Greetings from Outer Space!

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Heavy Metal Arrives in Russia

At 10.30 am on 12 February 1947, people around the Sikhote-Alin Mountains in Russia heard something that made them turn their faces quickly to the sky. What they saw they never forgot . . .

Above them a blazing bluish fireball, as bright as the sun, hissed and crackled across the clear morning sky, trailing a tail tens of kilometres long, of smoke and dust and smaller fireballs.

Only two years before, during World War Two, the first atom bomb had been dropped, just across the Sea of Japan, reducing the whole city of Hiroshima to lifeless rubble. At least one witness to the fireball thought it was another bomb!

A few kilometres above the Sikhote-Alin mountains the huge iron fireball exploded like a giant grenade. The blast sent hot, jagged shrapnel scything through the cold morning air, joining the smaller fireballs in a race towards the ground. The remains of the great fireball then plunged out of sight into the forest-covered mountains.

Moments later, rapid, thunderous booms echoed for hundreds of kilometres through the snowy landscape, shaking windows and rattling doors. For three more hours a towering tail of smoke and dust hung in the sky.

Visitors from Outer Space

Within days, pilots searching the region noticed an elliptical area of scorched forest, kilometres in length. It took two months for a team of investigators to battle their way successfully through the dense forest. They found a vast cratered area littered with meteorites, the largest weighing more than one and a half tonnes! The meteorites are now known as Sikhote-Alin meteorites, after their landing place.

A 1957 stamp from the former Soviet Union commemorating the ten year anniversary of the Sikhote-Alin meteorite fall. The image is based on a painting by a witness of the fall.

What had happened that icy winter's morning in 1947 was one of the most spectacular meteor falls ever recorded. A massive iron meteoroid weighing up to 100 tonnes had shot into Earth's atmosphere at the mind-boggling speed of about 13 kilometres per second. That's fast. At that speed someone could drive from Sydney to Melbourne in about 80 seconds! When the meteoroid struck Earth's atmosphere, it began to break up into smaller pieces. These pieces continued toward the ground, becoming luminously hot. As they moved downward through the different layers of Earth's atmosphere they changed colour from bluish-green to yellowish-red. Then, as witnesses described, the largest piece exploded just before hitting the ground.

So eyewitnesses had seen not an atom bomb, but a huge meteor delivering a hot, thunderous hail of meteorites to the surface of our planet.

Meteoroids, Meteors and Meteorites

But what are these visitors from outer space? Where do they come from? How do they get here? And what can they tell us about our planet and our planet's home, the solar system?

First, it's important to use the correct terms. A *meteoroid* is a small solid body — too small to be considered an asteroid (which is actually a very small planet) — travelling through space. When a meteoroid enters Earth's atmosphere it heats up until it is seen as a luminous streak in the sky known as a *meteor.* (Incidentally, meteors that become brighter than Venus can be called *fireballs* or *bolides*.) Any of the meteoroid that doesn't completely burn up or vaporise on its journey through Earth's atmosphere and reaches the ground is called a *meteorite*.

Where Do Meteorites Come From?

Most meteorites are probably pieces of *asteroids* that come from the *Asteroid Belt* between Mars and Jupiter, hundreds of millions of kilometres away. As we've seen, an asteroid is a very small planet. It orbits the Sun and it might have craters, mountains, volcanoes and even its own moons!

Image courtesy **NASA**

Meteorite material? Asteroid Gaspra — a huge rock, about 18 kilometres long, tumbling through space in the Asteroid Belt

The Asteroid Belt is a zone, 374 million kilometres wide, made up of hundreds of thousands of asteroids. The largest asteroid, Ceres, was the first to be discovered — in 1801. It is 933 km in diameter. Vesta (530 km), Pallas (522 km) and Hygeia (430 km) are the next largest. Most other known asteroids are considerably smaller.

The Asteroid Belt occurs where early astronomers expected to find a planet because of the large gap between the orbits of Mars and Jupiter. That is why scientists believe that the Asteroid Belt is actually made up of planetary matter that failed

to join together through collisions with one another to form one large planet — a process called *accretion*. Scientists believe that this is how the inner planets of the solar system — Mercury, Venus, Earth and Mars — were formed. This also means that the material of the asteroids, being the building blocks of the planets, is likely to be very old — up to 4.5 billion years old — the age of the solar system itself!

Long-Distance Travellers

In order for meteorites to end up on Earth they must travel a long way for a long time! Every now and then in the crowded, busy Asteroid Belt, asteroids crash into each other. But rather than join together, they break into bits. These bits of asteroid might then be set adrift on a new orbit in the solar system, sailing through space for millions of years until, if they pass near enough to Earth, they are captured by its gravitational pull and brought down to Earth's surface. (Sometimes, particularly large pieces, or even full asteroids, end up becoming moons of a planet, such as Mars's two small, potato-shaped moons, Phobos and Deimos.)

What Meteorite is that?

No two meteorites are are completely alike, but every meteorite belongs to one of three broad categories:

- *iron* meteorites
- *stony iron* meteorites
- *stone* meteorites.

It is believed that iron meteorites were formerly part of the core of asteroids. Stony iron meteorites are believed to be part of the asteroid's stony *mantle* — the layer around the core. Stone meteorites are believed to be from the asteroid's stony crust.

But in some cases, stone meteorites aren't from asteroids at all.

Mars Rocks and Moon Rocks

Some very rare meteorites are actually rocks from Mars and the Moon! As incredible as it might seem, this is made possible when large meteorites or even asteroids strike a planet or moon's surface. Rocks from that surface can be blasted into the sky as a result of the massive impact. To enter space, these rocks have to be ejected at a speed known as *escape velocity*. This is the speed something must reach to escape its planet's atmosphere and gravitational pull in order to enter space. The moon, for instance, has only one sixth of Earth's gravity and no atmosphere, so a rock from its surface only needs to be blasted into the sky a few times the speed of a bullet from a rifle. Mars's escape velocity is greater than the Moon's, but still a lot less than Earth's.

A rock from Mars found in Antarctica. The small cube is 1 cm.

Images courtesy **NASA**

Meteorites from the Moon are always stone meteorites because they are from the Moon's rocky surface. Two types have been discovered: stones from the Moon's low lying "seas" (smooth, former oceans of molten lava), and stones from the Moon's rocky highlands. Even though astronauts have visited the moon six times and collected many rocks, specimens from the Moon's rugged highlands are extremely rare. They are different from the lowland rocks and are very useful for research.

A rock from the Moon found in Antarctica

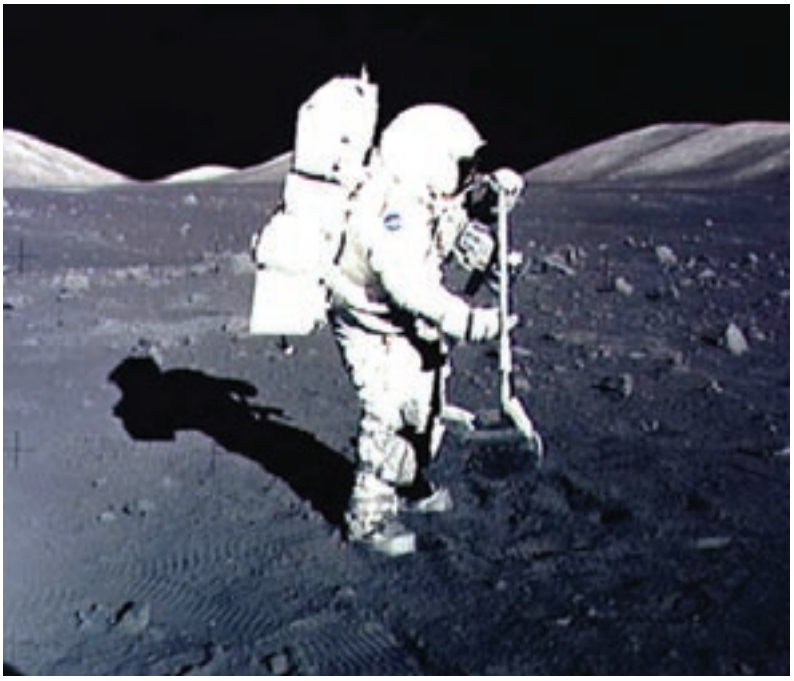


Image courtesy **NASA**

The more expensive way of getting rock from the moon. An astronaut from the Apollo 17 mission collecting rock samples from the Moon's surface.

How to Identify a Meteorite

Although meteorites are made of materials that can be found on Earth, they have features that tell us these objects could only have come from somewhere else in the solar system.

Six major features help to identify a meteorite:

- *presence of iron*
- *density* (iron meteorites are typically 3.5 times as heavy as the average Earth rock, while stony meteorites are about 1.5 times as heavy)
- *magnetism* (due to the presence of iron)
- *fusion crust* (due to the meteorite's hot journey through Earth's atmosphere)
- *chondrules* (1 mm diameter stony balls found inside common stone meteorites)
- *regmaglypts* (flight markings that look like thumb impressions in playdough).

Fireworks and Fusion Crusts

The fusion crust of a meteorite is the result of its turbulent, intense passage through Earth's atmosphere. As mentioned earlier, meteorites (or meteoroids as they are called at this stage) strike Earth's atmosphere at phenomenal speeds. Just as you feel the friction of air as it passes you when you're on a roller-coaster, so too does a speeding meteoroid feel friction when it enters the thick, particle-filled, gaseous layers of Earth's atmosphere — only in a much greater way! The resulting friction causes the meteoroid's surface to reach temperatures in excess of 1,600° C. At this heat the surface turns to liquid, then gas, and bursts into blazing light like a firework! In most cases, these are the "shooting stars" that brightly dart across Earth's night skies.

Meteors as small as a grain of sand totally burn up at this stage, but larger ones that survive to hit the ground are marked by their journey. Their surface has a crust that melted during the meteorite's fall, then solidified when it cooled. This is the fusion crust. Sometimes it is blackened by its fiery journey.

The smooth, shiny fusion crust of the Sikhote-Alin meteorites makes them some of the most beautiful and unearthly-looking of all meteorites. The crusts marvellously tell the story of the meteorite's journey to Earth.

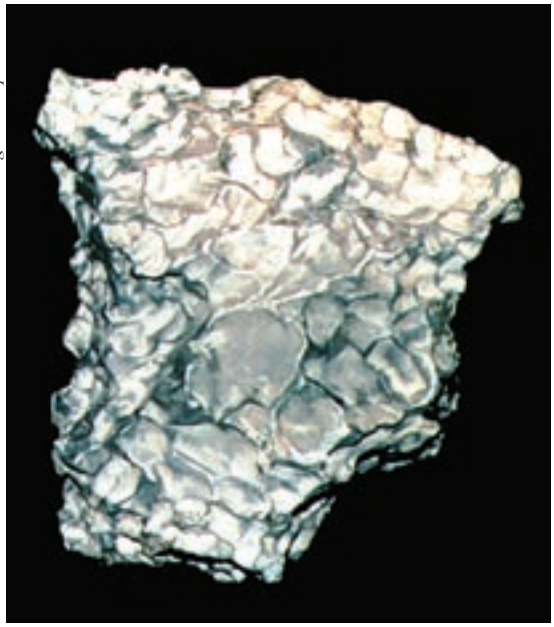


Image courtesy NASA

A Sikhote-Alin meteorite clearly displaying regmaglypts and a smooth, shiny fusion crust

Regmaglypts

This unusual word — try using it in casual conversation — refers to another remarkable feature found in some meteorites, particularly iron ones such as Sikhote-Alins. A regmaglypt is a sculptural impression in a meteorite's surface that looks as if it has been made by a thumb. It results from the same conditions that created the meteorite's fusion crust. As the meteorite heats up, parts of its surface melt at different temperatures. The parts that melt first, usually certain minerals, are scalloped out of the meteorite, and this leaves cavities or "impressions" in the surface.

Message in a Bottle

Many iron meteorites arrive on Earth with an extraordinary secret inside them.

If you were to slice one of these iron meteorites cleanly in half, then etch and polish the surface of its cross-section, an unusual pattern in the iron would be revealed — the amazing *Widmanstatten* pattern!

This angular, crystalline pattern is the result of a truly awesome set of circumstances, and it can only be found in iron meteorites that have journeyed for almost an eternity through time and space.

Think about this! The mixture of iron and nickel that makes up the meteorite needs to have formerly been in an extremely hot, molten state, such as within the core of an asteroid. Then, having been released from the asteroid's core through a collision with another planetary body, it needs to have been allowed to cool in near-zero gravity conditions — such as in space — at a rate of as little as 1°C per million years . . .

Imagine waiting for a piping hot bowl of soup to cool — not for a few minutes, but for hundreds of thousands of years!

Nonetheless, the result of this slow cooling of iron meteorites is the Widmanstatten pattern, and it is clearly visible in the meteorites that fell in Sikhote-Alin.

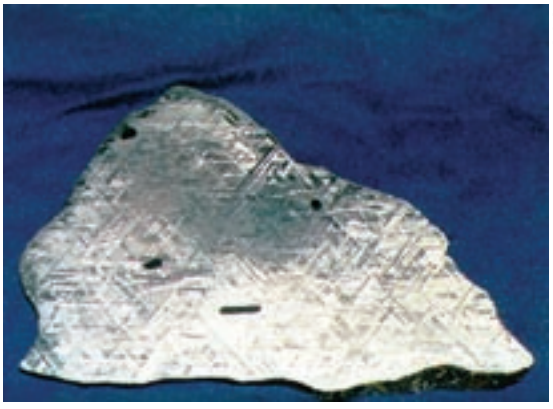


Image courtesy NASA

The geometrical Widmanstatten pattern visible on the face of a cleanly sliced and prepared Sikhote-Alin meteorite

Craters

Craters are spectacular evidence of meteorite falls. Interestingly, it is only in the last fifty years that people have accepted that this is how some craters on Earth were formed.

The most famous crater is probably Meteor Crater in Arizona, in the United States. This crater is nearly 1,200 metres across and 180 metres deep. It would have taken a meteorite more than 50 metres across, weighing many millions of tonnes, to make a crater this size.

Australia has many significant craters. The most impressive are Wolfe Creek Crater in Western Australia (875 metres across and 48 metres deep) and the much smaller Henbury craters in the Northern Territory.

Visiting Giants

The largest known meteorites on Earth are either in museums or are so big they cannot be moved from where they were found! This is definitely the case of the very largest — the 61-tonne iron Hoba meteorite in Namibia, Africa.

The 34-tonne iron Ahnighito meteorite originally lay in the snows of Greenland. For centuries it was visited by the local Inuit people who cut pieces from it to make knives and harpoons. In 1897 the polar explorer Robert Peary located it and, after an amazing feat of ingenuity and engineering, sailed into New York harbour with Greenland's great meteorite aboard. Its sale paid for him to be able to become the first man to reach the North Pole in 1909.

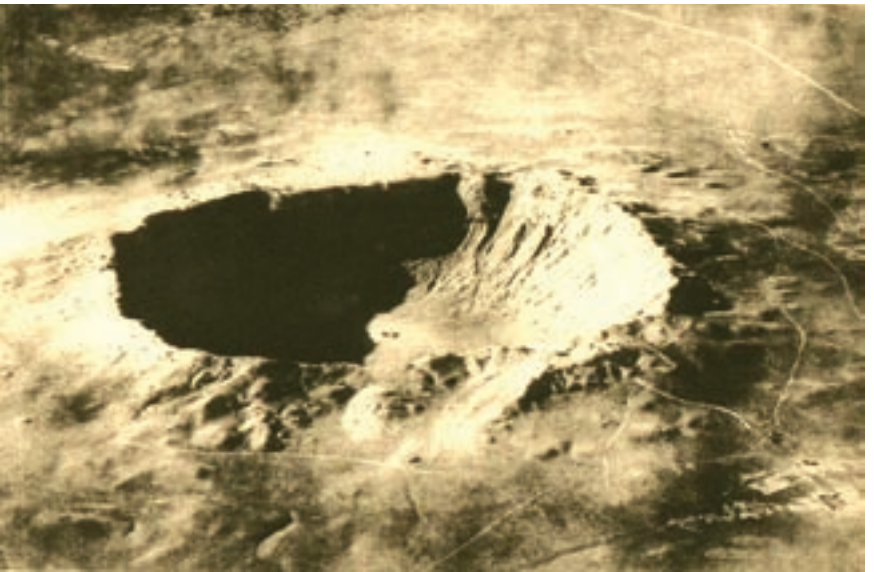
Many similarly unusual tales of adventure and discovery can be told about the various great meteorites in the world's museums. Interesting tales can be told about smaller meteorites too. The unusual iron Tucson Ring meteorite (687 kg) was being used as an anvil in a remote Mexican garrison until it was bought by a collector in 1853.

Near Misses

In all recorded history there does not seem to be a single case of someone being killed by a meteorite. However, there have been some near misses.

In 1954, a woman lying on her couch in Alabama in the United States was struck on the hip by a 4-kilogram meteorite — but only after it had passed through her ceiling and bounced off her radio. Having been slowed down by these impacts, it then landed on the doubly thick quilt she was under, giving her a nasty bruise.

In 1992, in Peekskill, New York, also in the United States, the owner of a car was more than surprised when a 12-kilogram meteorite, still warm and smelling of sulphur, plummeted into the car's



Meteor Crater in Arizona, at least 20,000 years old

Image from the Smithsonian Scientific Series (1929), taken by the US Army Air Service

boot! The car, now known as the Peekskill Meteorite Car, is famous and tours the world as an exhibit.

Australia had its turn in 1984 when a meteorite shot into the sand beside two sunbathers at a beach in Western Australia. The 488-gram Binningup Beach Meteorite had streaked unnoticed across the morning sky before its surprise landing. Hearing a sound like gunfire, the two women thought they had been shot at!

Although humans appear to have been spared death by meteorite, sadly the same can't be said for a dog in Nakhla, Egypt that died in 1911 when it was struck by a rock from Mars.

Meteoritics

Meteoritics is the study of meteorites and the origin of the solar system. The information that meteorites are revealing to humankind is rapidly revolutionising ideas about the origins of life, planets and the solar system . . . not to mention evolution. Only since the 1980s has the sudden extinction of dinosaurs been explained by a huge asteroid colliding with Earth. Meteoritics is very new, very rich and very exciting scientific territory!

Famous Last Words

Meteorite falls and showers — or as William Shakespeare once put it, "This majestical roof, fretted with golden fire" — have appeared in art and literature throughout history. English poet Samuel Taylor Coleridge describes what appears to be a meteor shower in "The Rime of the Ancient Mariner". This wonderful description set at sea may have been inspired by the Leonid meteor shower Coleridge witnessed in 1797:

A woodcut depicting the Leonid meteor shower of 1799

The upper air burst into life!
And a hundred fire-flags sheen,
To and fro they were hurried about!
And to and fro, and in and out
The wan stars danced between
And the coming wind did roar more loud,
And the sails did sigh like sedge;
And the rain poured down from one black cloud;
The moon was at its edge.

As they have in the past, meteors and meteorites continue to inspire awe and amazement. And, by their spectacular entry into our world, these fiery messengers from outer space continue to inform, enchant and remind us of the colossal universe of time and space — of which we are such a tiny, tiny part.