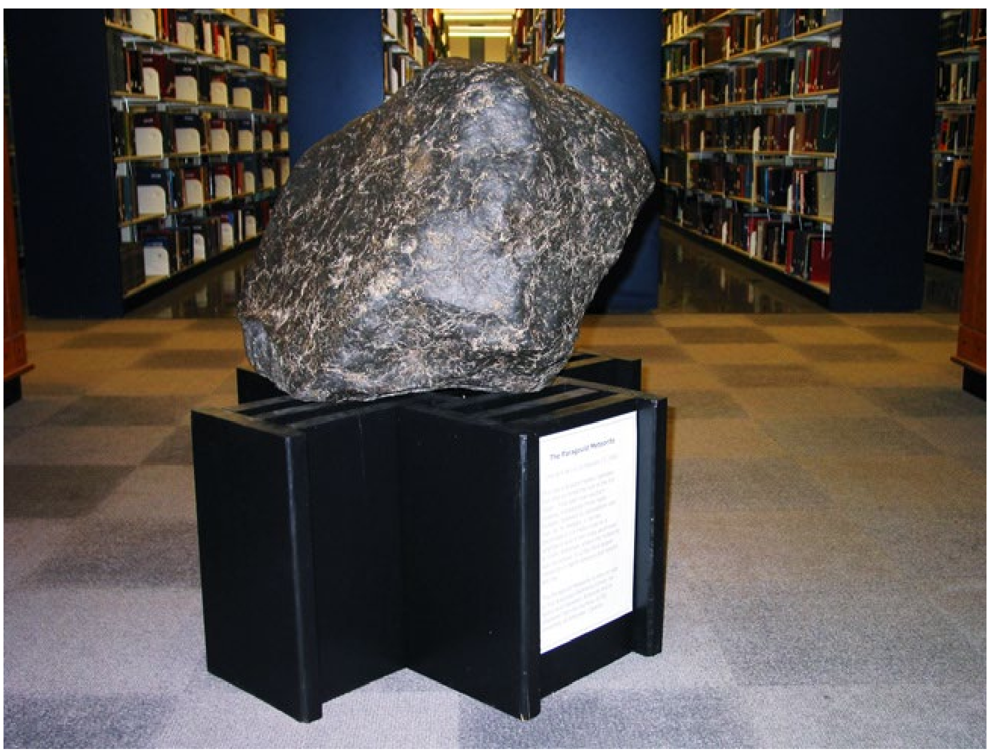

Figure 13 - The Paragould meteorite is a chondrite. It is 16 in. x 41in. x 24 in, and weighs 870 lb. It is one of the largest stony meteorites ever recovered. It is on display in the Arkansas Center for Space and Planetary Sciences Building, in Fayetteville, Arkansas.

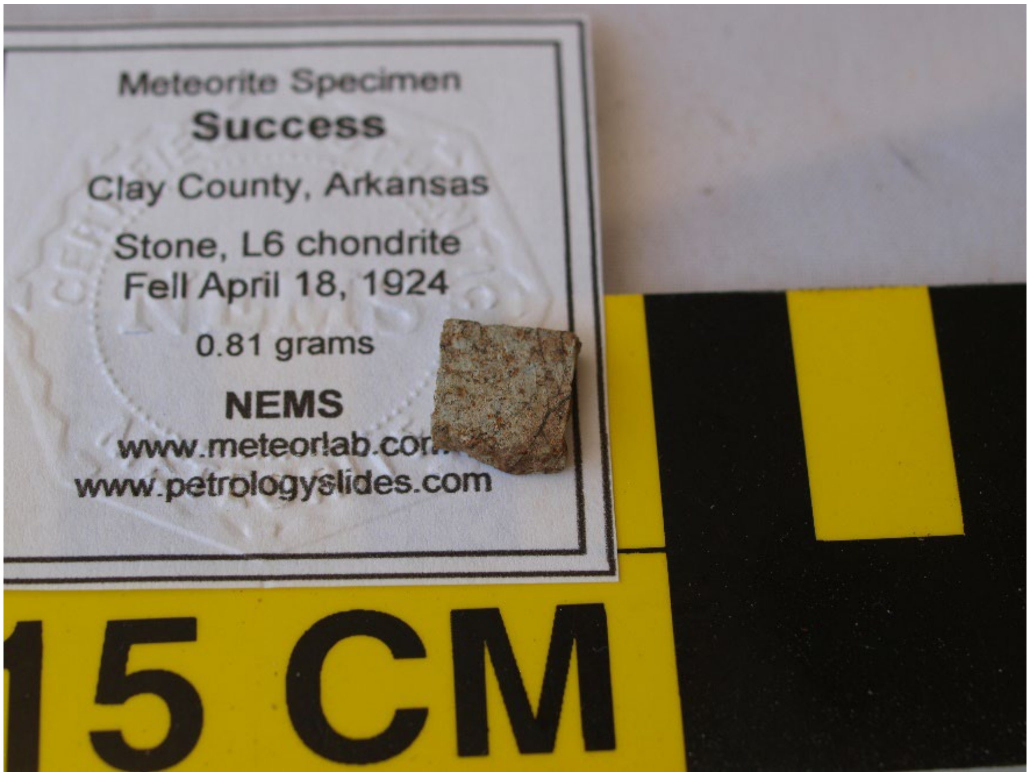

Figure 14 – A slice taken from the Success meteorite. Sample from author's personal collection.

Other Materials Related to Meteorites

Tektites

Tektites are round to teardrop shaped silicate-rich glassy objects (Fig. 15) formed from melted terrestrial rock that was blasted into the air by a large meteorite or comet impact. They range in size from microscopic to up to 4 inches long. Tektite color ranges from green to brown to black and they vary in age from millions to thousands of years. Some are from known large impact craters while others have not been linked to specific impacts. To date, tektites found in North America have not been linked to any specific impact.

Figure 15 - Tektites from Southeast Asia. From author's personal collection.

Meteor-wrong Materials

Many terrestrial rocks and minerals, along with man-made materials, can be found in Arkansas and have been mistaken for meteorites. This is a short list of many "meteor-wrong" materials. The following photos are of specimens from state and private collections that were taken by Corbin Cannon.

Other Natural Rocks and Minerals

Rocks with rounded shapes and minerals that are rounded and magnetic are sometimes mistaken for meteorites. Magnetite is a naturally magnetic mineral that is heavier than expected and is black. It occurs in the Magnet Cove area of Hot Spring County (Fig. 16 and 17).

Figure 16 – Magnetite and lodestone (magnetic) from Magnet Cove, Arkansas. From OSG collection.

Figure 17 - Magnetite crystals (magnetic) from Magnet Cove, Arkansas. From OSG collection.

In many other parts of the state, rounded nodules of iron sulfide made up of pyrite or marcasite (Fig. 18 and 19), and iron oxide (hematite) (Fig. 20, 21, and 22) can be mistaken for meteorites.

Figure 18 - Marcasite nodule exterior (non-magnetic). From OSG collection,

Figure 19 - Marcasite nodule interior (non-magnetic). From OSG collection.

Figure 20 - Ironstone nodule containing hematite (non-magnetic). From author's collection.

Figure 21 - Interior of ironstone nodule containing hematite (non-magnetic). From author's collection.

Figure 22 - Interior of ironstone nodule containing hematite with rounded center nodule removed (non-magnetic).From author's collection.

Man-made Materials

Discarded man-made materials may be found later and mistaken for meteorites. Such materials fall into several categories. One is the fused remains of unburnable material left over from fires in boilers or forges known as **clinker** (Fig. 23 and 24)**.** These can be magnetic and may exhibit some of the characteristics of a meteorite, but the presence of holes and bubbles indicate that they are not meteorites. Another term used to describe open spaces between grains in a rock or man-made material is vug, or vuggy.

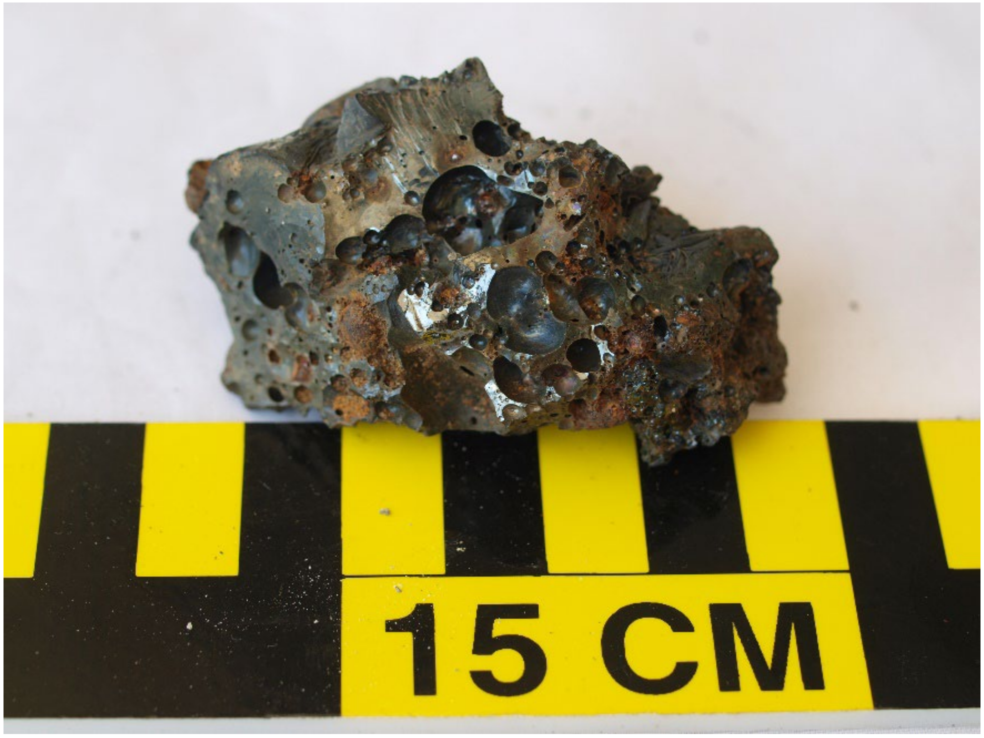

Figure 23 – Clinker, or man-made material, with large round gas bubble holes (magnetic).

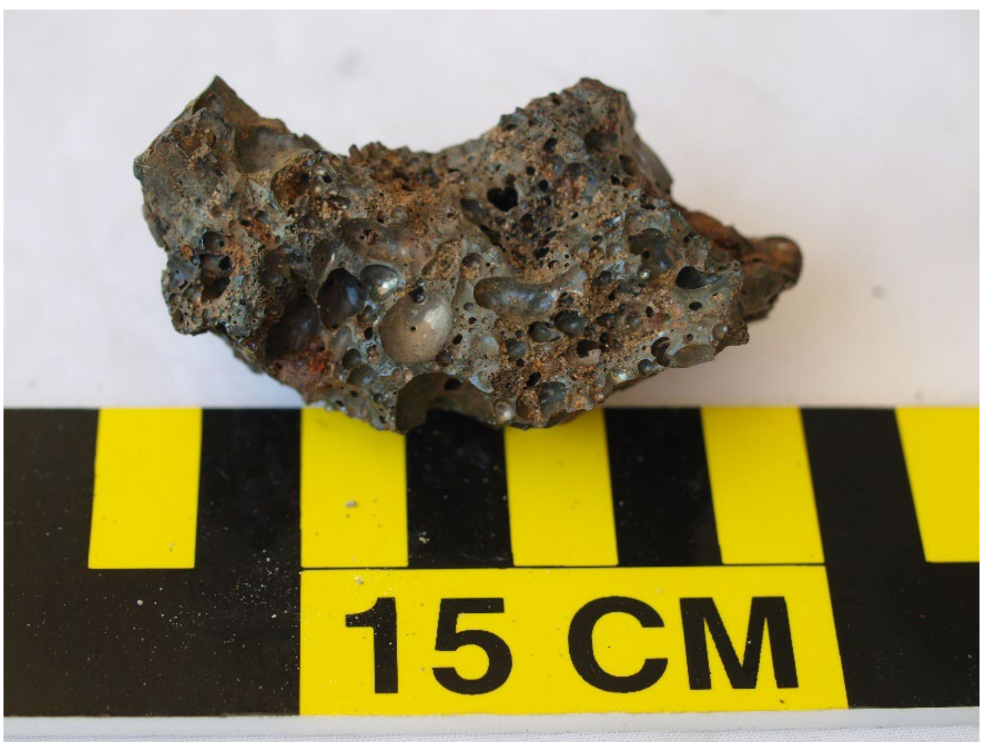

Figure 24 – Clinker, or man-made material, with large round gas bubble holes (magnetic).

Slag is another type of material frequently mistaken for meteorites. Slag, commonly called glass (Fig. 25), is a waste material from the production of pig iron, an intermediate product of smelting iron for steel production. This production was common in north Arkansas.

In the central Arkansas area, there is an abundance of metal alloys and slags leftover from over a hundred years of refining local bauxite into aluminum metal. Metal alloys are created by combining metals such as copper, iron, and antimony to the aluminum to make it stronger. Other metal alloys can be created by combining metals with non-metals. Many alloys appear metallic while others look more like rocks. There are fragments of elements and of compounds such as silicon and silicon dioxide present in some of these alloys.

The following photos illustrate various slag found by the public and donated to the OSG .

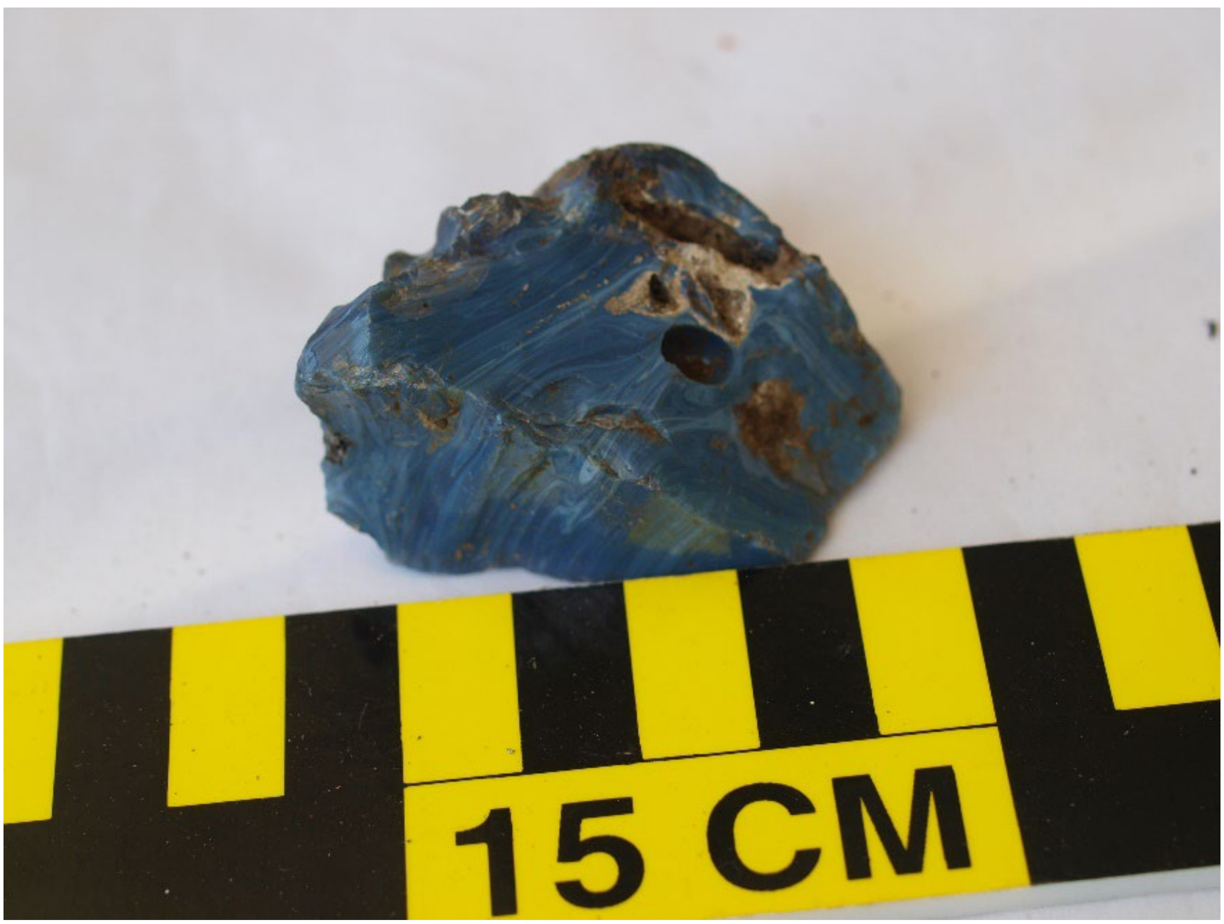

Figure 25 - Blue glass from northern Arkansas (non-magnetic).

Figure 26 – Slag made up of antimony (non-magnetic).

Figure 27 - Magnesium aluminum iron alloy that was created as a waste material of aluminum production in Arkansas (magnetic).

Figure 28 - Iron aluminum alloy (non-magnetic).

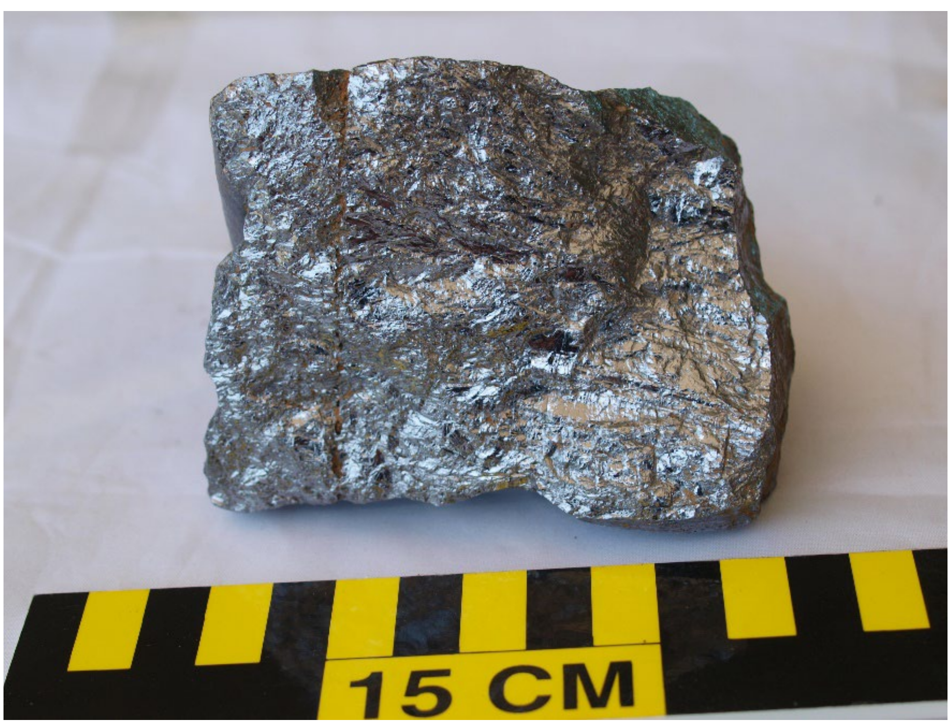

Figure 29 - Metallic silicon alloy (non-magnetic).

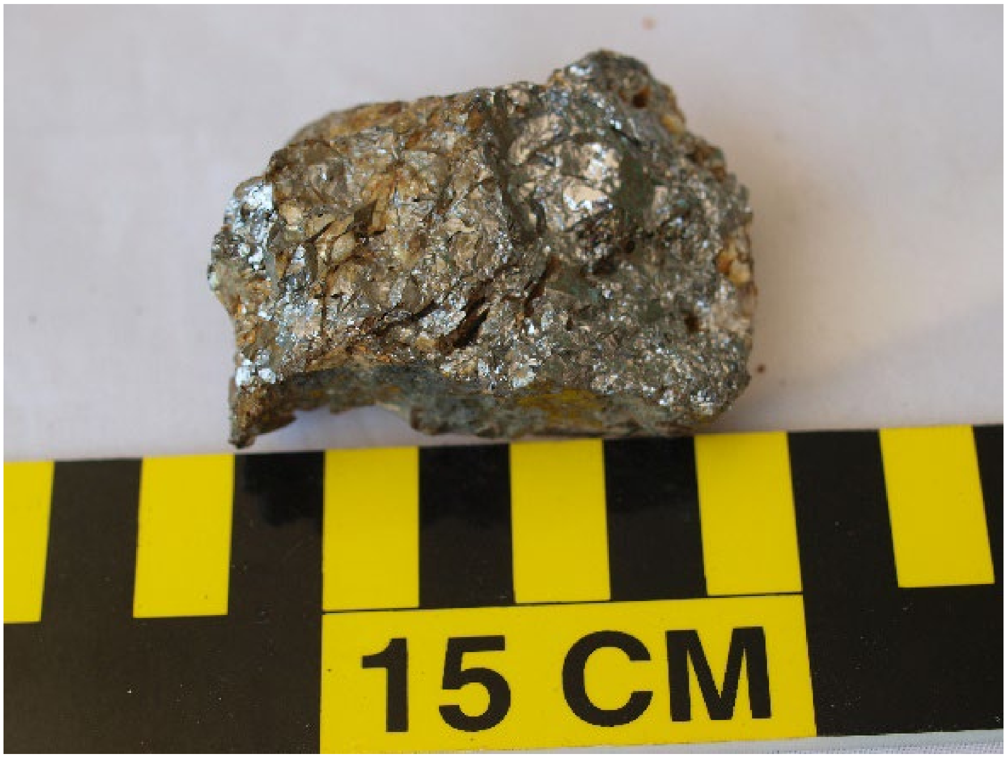

Figure 30 - Iron aluminum alloy (non-magnetic).

Figure 31 - Iron chromium alloy (magnetic).

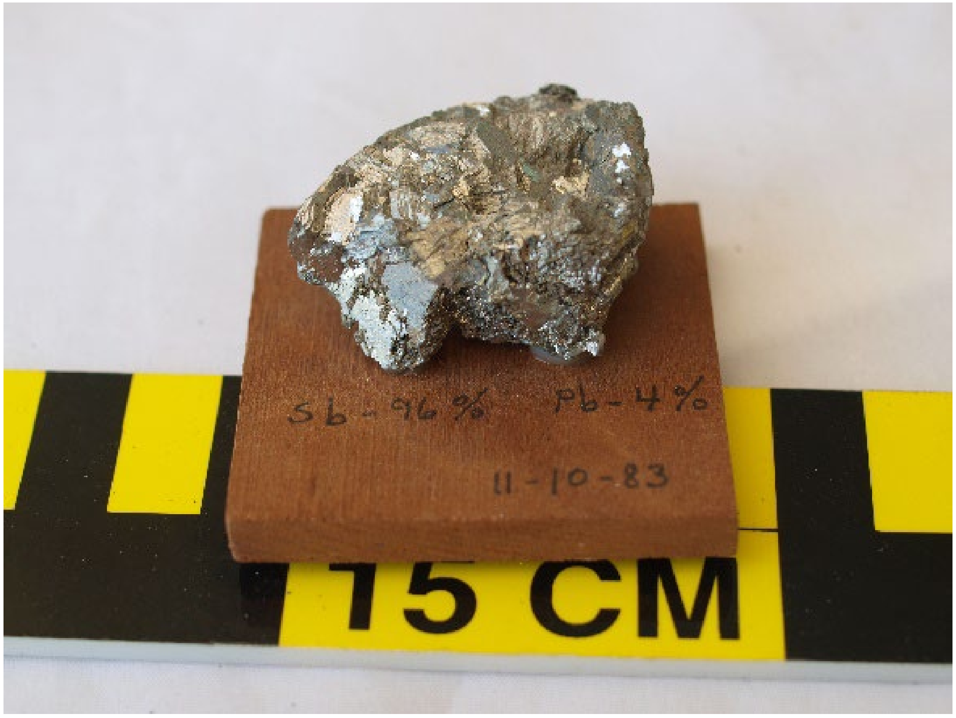

Figure 32 - Antimony iron alloy (non-magnetic).

Figure 33 - Silicon carbide (non-magnetic).

Figure 34 - Vuggy, glassy clinker (non-magnetic). A vug is a cavity or large pore in a rock or man-made material.

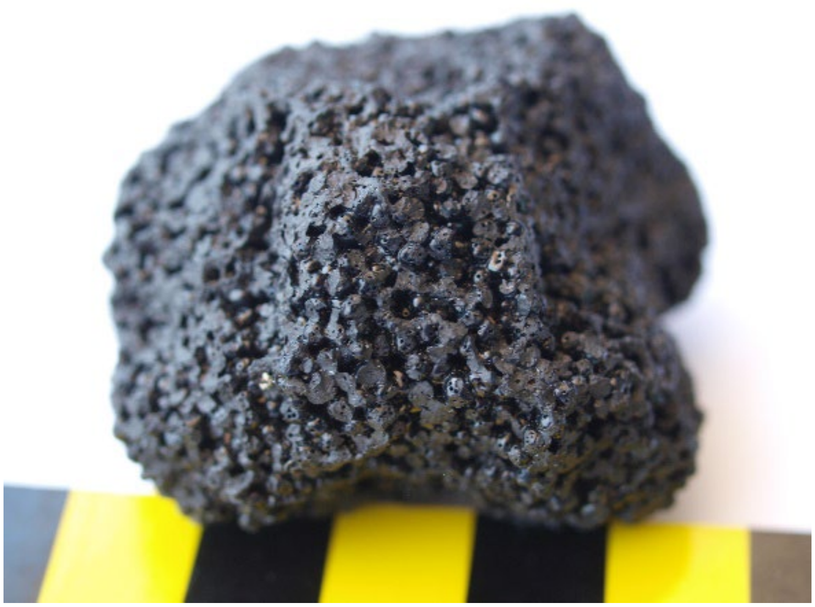

Figure 35 - Close-up of vuggy clinker (non-magnetic).

Figure 36 - High magnification of vuggy clinker texture.

Remember, there are many natural and man-made materials that can be confused with meteorites. It may take an expert to determine if an object is a meteorite or a small fragment of the object may need to be donated for a detailed analysis. Either way, keep your mind open to science and your eyes open to finding cool rocks or meteorites!

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