Meteorites

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Meteorite: Objects composed of stone, metal or mixture of stone and metal originating in outer space that survive their fall from space to land on the Earth.

Meteor: Objects from outer space that burn-up/vaporize in the atmosphere and do not survive to land on the Earth's surface.

Meteorite Sizes

Micrometeorite Dust – Hundreds of tons per day fall onto the Earth's surface

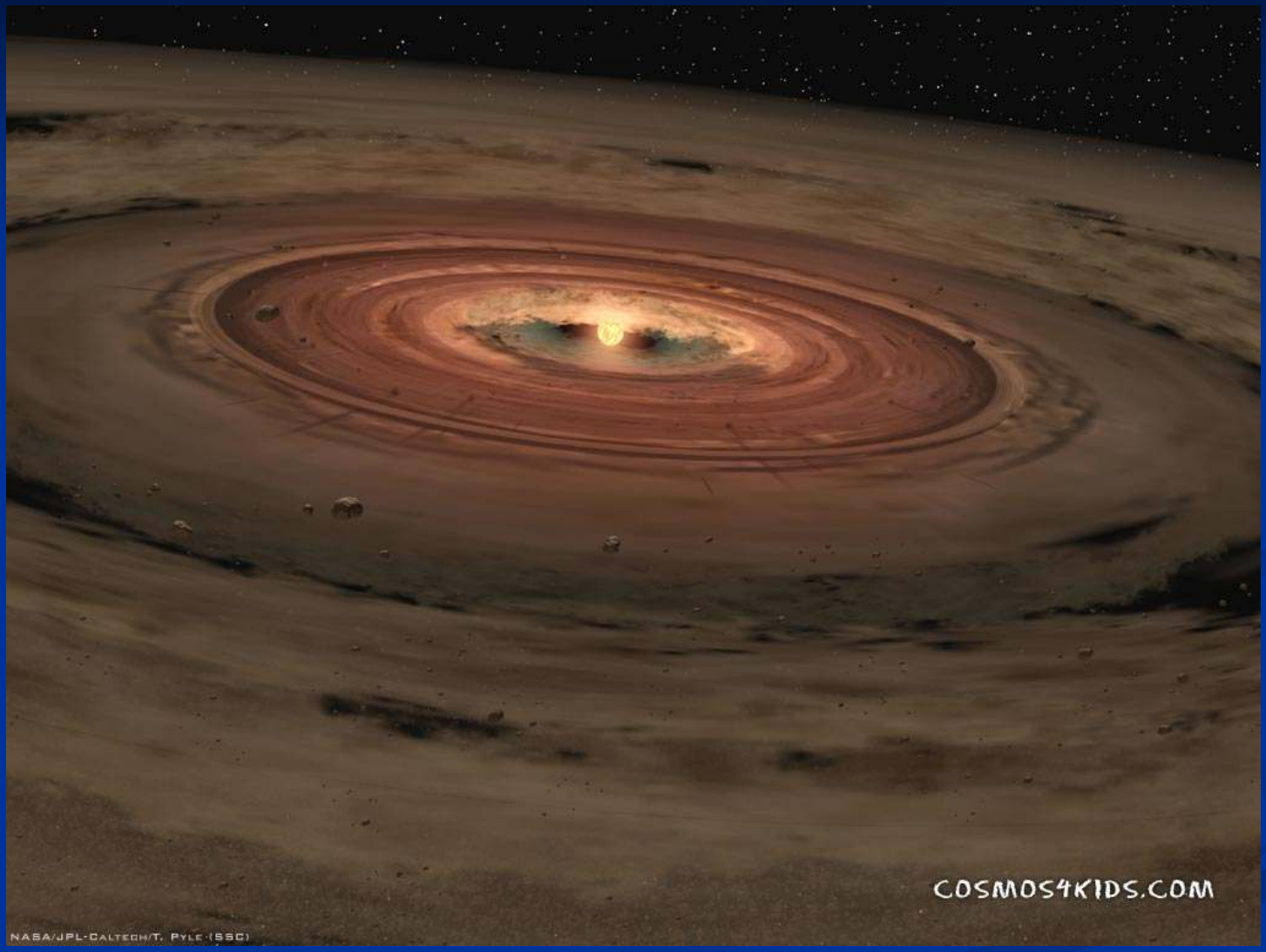
Hoba Meteorite: Largest Known on Earth, 60 tons, Namibia

Origin of Meteorites

- The vast majority of meteorites originate from the asteroid belt located between the orbits of Mars and Jupiter (99.3%), a few come from the planet Mars (0.2%) and the Moon (0.4%) and a very rare type of meteorite comes from comets (<0.1%).

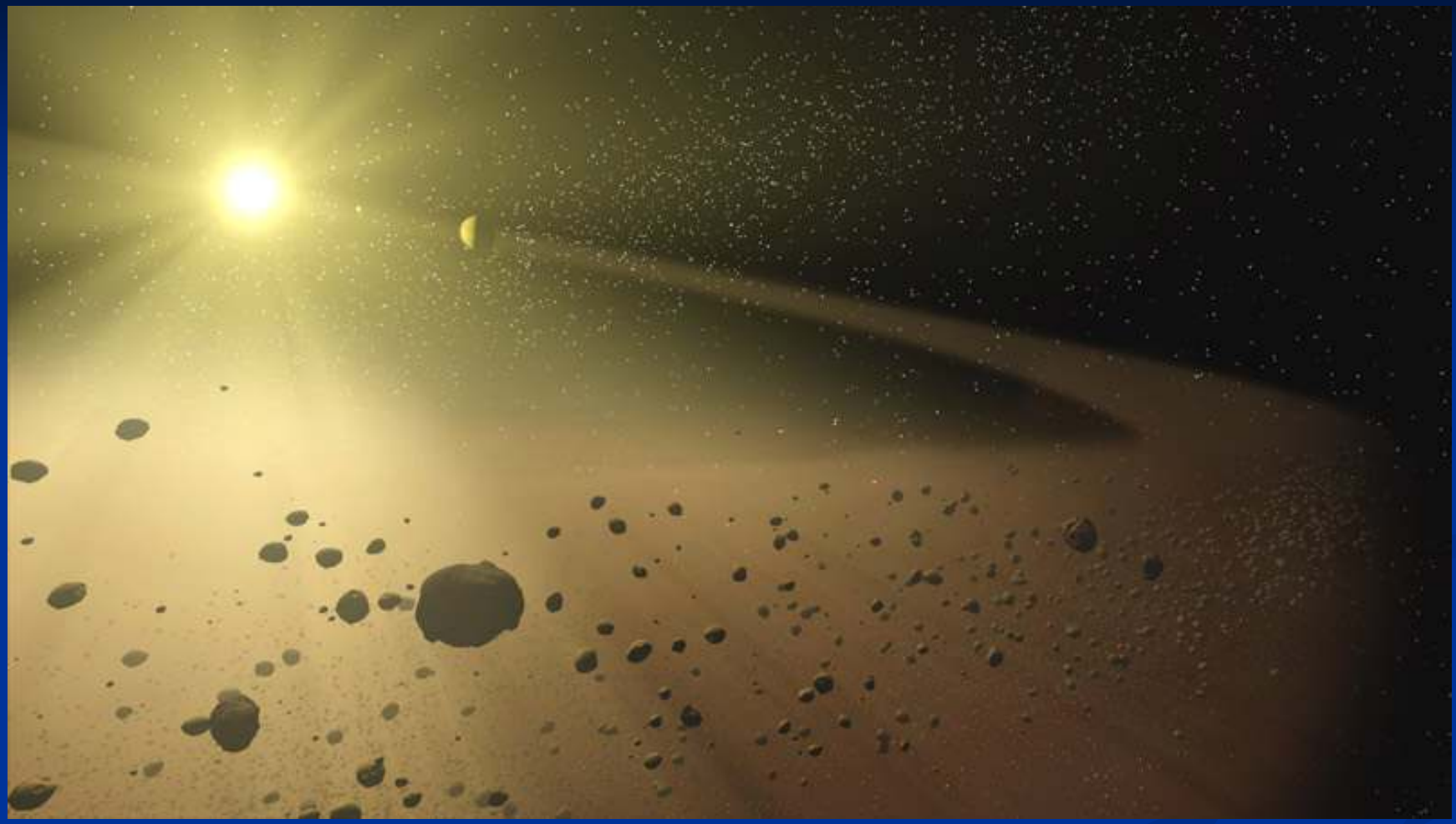
- Asteroid meteorites are 4.57 billion years old and are the remains of the building blocks of the solar system that never collected to form into a full-sized planet.

- No Earth rocks are as old as asteroid meteorites because they have all been ground up and reformed repeatedly by erosion and the Earth's tectonic plate system.

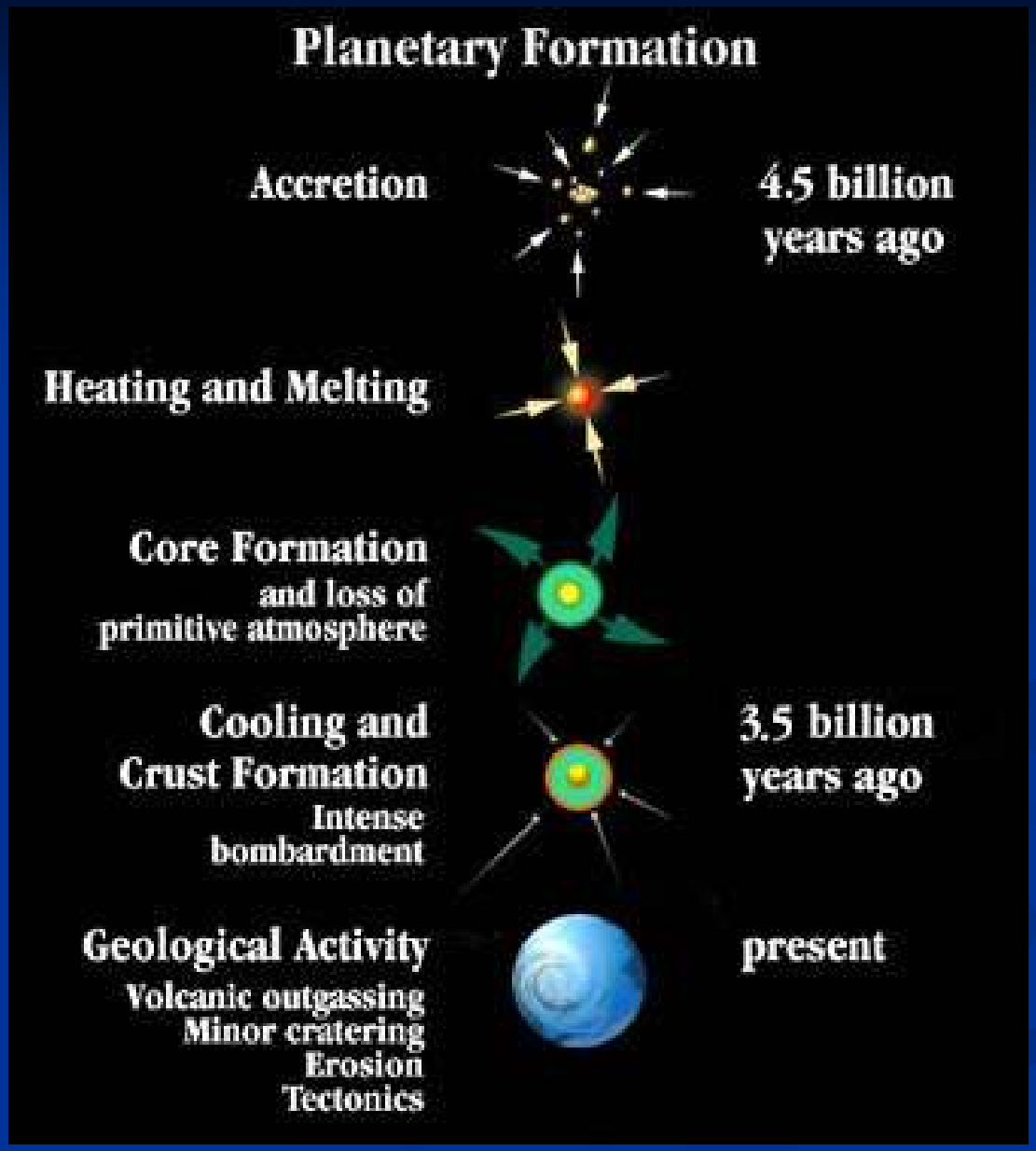


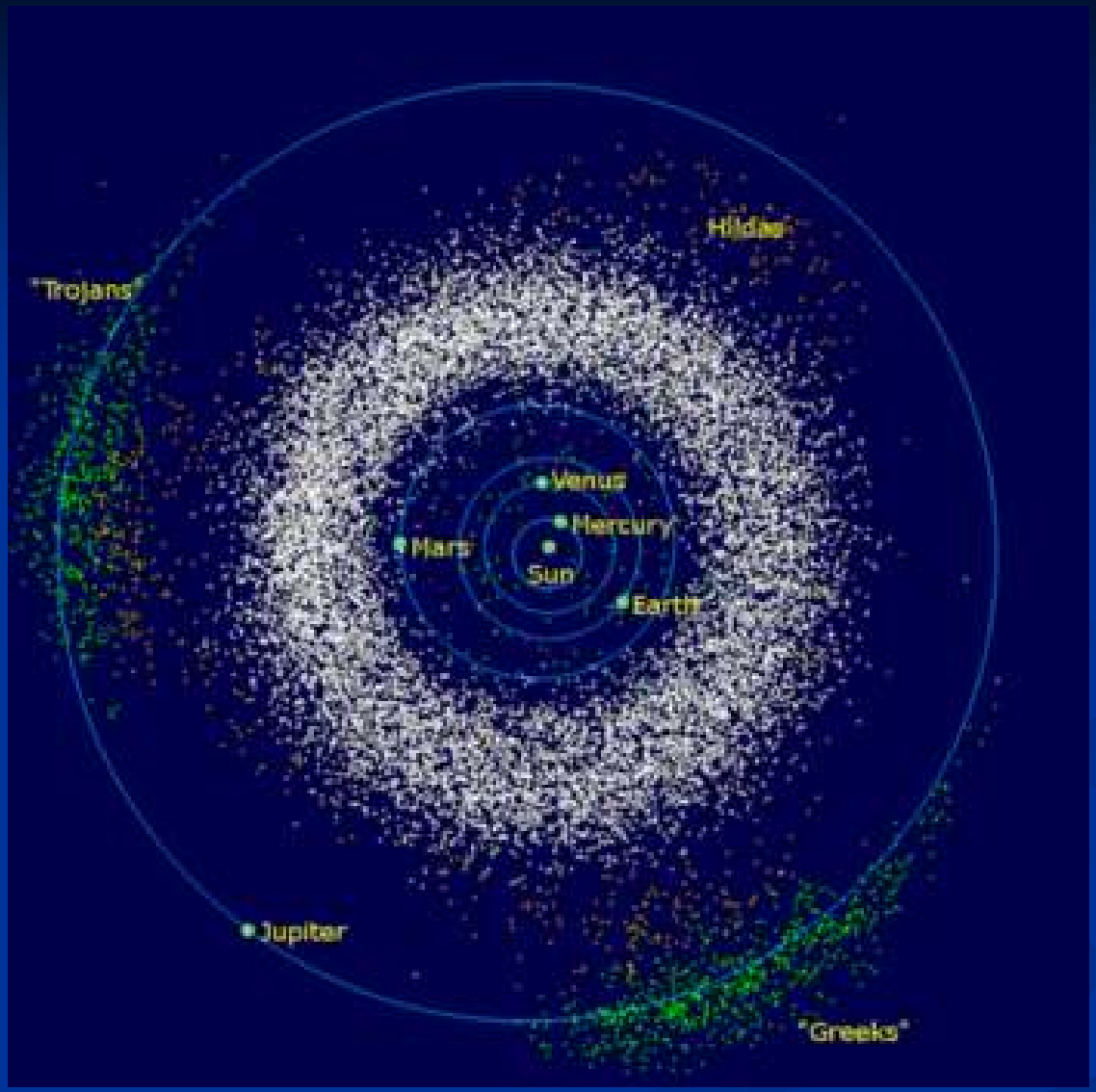
Solar System Disk of Gas and Dust After Formation of the Sun

Early Solar System Formation



Asteroid Belt shortly after planet formation was complete


Planetary Formation
Accretion
4.5 billion years ago
Heating and Melting
Core Formation
and loss of primitive atmosphere
Cooling and Crust Formation
Intense bombardment
3.5 billion years ago
Geological Activity
Volcanic outgassing
Minor cratering
Erosion
Tectonics
present



Asteroid locations in the solar system

Asteroid Examples

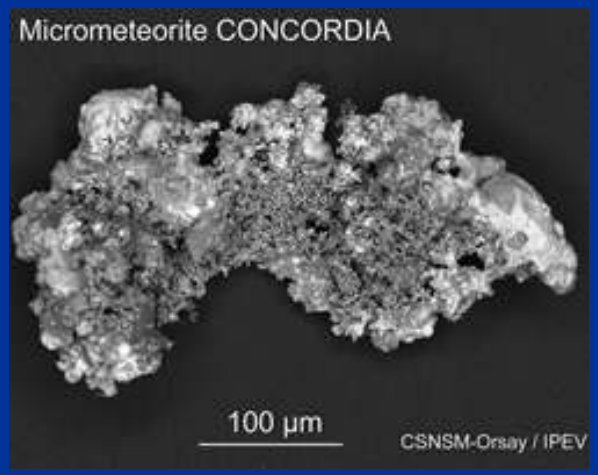
Before entering the Earth's atmosphere meteorites are
Known as Meteoroids and are traveling in space at an
An approximate velocity of 68,000 mph (18.8 miles/sec)

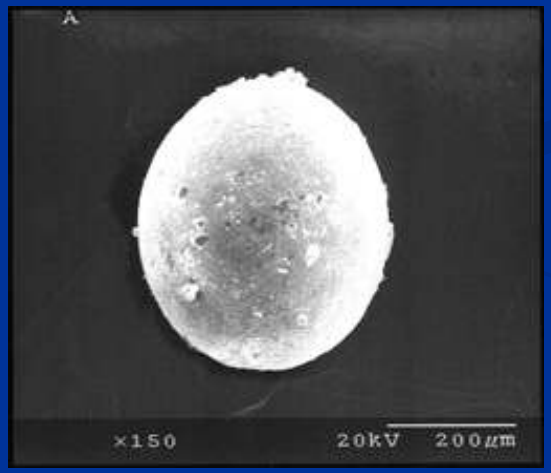
As a meteoroid reaches the Earth's atmosphere it begins to slow down due to friction with the atmosphere and heats up and is then called a Meteor.

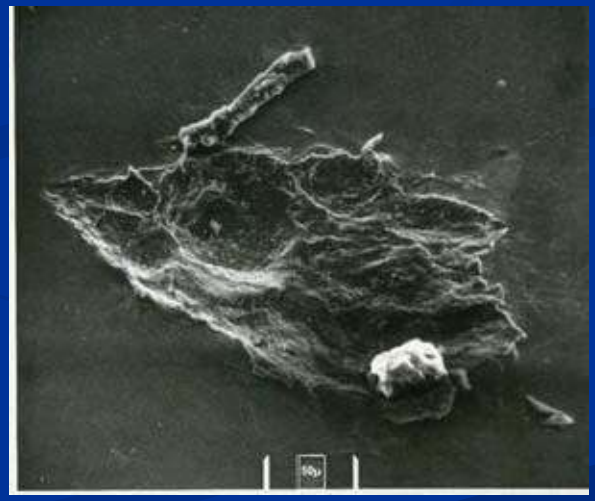
Most meteors do not survive the pass through the atmosphere since the entire object is vaporized and destroyed.

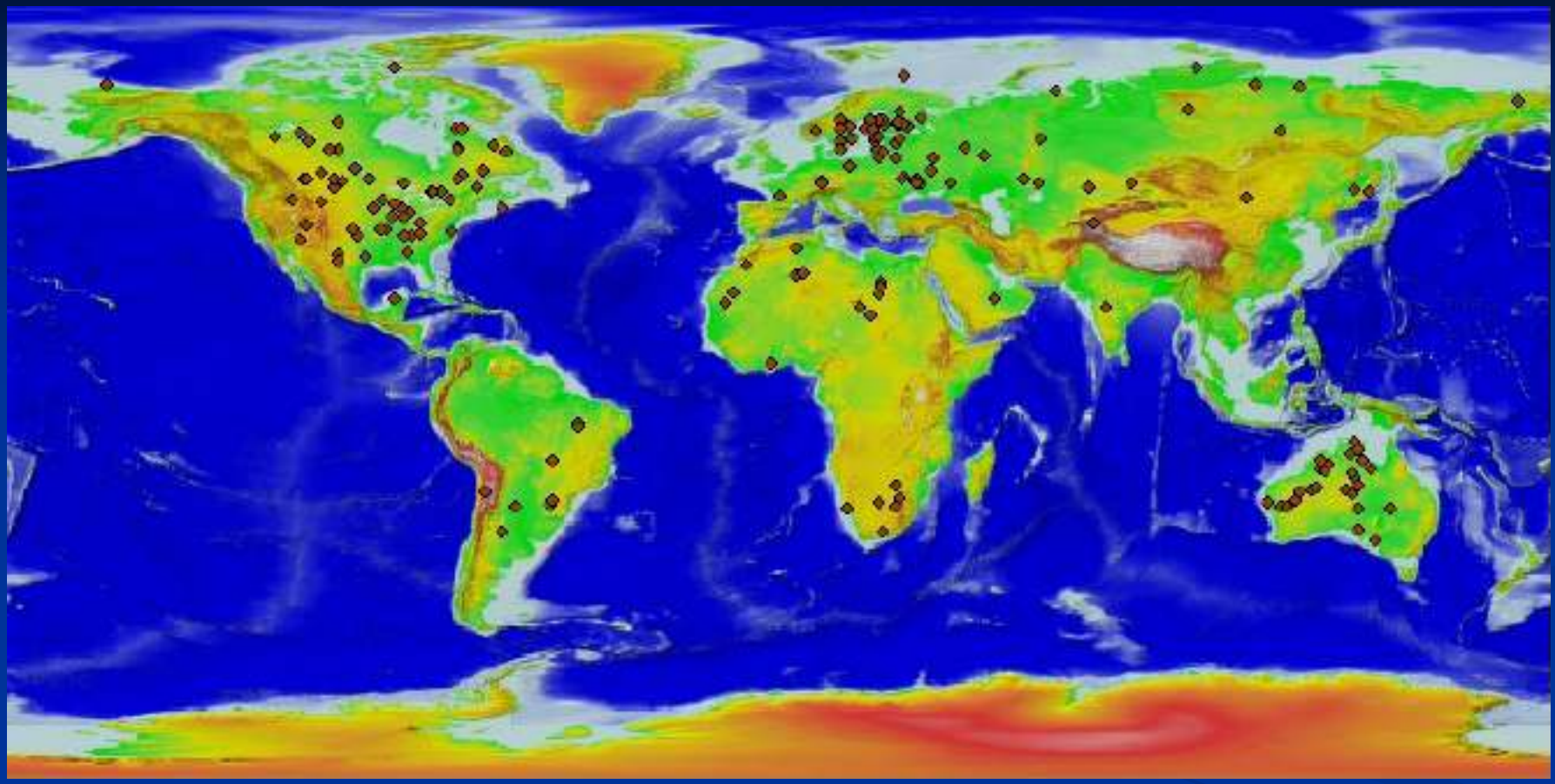
For those meteors that do survive to become meteorites, as it travels through the atmosphere only the outermost layer melts. As the meteor is further slowed down by the atmosphere its molten surface forms a glassy coating called a fusion crust. The interior will remain cool and as it comes into contact with the cold upper atmosphere (40,000 to 80,000 feet), the outer layer will cool and only be slightly warm when it lands.

The vast majority of meteors that land on the Earth are in the form of tiny dust grains <1mm in size when they enter the Earth's atmosphere. Since they are so small, the radiate away frictional heating so rapidly that they do not melt and survive their fall to Earth intact.









There are 180 well characterized meteorite craters scattered across The Earth's surface.

A well known crater formed by a 150’ diameter meteor is the Meteor Crater in Arizona also known as Canyon Diablo Crater and Barringer Crater.

The impact occurred about 50,000 years ago and until 1960 was thought to be of volcanic origin until Astrogeologist, Eugene Shoemaker, discovered the mineral Stishovite which can only be formed by an instantaneous overpressure.

Over 30 tons of meteorite material has been recovered representing only 0.01% of the mass of the impactor. The rest of the material vaporized on impact.

Meteorites are always named for the place where they were found usually a nearby town or geographic feature.

In cases where many meteorites were found in one place, the name may be followed by a number or letter, i.e. Allan Hills 84001.

Canyon Diablo Meteorite

Types of Meteorites

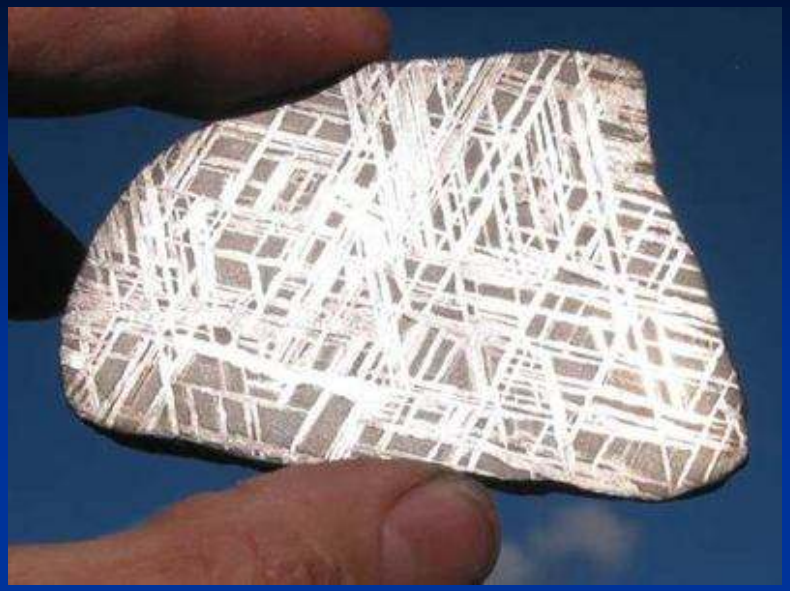
Meteorites are divided into three main types: Stones, Irons and Stony-Irons.

Stony meteorites are further sub-divided into the unmelted Chondrites and the melted Achondrites.

During the formation of the solar system, asteroids that have been heated to their melting point will have the silicate material (stone) melt and flecks of metals such as iron will coalesce and this heavier metal material will sink to the core of the asteroid even under low gravitational forces. Meteorites will come from various areas of this differentiated in-depth asteroid broken loose from asteroid collisions. Some asteroids coalesced from dust from the original solar nebula and did not melt.

Iron Meteorites

Iron meteorites are composed of iron with varying amounts of nickel dissolved throughout and come from the cores of differentiated asteroids.



The structure of iron meteorites is seen primarily in the Widmanstatten pattern, a texture that forms from very slow cooling from 1,292 F to 842F and forms only when the iron becomes solid. When elements move between minerals when the rock is solid, it is called diffusion. Diffusion happens very slowly and this pattern is not found on Earth. An asteroid core was well insulated and took a very long time to cool. The Widmanstatten pattern is revealed when an iron meteorite is cut and etched with acid.

Stony Iron Meteorites

Stony Iron Meteorites are a mixture of iron-nickel metal and silicon material. These come from the core-mantle boundary of a differentiated asteroid.

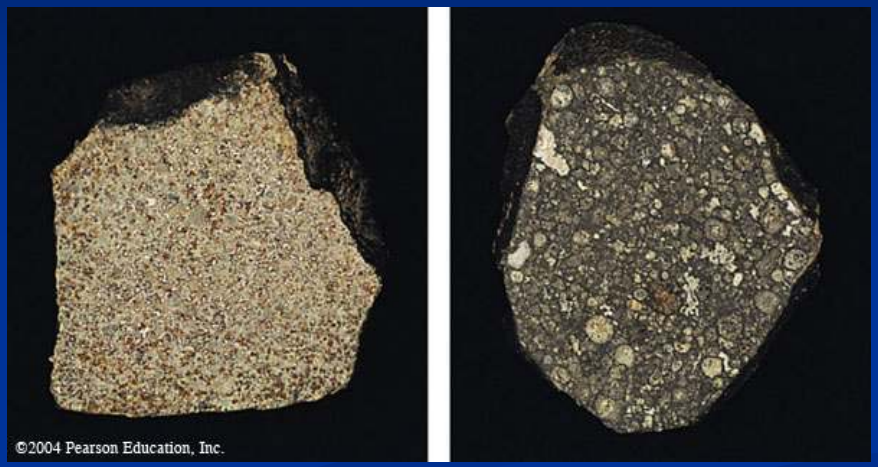
Stony Iron Meteorites

Pallasite

Mesosiderite

The two types of Stony Irons are Pallasite that is composed of the Mineral olivine embedded in a metallic matrix and Mesosiderite that is a jumbled mixture of basaltic and metalic material that formed When two molten asteroids, half iron and haf silicate, collided.

Stony Meteorites



Stony Meteorites are composed of silicate minerals similar to those found in rocks on Earth and come from the upper crusts or mantles of asteroids.

Stony Meteorites are sub-divided into unmelted Chondrites and melted Achondrites

Chondrites: Formed at the same time and from the same material as the inner rocky planets of the solar system.

Four Main Classes of Chondrites:

1. Ordinary (O): Accounts for 90% of all meteorite falls
2. Carbonaceous (C): Rich in carbon bearing compounds, some contain amino acids (Murchinson Meteorite)
3. Enstatite (E): Very oxygen poor composition
4. Rumuruti (R): More oxygen for bonding and devoid of metal

Achondrites: Their textures are igneous (previously melted) and crystallized from a molten state.

Achondrite

Achondrite

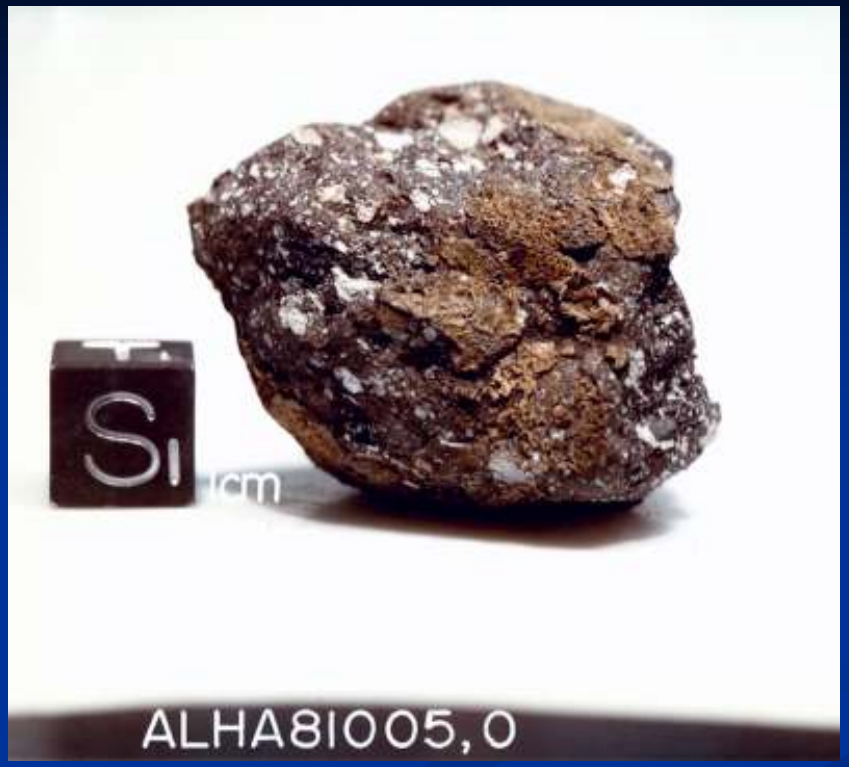
Chondrite

Chondrite

Lunar Meteorites

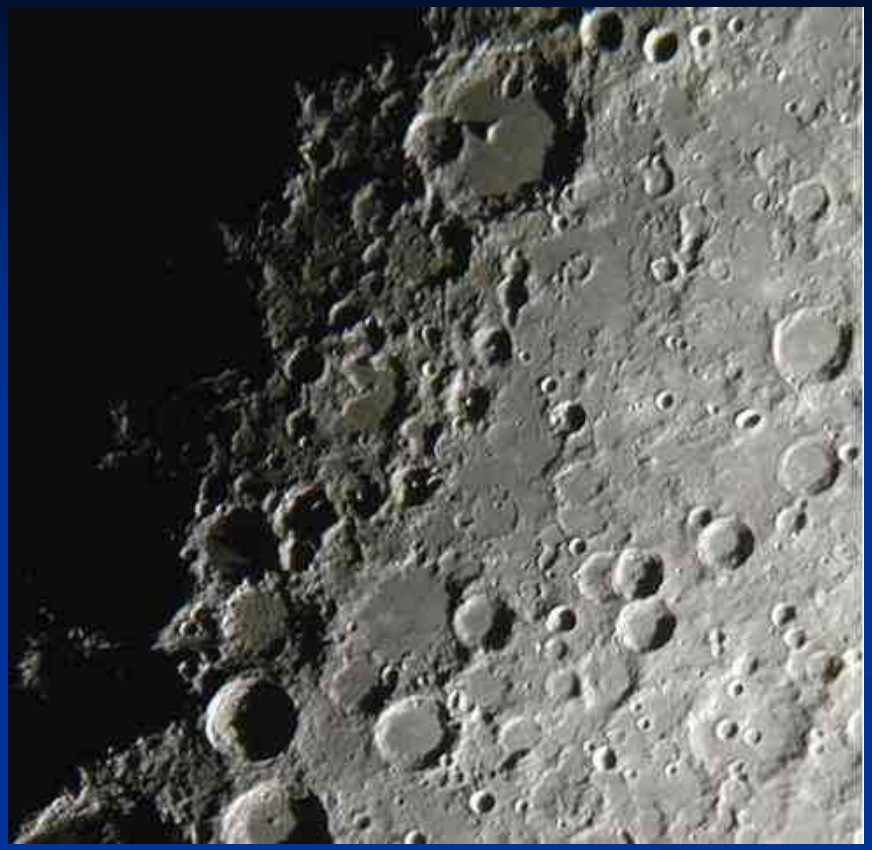
Most meteorites from the Moon have been found in Antarctica (Allan Hills 81005) and the Sahara Desert

Lunar Meteorite
Allan Hills 81005



Meteorites were confirmed to be from the moon because the percentages of elements within them match those measured by remote sensing of the Moon and through direct analysis of Apollo samples.

The oxygen isotope composition of lunar meteorites is identical to that found in the Apollo samples.



Lunar meteorites are debris from the impact of meteors that were ejected into space and after several billion years of traveling in separate orbits in the solar system, some were captured by Earth's gravity and landed on the Earth's surface.

Martian Meteorites

Rocks from Mars are launched from Mars into space by impact ejection. As of 2009, there are 42 meteorites found that originated from Mars.

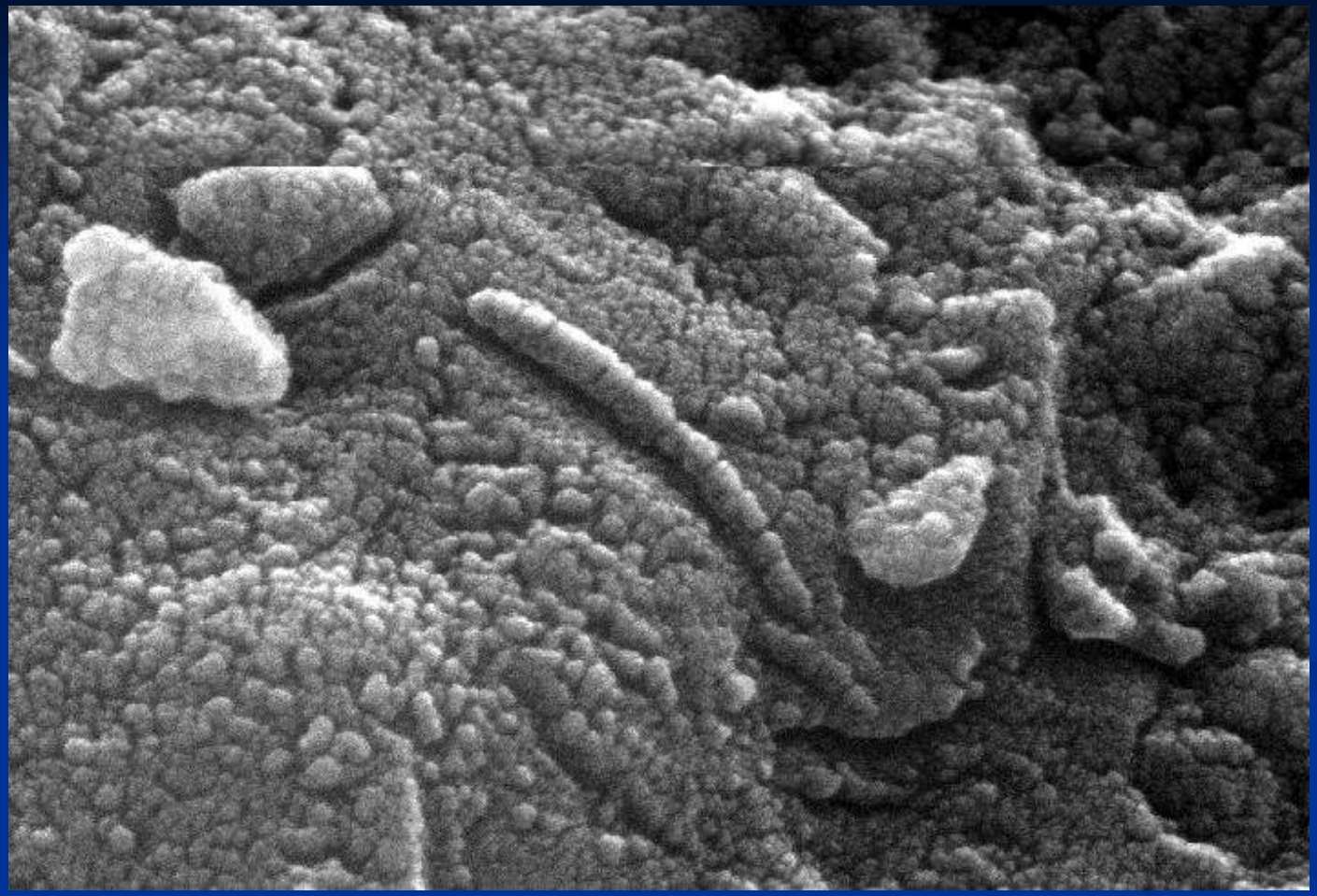
Martian meteorites are 165 million to 1.3 billion years old and the ones found are all igneous and thus only crystallized from a melt.

The martian meteorites are known to be from Mars since the ratio of minerals matches the composition of Mars rocks determined By the Viking landers and Mars rovers.

Also, the composition of gases that are trapped in some martian meteorites (Elephant Moraine A79001) inside black glass pockets s identical to the composition of the air at the surface of Mars measured by Mars landers.

A79001
Martian Meteorite

Meteorite found on Mars by the Rover Opportunity



Mars Meteorite ALH 84001: Electron microscope view (1 micron size) showing a possible microfossil of fossilized bacteria. This is still being debated since the formation could be from a natural mineral process.

Meteorite Collecting

- To find meteorites on your own you need training on what to look for of the many types and would need to travel to desert areas in the U.S. southwest and other parts of the world or other flat open terrain areas with minimal erosion over time.
- The easiest way to start collecting is to buy meteorites from reputable dealers.
- Start out with the basics. Collect some nice inexpensive irons, then some stony and stony-irons and then move on to named pieces that have more history.

Iron Meteorite Fragment – Octahedrite
Campo del Cielo, Argentina

First discovered in 1571, this meteorite fell 4,000 to 6,000 years ago. The composition is 92.2% iron, 6.68% nickel, 1.12% cobalt, phosphorous, germanium, and gallium.

To locate reputable dealers and articles and websites on meteorites use the following:

- **www.meteorite.com**

- **International Meteorite Collectors Association (IMCA), www.imca.cc**
- **Sky and Telescope and Astronomy Magazine's advertisers section**

- **Local Rock, Gem and Mineral Shows. Example: Gem, Rock & Mineral shows; Example: Lebanon PA Fairgrounds, every late August/early September**