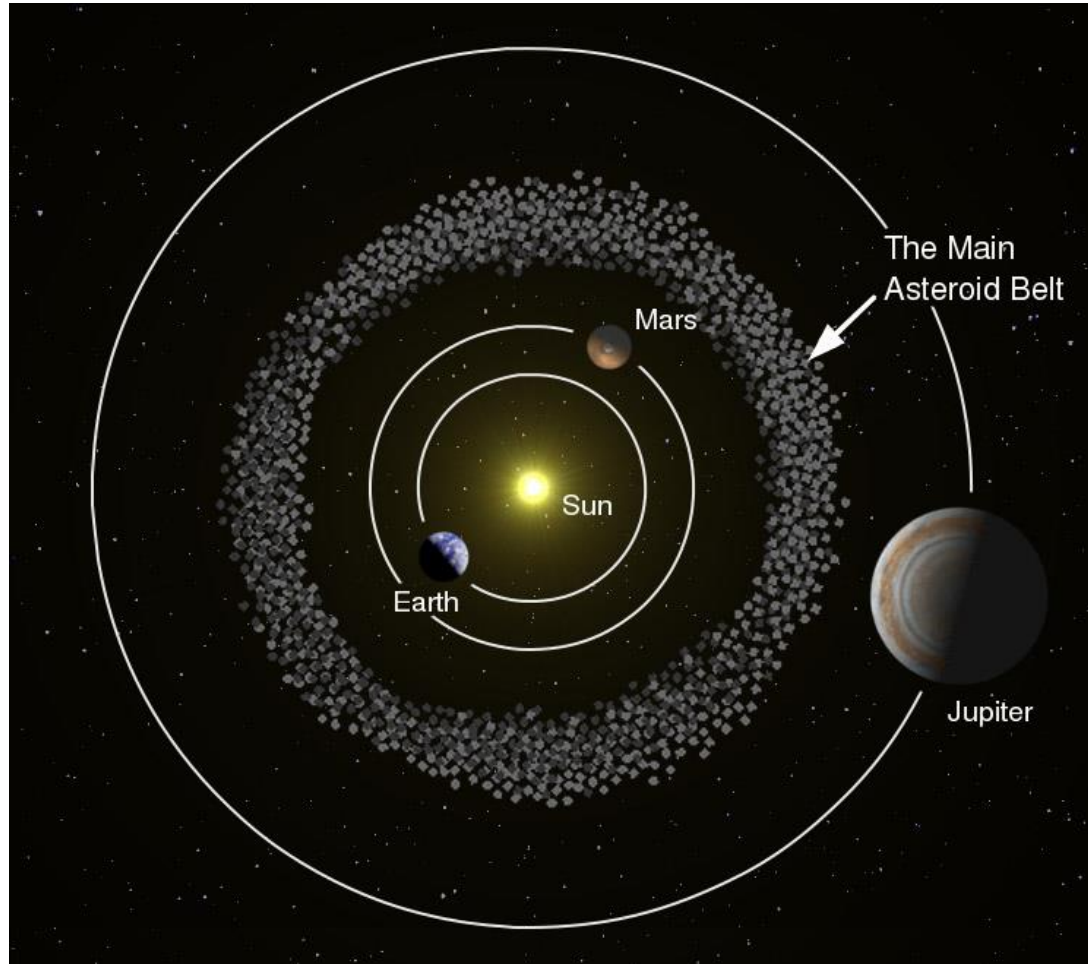


## Lesson 09

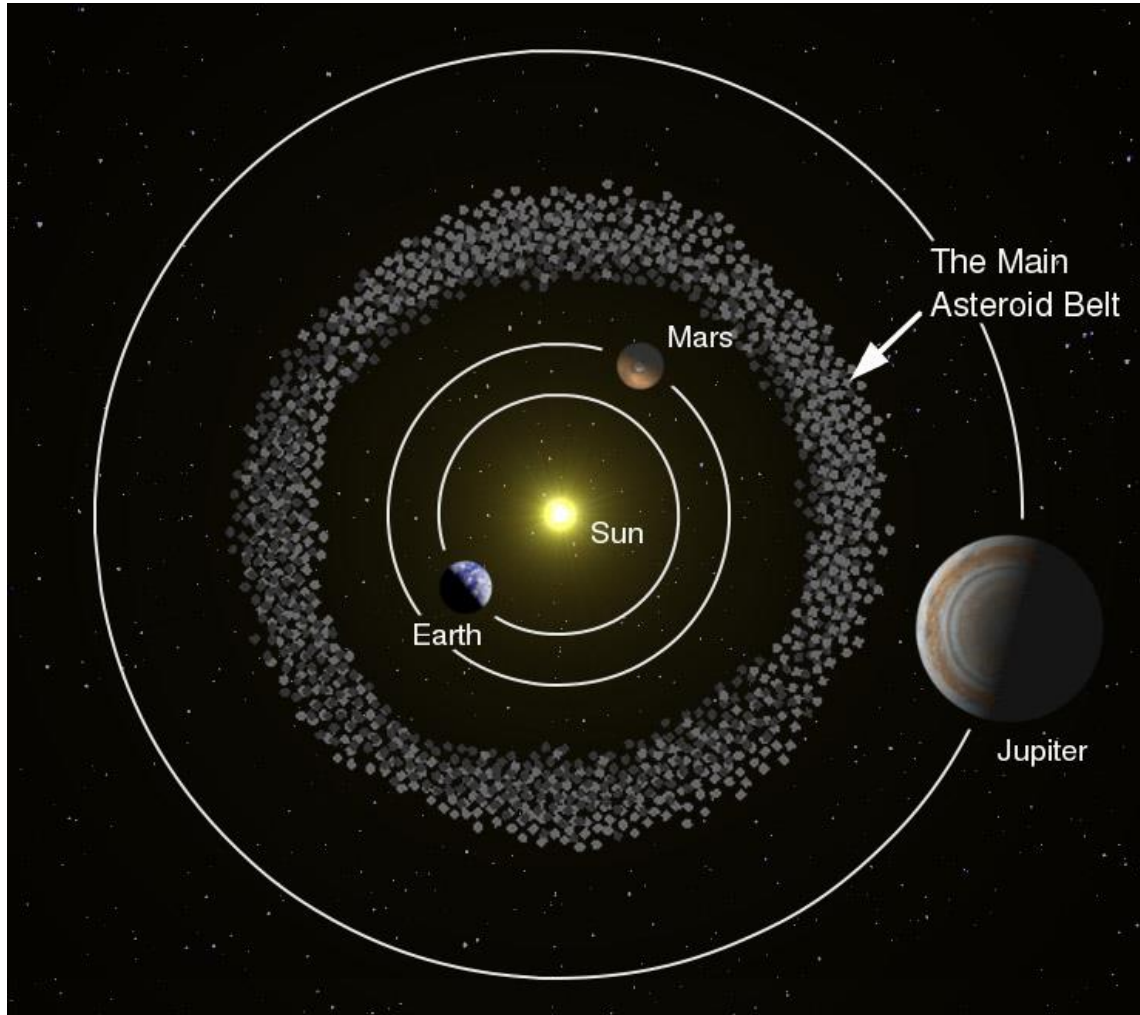
# **Main Asteroid Belt and Impacts**

**Main Asteroid Belt:** The wide ring-like region between Mars and Jupiter's orbit that contains billions of orbiting rocky & metallic bodies (asteroids, planetesimals).



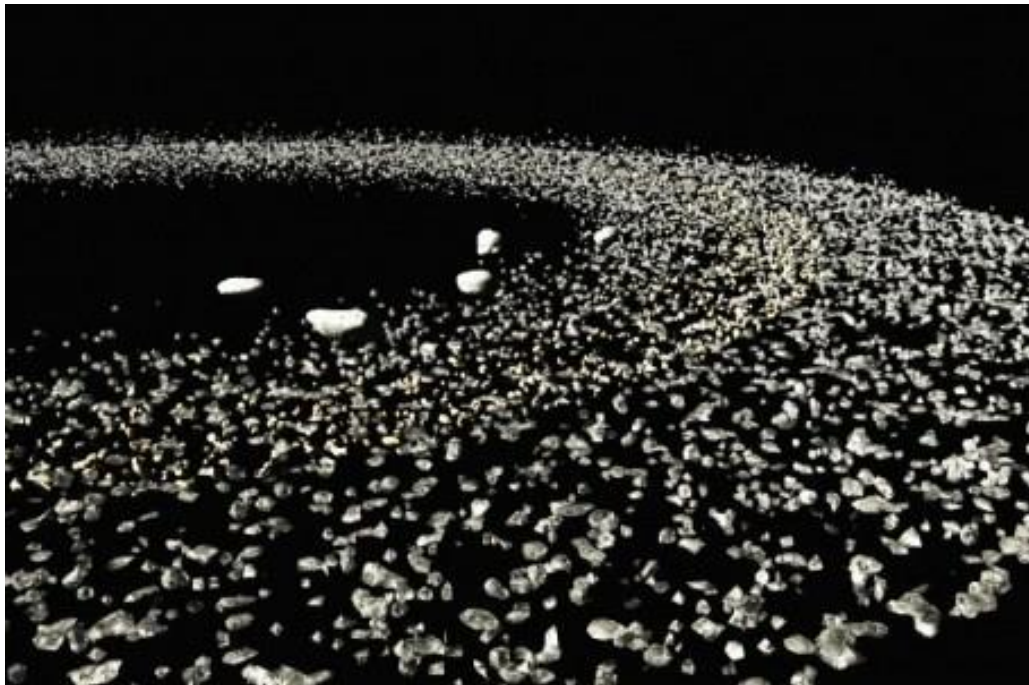
The main asteroid belt lies between the orbits of Mars and Jupiter.

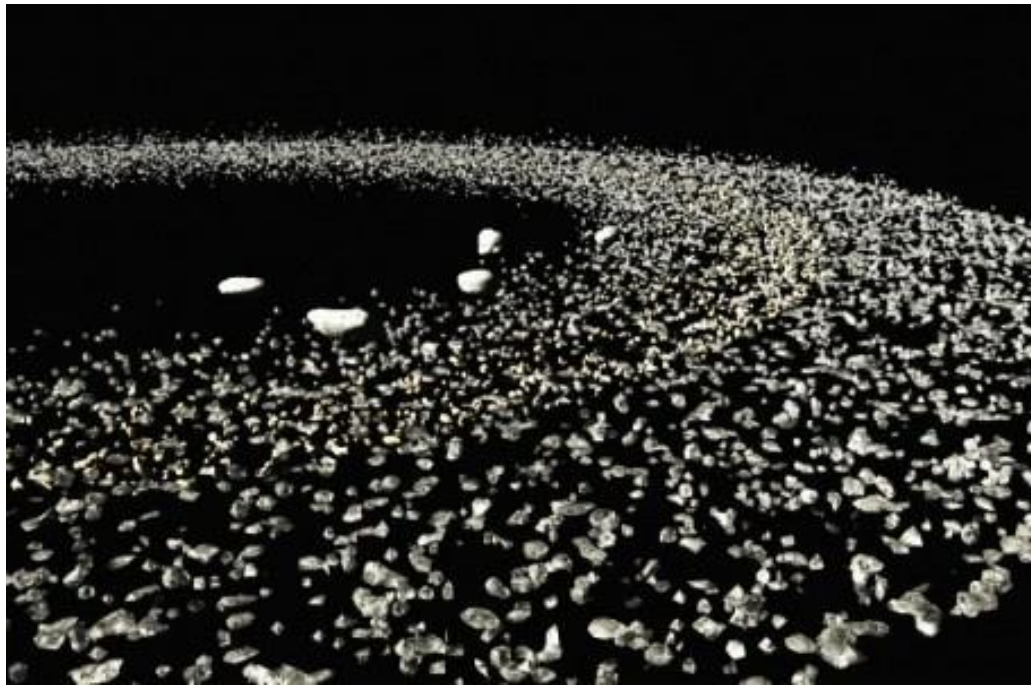
The main asteroid belt is the source of most *meteoroids* that stray into the inner solar system. Some of the asteroids from the main asteroid belt become *Trojan asteroids*.



**Asteroids** are small chunks of rock and metal in space. The sizes of asteroids range from less than 1 meter in diameter to hundreds of km wide.

- Some are made of iron and metal only.
- Some are made of iron, metal, and rock.
- Some are made of iron, metal, rock, and traces of the lighter elements (C, N, S, P, K, Na) and water.





According to evidence, the planets formed 4.5-4.6 billion years ago as planetesimals, asteroids, and dust came together by gravity.

Asteroids are theorized to be “leftover” building block material from the formation of the solar system 4.6 BY ago that did not come together to make a planet. They are thought to be a representation of raw materials from the beginning of the solar system.



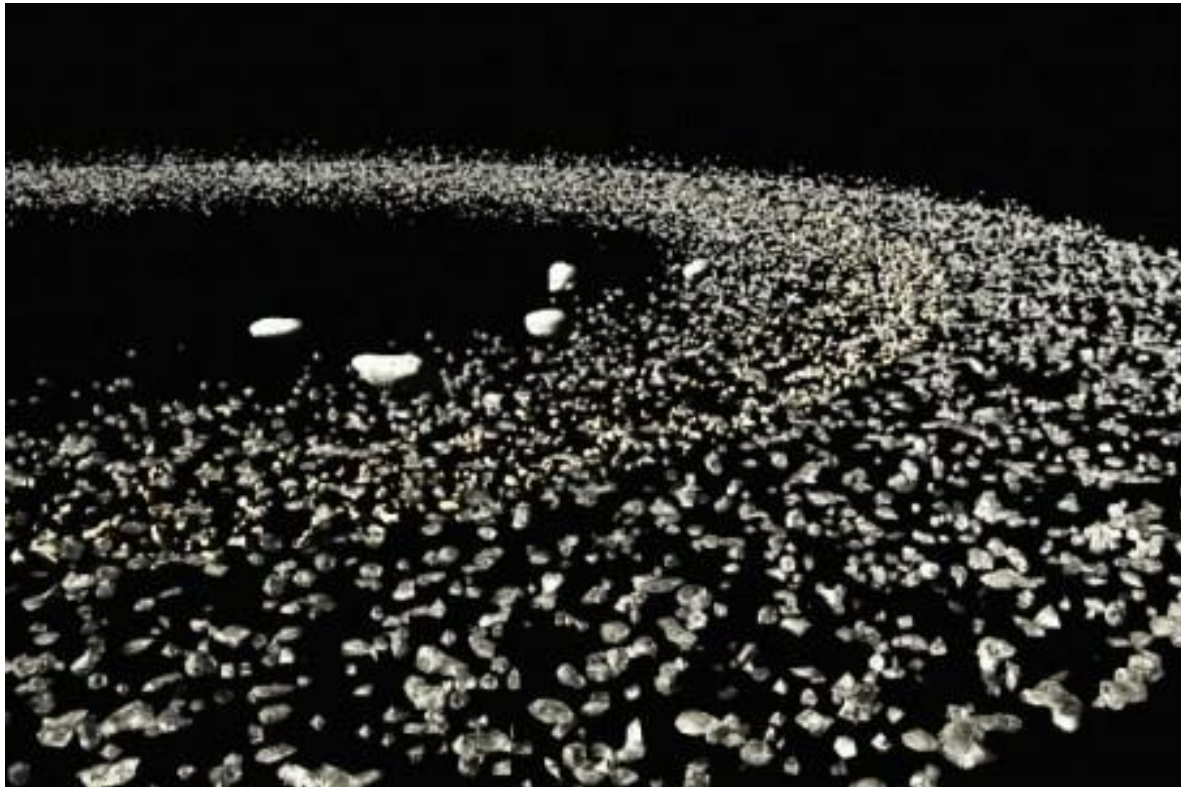
Most asteroids are small, 10-100 m or smaller.

Larger asteroids, 10's to 100's km in size, are sometimes described as **planetesimals** or “small planets”.

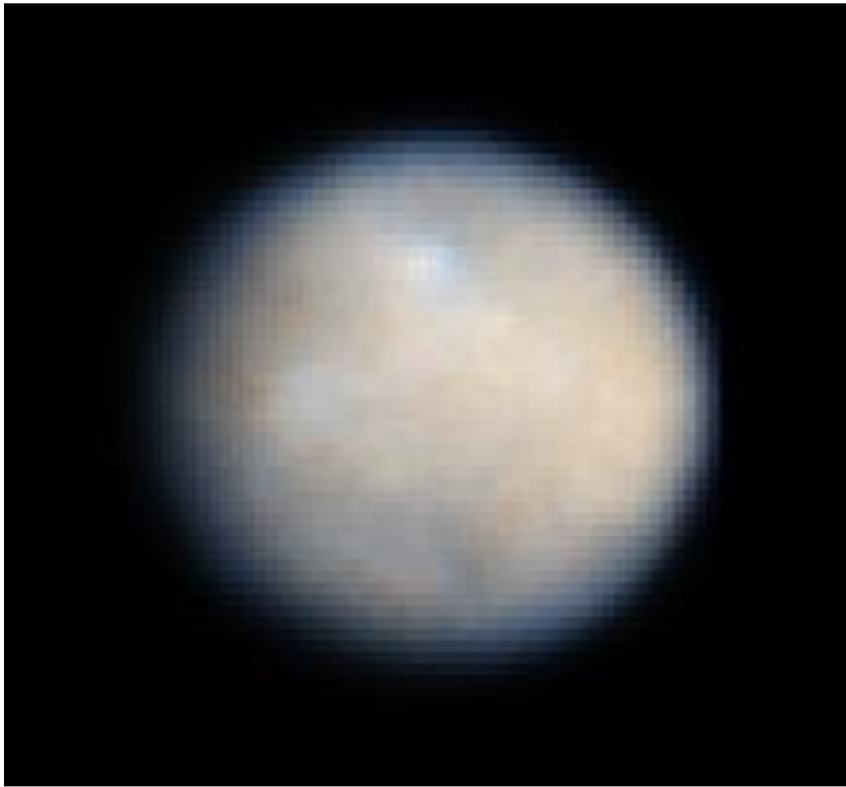
**Planetesimals** are the larger chunks of rock and metal (larger asteroids) that formed when dust, rock, and smaller asteroids clump together under the influence of gravity to make larger and larger bodies.

**Planetesimals** never grew large enough to become a dwarf planet or a true planet. They do not have enough mass and not enough gravity to become spherical when they formed. They have irregular shapes.

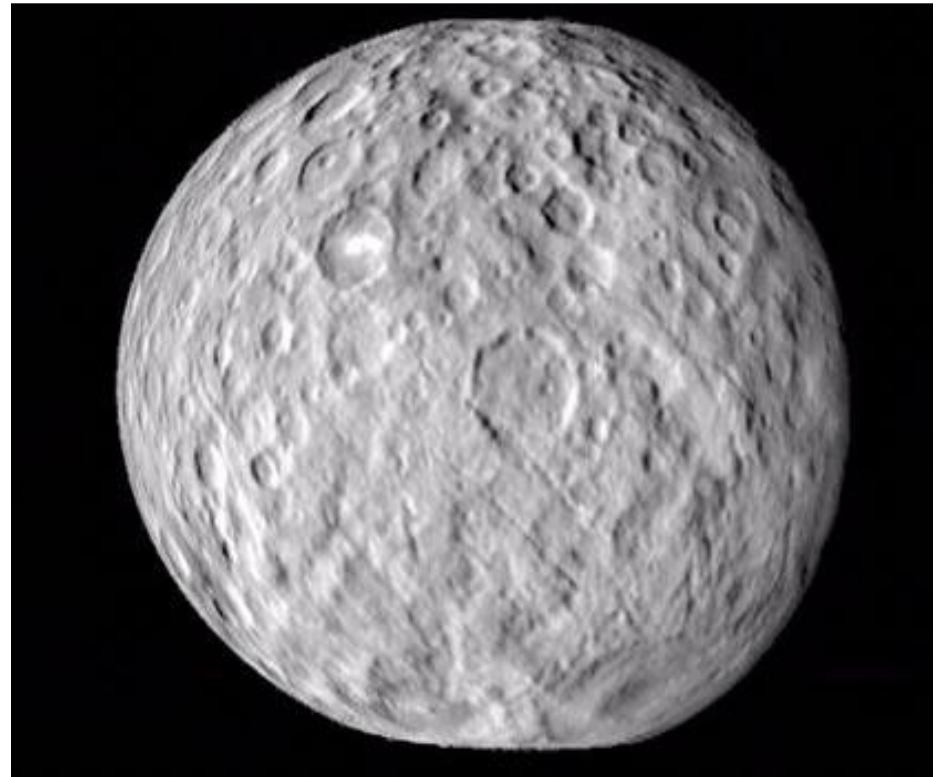
The total mass of all rocky and metal materials in the Main Asteroid Belt is only 4% of the mass of Earth's moon. About 30% of the total mass of the Main Asteroid Belt is in the dwarf planet Ceres.



**Ceres** is a **dwarf planet** and largest object in the Asteroid Belt. It has a size of  $\sim 900$  km in diameter. Ceres grew into a large enough mass that its gravity allowed it to form into a spherical shape.

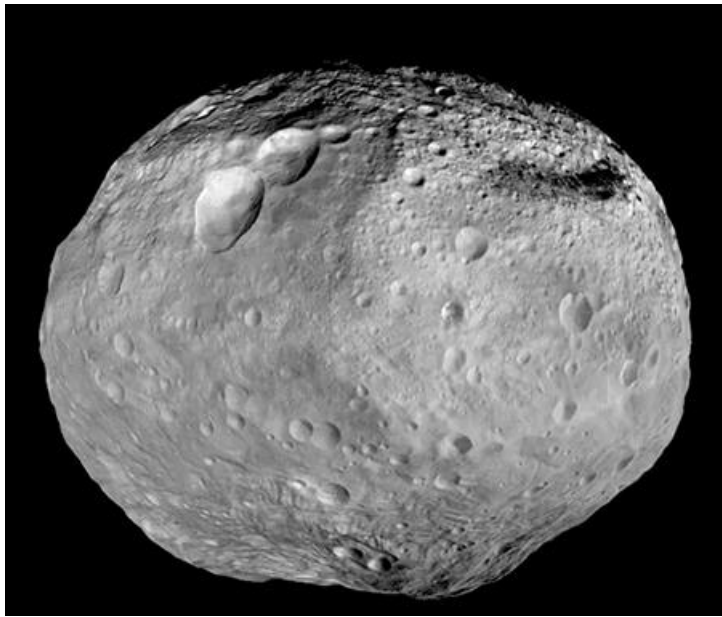


From Hubble Telescope 1999



From Dawn Mission 2015





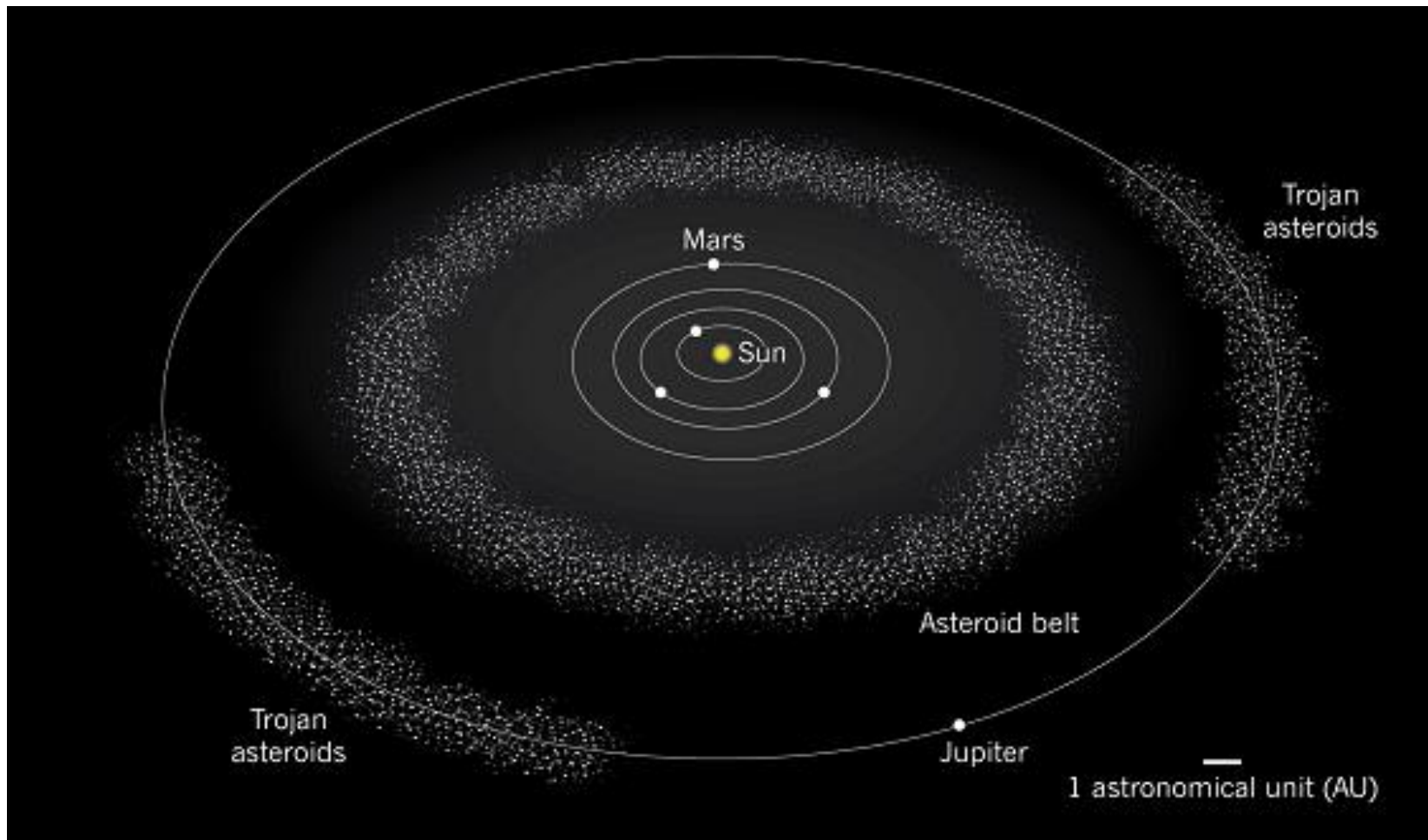
Asteroid **Vesta**, 2<sup>nd</sup> largest object in the Main Asteroid Belt.  
~ 500 km in diameter. Vesta is a larger planetesimal, bordering on dwarf planet.



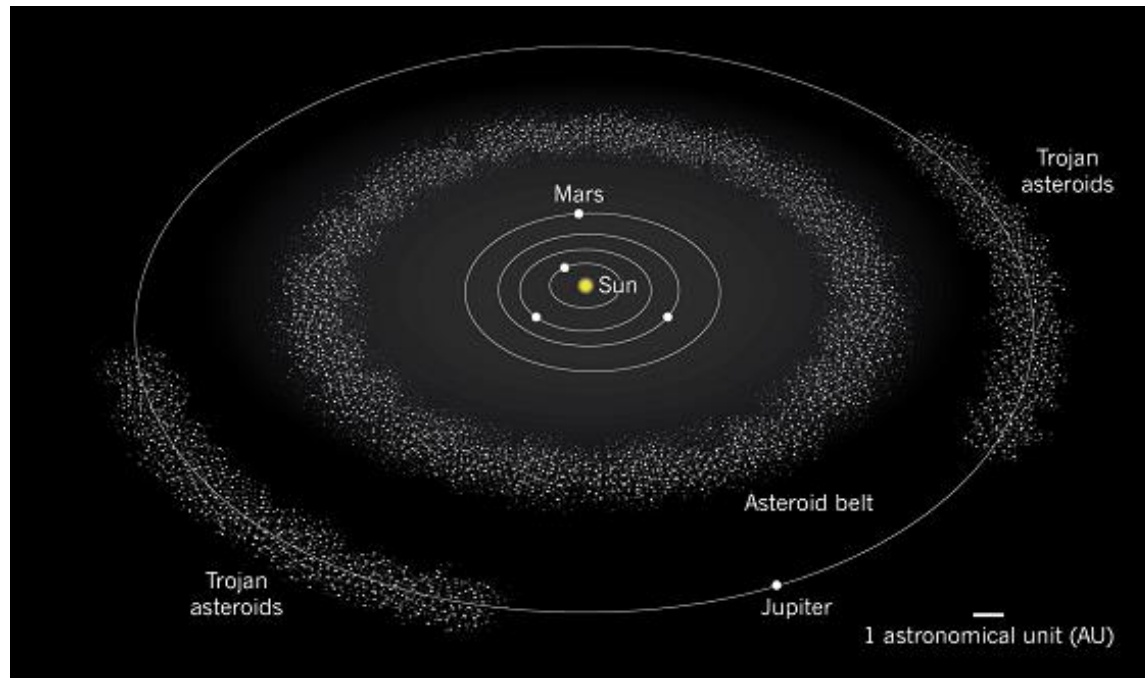
Asteroid **Ida** and its “satellite” asteroid **Dactyl**

56 km in longest dimension

**Trojan asteroids** are asteroids that are gravitationally associated with a planet and follow that planet in the planet's orbit in the 4<sup>th</sup> and 5<sup>th</sup> **LaGrange points**.



**LaGrange points** are places in the orbit of a planet where the gravitational attraction between the planet, the Sun, and the trailing asteroid is strong enough to keep the asteroid following the planet, but not too strong where the planet's or Sun's gravity pulls the asteroid into the planet or into the Sun.



Trojan asteroids follow the planet in its orbit at exactly the same distance behind in the same orbit at all points in the orbit.

# Trojan asteroids

Venus = 1

Earth = 2 (Cruithne & 2010 TK7)

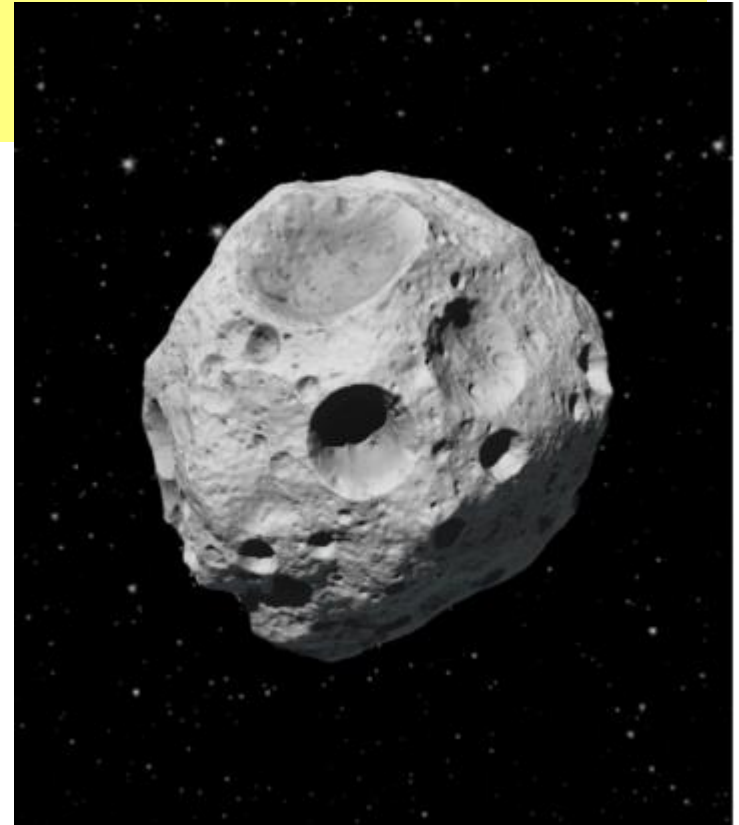
Mars = 7

Jupiter = > 6000

Uranus = 1

Neptune = 13 (most likely comets)

Cruithne is the largest of Earth's trojan asteroids. It has a diameter of ~ 5 km.



Occasionally, asteroids in the asteroid belt crash into each other. Sometimes the very strong gravity pull of Jupiter or Mars will disturb asteroids. As a result, asteroids can be bumped or pulled out of the asteroid belt and sent into the inner solar system or into the outer solar system.



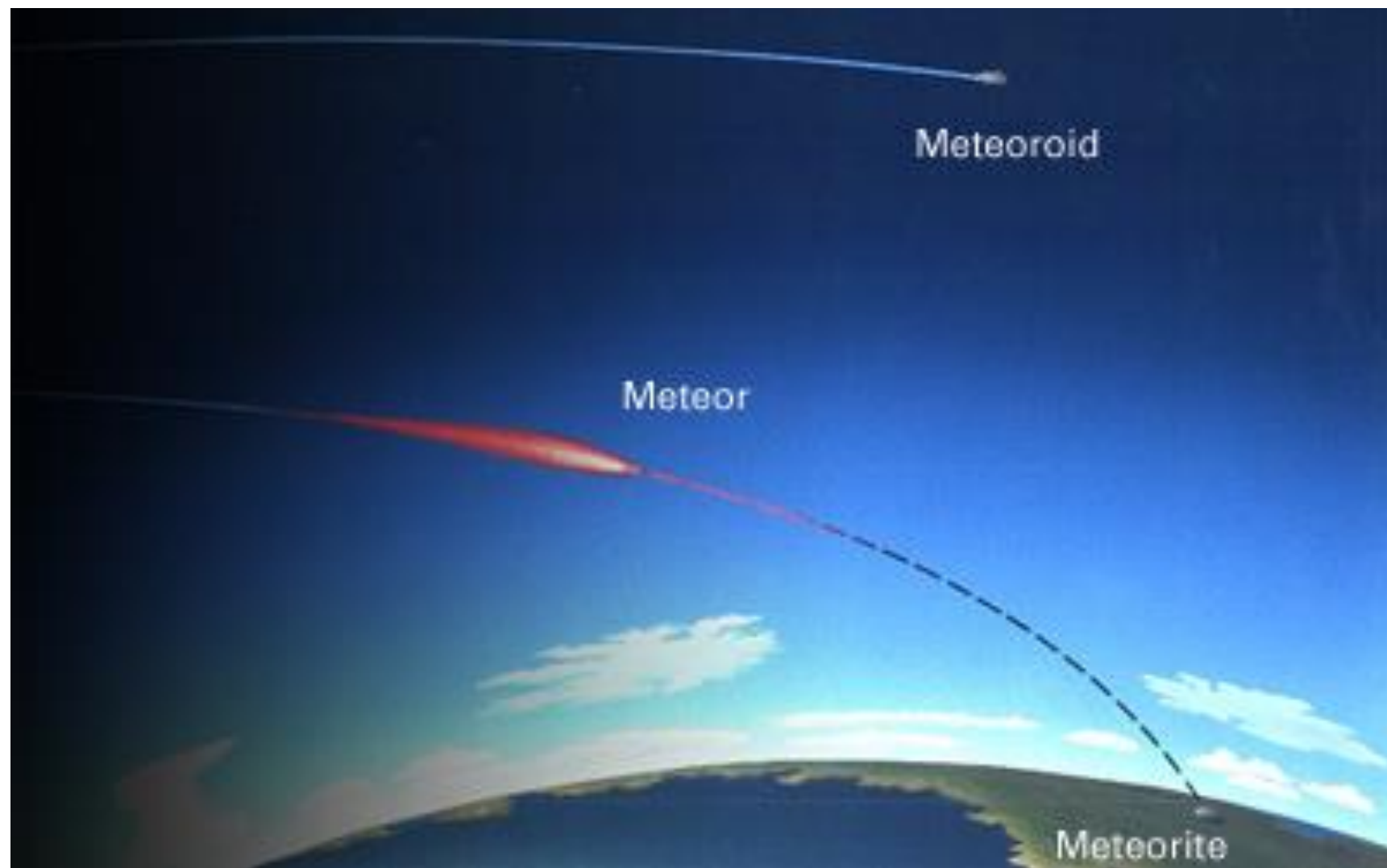


Meteoroids, meteors, and meteorites are the same space rock, but are classified differently depending on their locations.

**Meteoroids:** Space rocks that approach Earth or a planet, but are still in space outside of Earth's or the planet's atmosphere.

**Meteors:** Space rocks that pass through Earth's or the planet's atmosphere and flare due to air resistance. Appear as shooting stars.

**Meteorites:** Space rocks that impact the Earth's crust or the planet's crust.

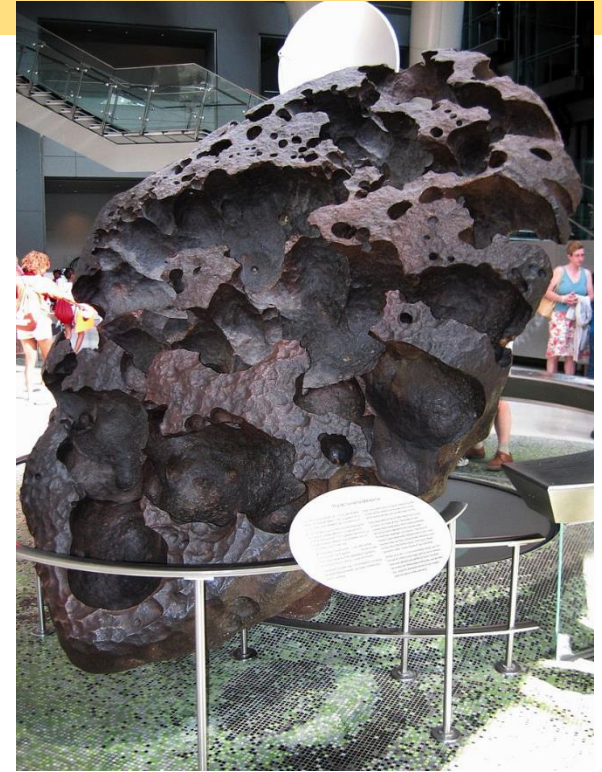


**Meteors** pass through the Earth's atmosphere moving 10,000 to 30,000 km/hr. Meteors are “**shooting stars**”. The **air resistance** (drag force) superheats the meteor, causing the rock to burn up or vaporize in the upper atmosphere.





Most meteorites are very small and have charred surfaces from passing through the atmosphere



Earth is hit by millions of sand grain sized meteors every day. Larger impacts are less frequent.

Meteorites are classified by their composition (what they are made of).

**Iron meteorites:** Meteorites that are exclusively iron and nickel with no silicate rocks. Magnetic.

**Stony-iron meteorites:** Meteorites that are mixtures of metal and silicate rock.

**Stony meteorites:** Meteorites that are mostly silicate rock and no metals.





Meteorites and asteroids can also be described by their degree of alteration.

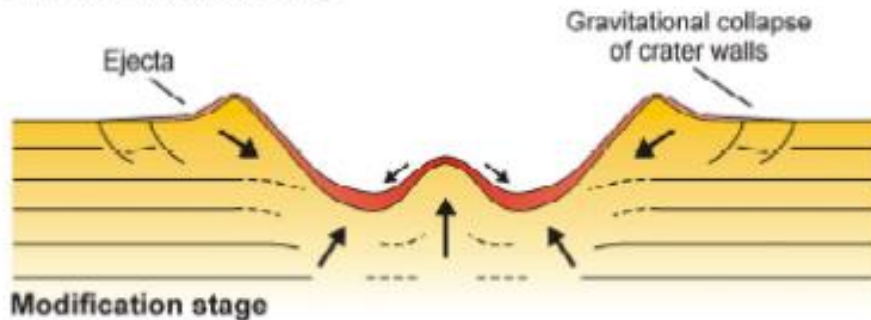
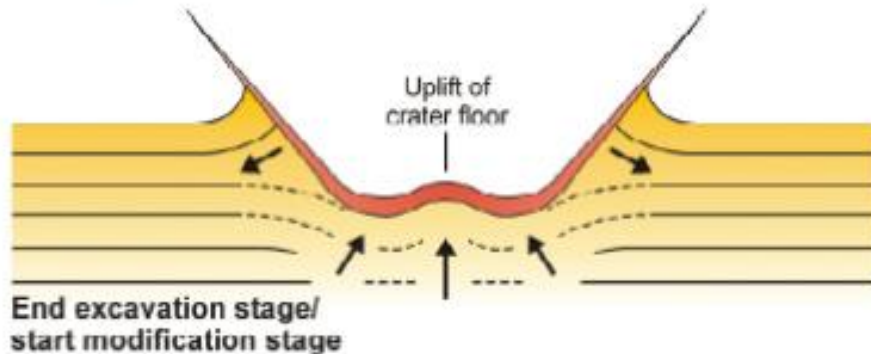
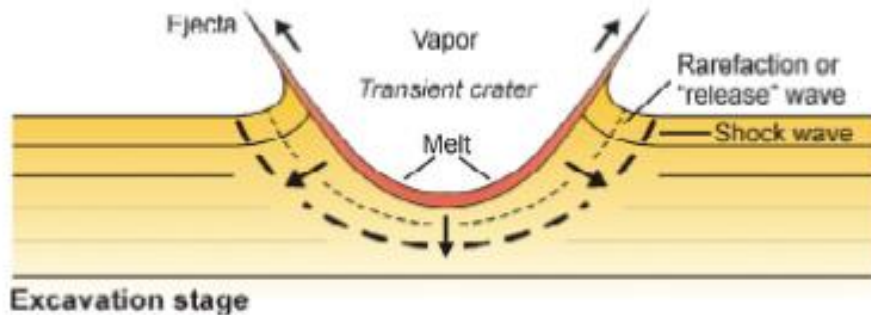
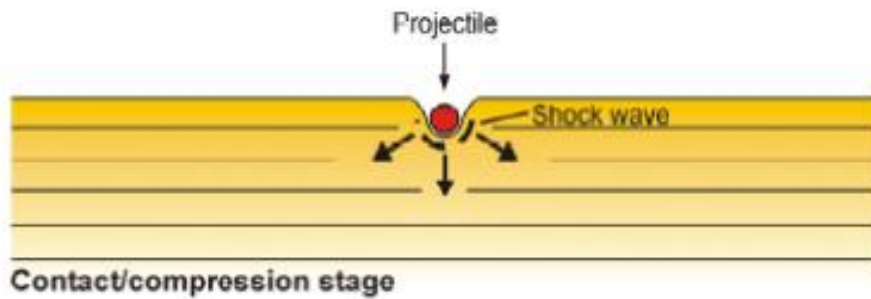
**Achondrite meteorite:** Meteorites that are exclusively rock and metal, and do not contain *chondrules*.

- An altered meteorite (or asteroid)
- The original asteroid had been heated by an impact or chemically altered by another cosmic event.
- Lacks carbon, nitrogen, and volatile elements.

**Chondrules** are minerals, nodules or deposits of lighter elements such as carbon, nitrogen, phosphorus, sulfur, potassium, and sodium. They are vaporized out of the rock if the rock is heated too much by impacts or other destructive processes.

**Chondritic meteorite:** Meteorites or asteroids that contain mixtures of rock, metal, and ***chondrules***

- Unaltered or pristine meteorite or asteroid.
- The original asteroid had not been altered by heat or by another cosmic event.
- Contains carbon, nitrogen, phosphorus, sulfur, potassium, and sodium.
- The most representative of the materials that formed the solar system.

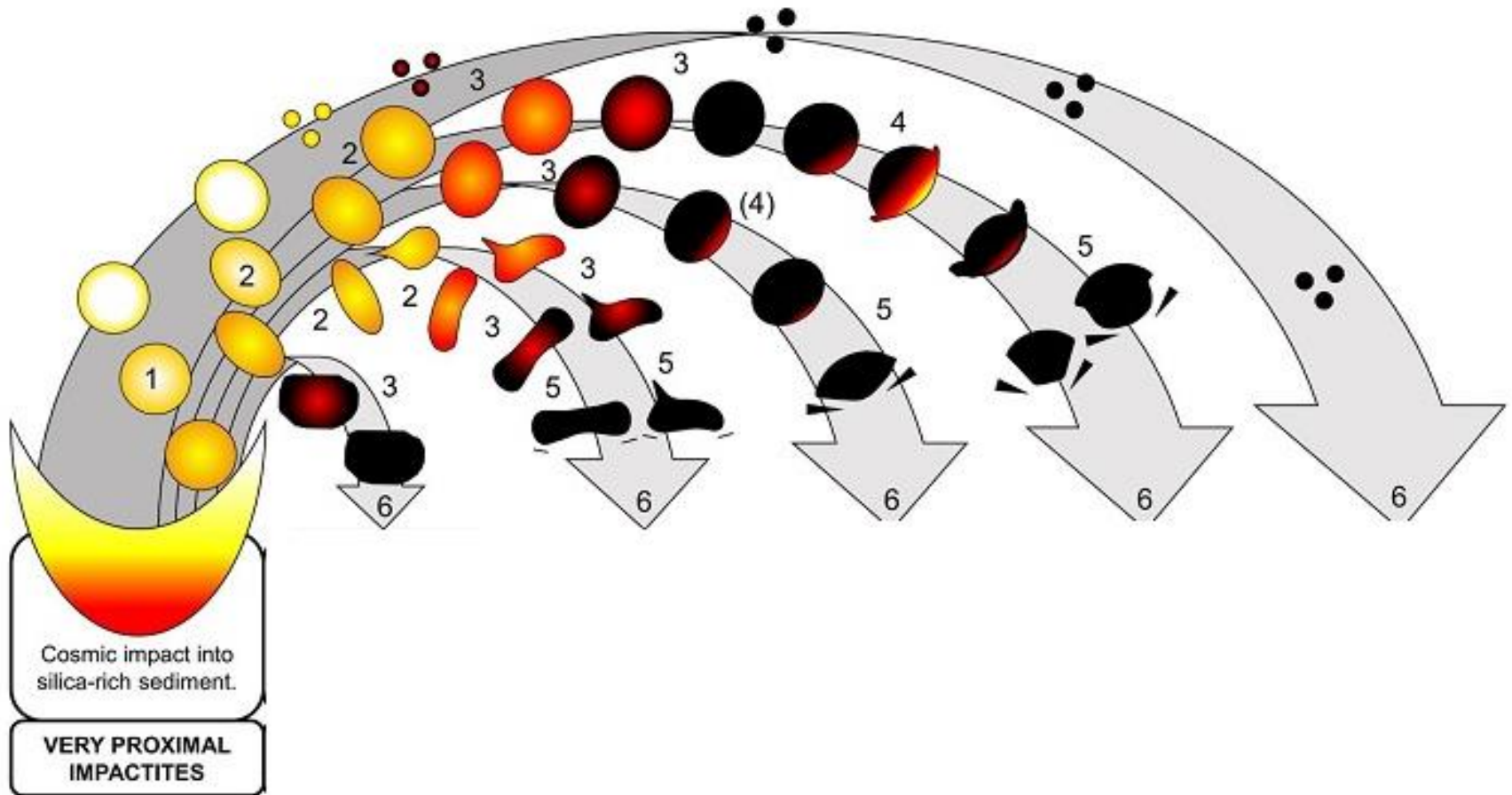


**Craters:** Bowl-shaped depressions excavated by impactors (meteorites and comets).

Some are simple craters  
Some are complex.

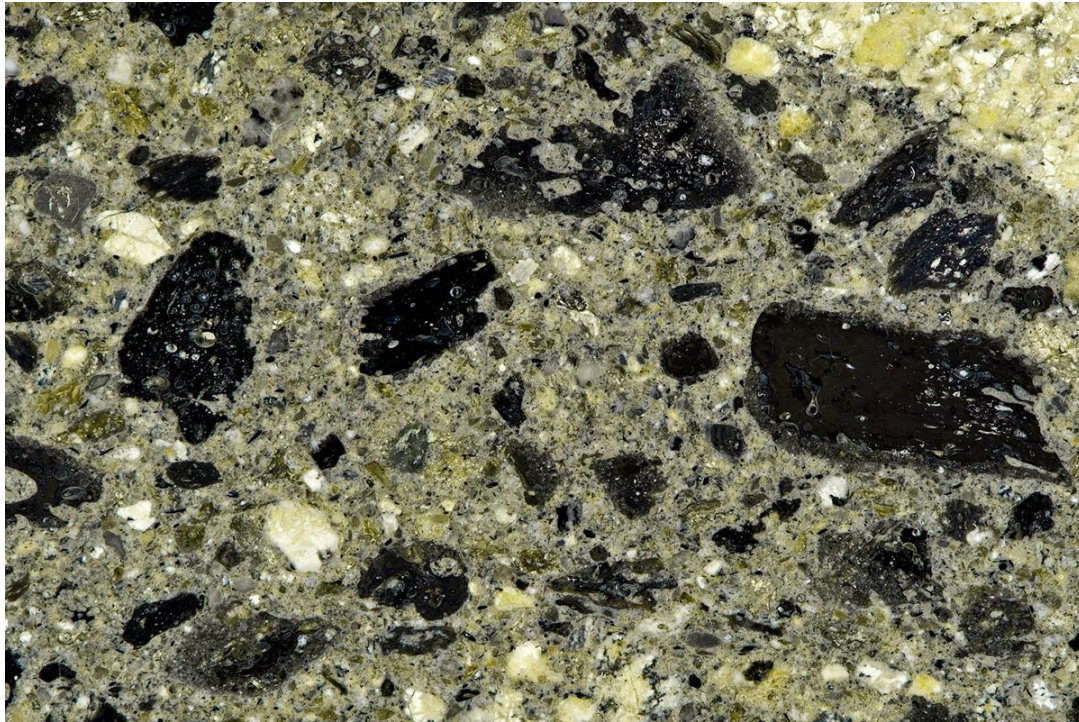
- Crater rim
- Rebound uplift
- Fractures and faults

**Ejecta** (ejected materials) is any rock or debris that is blasted out of the crust during an impact.





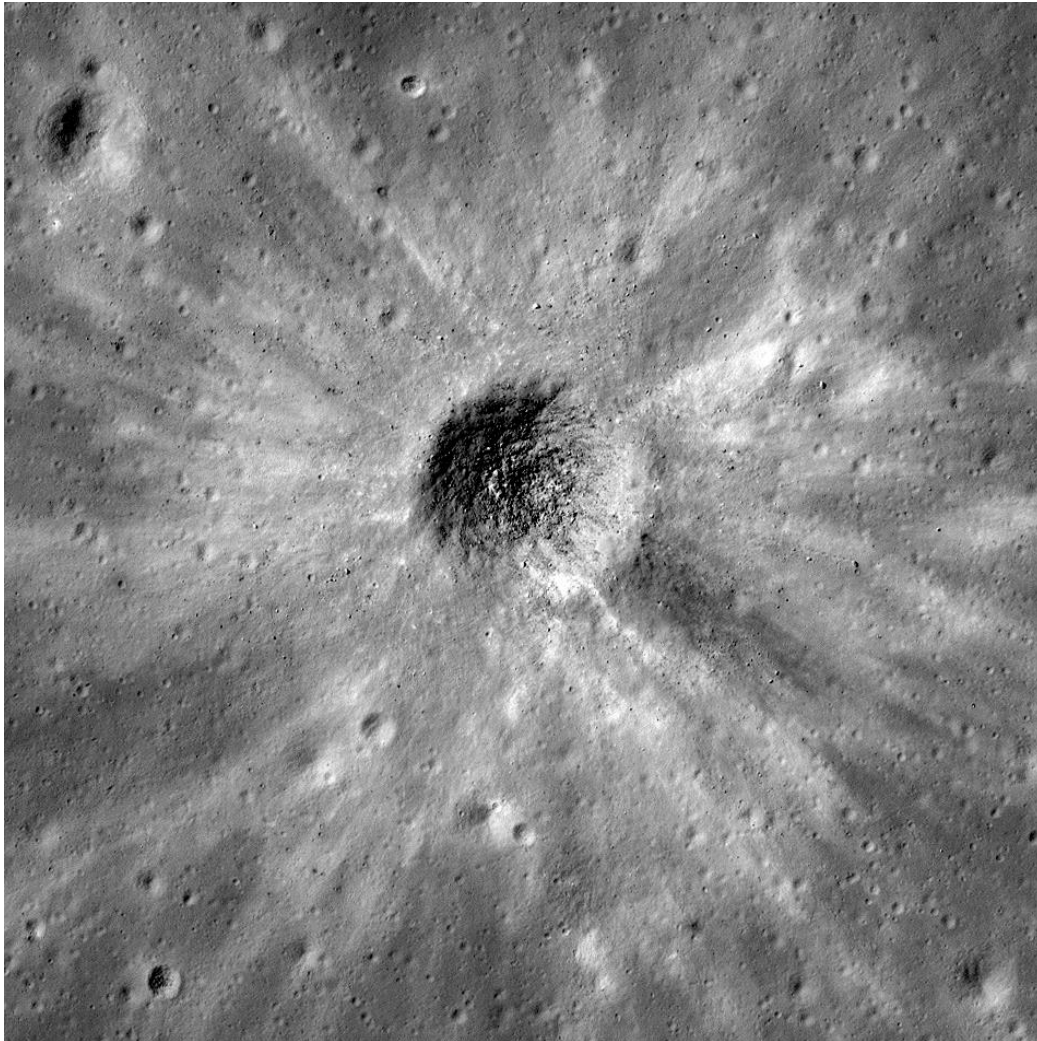
The rock below is called **ejecta breccia**. Breccia is a rock that contains broken angular shards of rock and minerals fused together by extreme heat during the impact.



Rock is blasted out of the crater. The extreme heat fuses the debris together. Breccia surrounds the crater.



**Rays** are streaks of pulverized rock and dust that is blasted out of the crust by the impact. Rays radiate away from the impact crater.



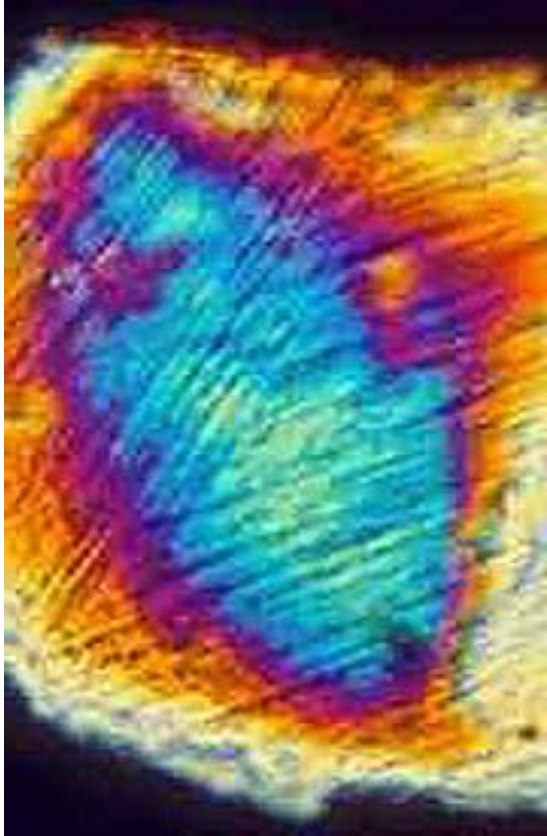
Rays tend to be absent from Earth because wind, weather, and erosion will carry the debris away since it is unconsolidated and on the surface.

**Tektites:** Glassy, smooth teardrop-shaped ejecta, most are the size of pebbles and cobbles. They fall to Earth hundreds to thousands of km from the site of the impact.

When the impact happens, the extreme heat from the impact and blast will melt and vaporize the rock at the point of impact. As the melted rock and vaporized rock fly through the air, they condense into hot globs that cool and solidify as before they hit the ground.

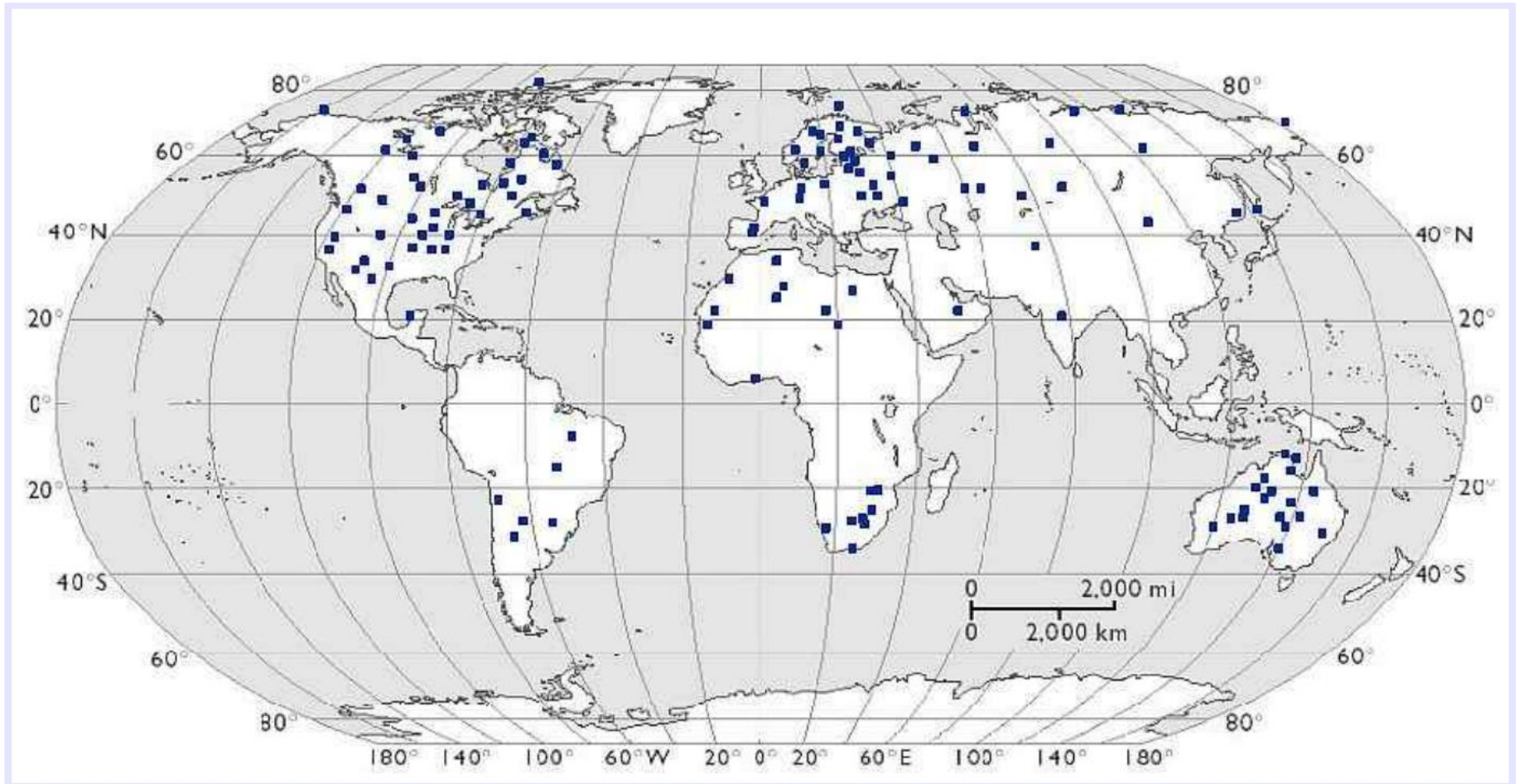


**Shocked quartz:** Quartz crystals in the rock around the impact crater are broken and flattened. When the asteroid or meteorite hits the crust, the shockwave of pressure from the force of the impact pushes through the crust, squeezing and flattening the quartz crystals in rocks and minerals.





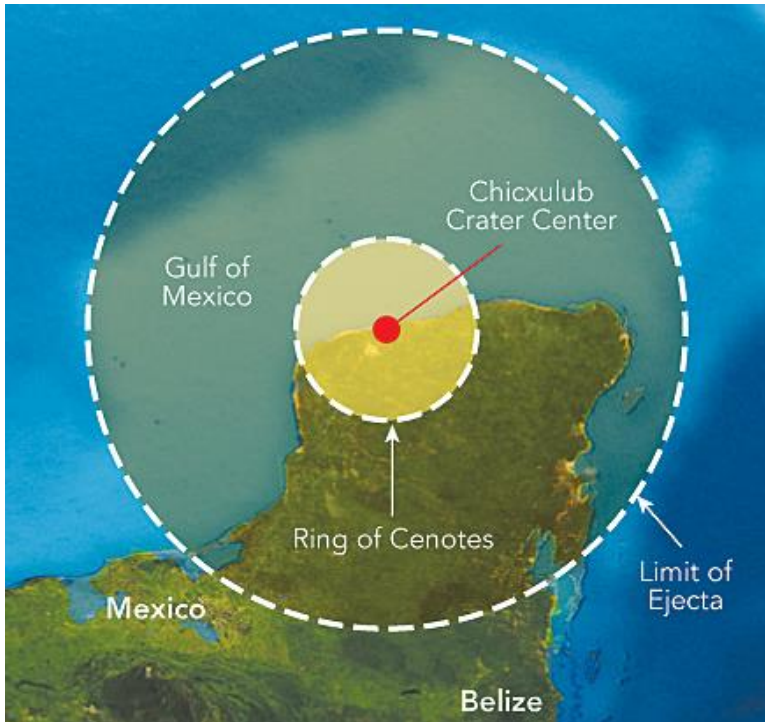
Map of major impact craters on Earth. There are around 180 major impact craters on Earth.



## Meteor Crater, Arizona

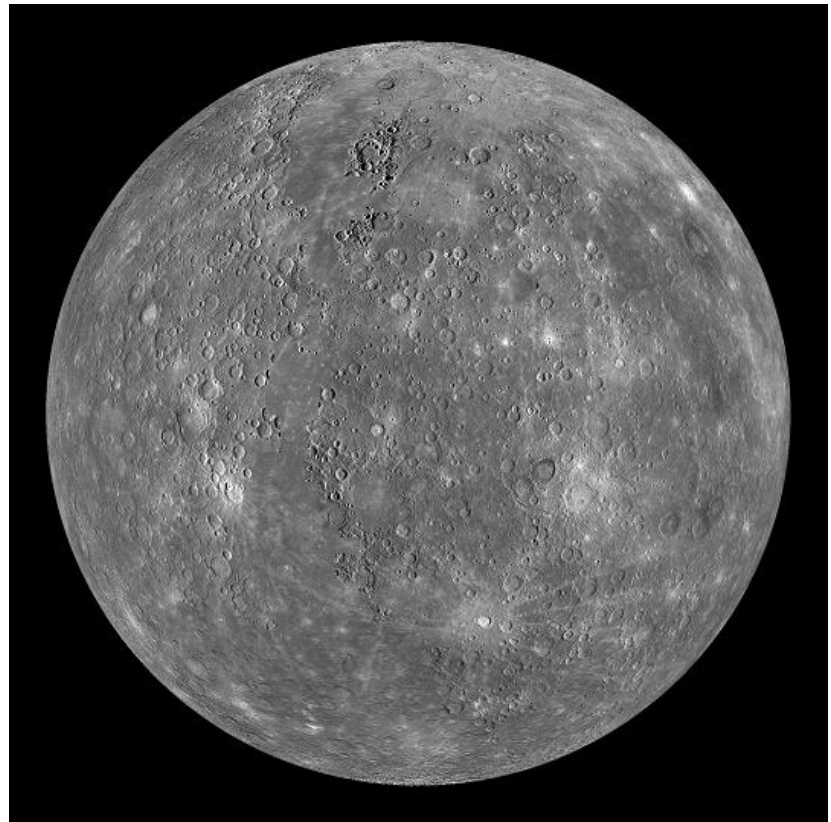
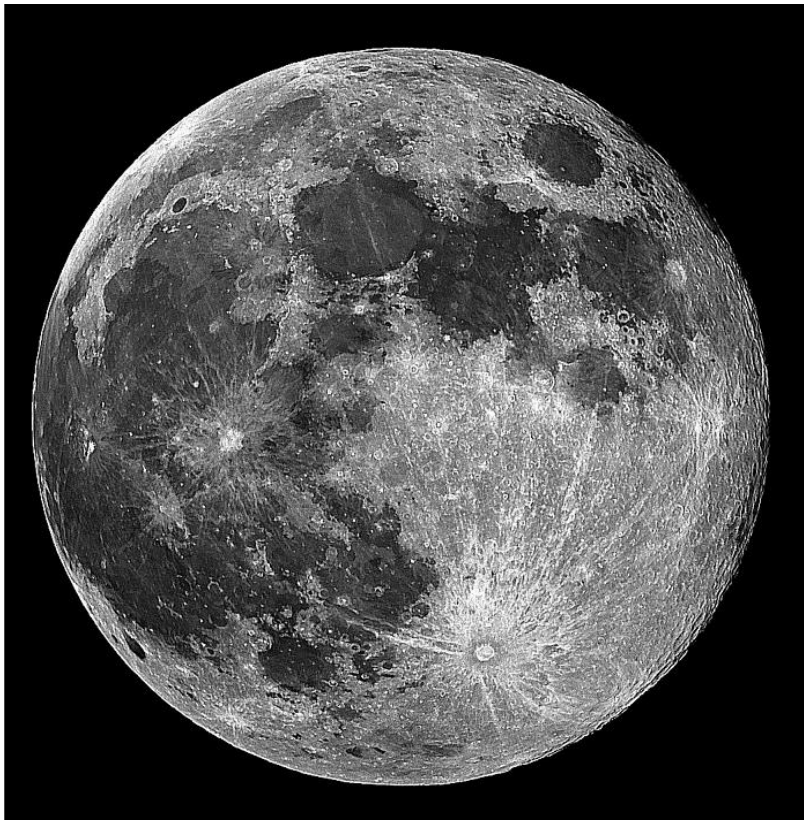


## Manicouagan Crater, Quebec Canada



## Chicxulub Crater, Yucatan Penninusula, Mexico





Earth's moon and Mercury are covered with 10's-100's thousands of impact craters. Many of the impact craters overlap with other impact craters.

*Why are there so few on Earth?*

The frequency of impacts is a function of size.

Small impacts are very frequency.

- Every day the Earth is impacted millions of times by sand size meteors.
- About 1 time per year the Earth is hit by an object of 0.5-1.0 meters in diameter.
- About 1 time per century, the Earth is hit by an object of 20-30 meters in diameter.
- The larges and most devastating impacts are very, very infrequent, like every 10 million to 100 million years.

