Terrestrial Planets

Week 7

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FD Adams 131C

Meteoroids, asteroids, comets

Meteroids, **asteroids** and **comets** are the left-over **remnants** that were not assembled into planets. The divisions between them and **dwarf planets** is "colloquial" .

My colloquial definitions:

- **Meteoroids** are rocky-to-metallic bodies that are not as large as what we might call asteroids. Those that manage to survive a fall through the atmosphere to Earth's surface are called **meteorites**.
- **Asteroids** are large equivalents of meteoroids some scaling large enough to be considered "dwarf planets" (e.g. Ceres).
- **Comets** are bodies largely composed of water and other ices and dusts.

Meteorites

Meteorites, small meteoroids that fall on Earth, provide the best information we have about the minerals, ices and elements of the inner Solar System and the original proto-solar nebula.

Our model for the composition of Earth, itself, is based on the elemental and mineral composition of meteorites, in particular a class of meteorites called chondrites.

We presume such bodies provided the **elemental building blocks** of the Earth and terrestrial planets.

Meteorites -- Iron

These images show iron meteorites which are comprised largely of metallic iron and nickel. They are probably remnants of a core-like interior of large asteroids that have broken up through collisions in the asteroid belt. These asteroidal cores typically cooled slowly under an insulating layer of mantle-like rock.

Evidence for that slow cooling is seen in the left-most image which is a polished surface showing large crystalline Widmanstätten pattern.

Meteorites – Stony-Iron

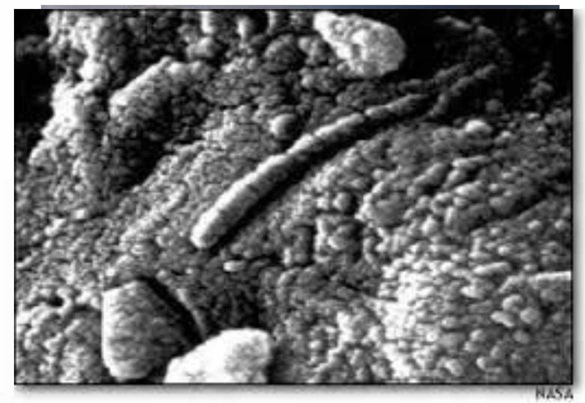


Stony-iron meteorites are thought to form from fragments of asteroidal iron and rocky materials re-cemented into a breccia-like matrix.

The matrix may be iron with rocky inclusions, Pallasites, or rock-like with metallic inclusions, Mesosiderites.

Meteorites – Stony: Achondrite





These ***Achondrites*** might easily pass for an ordinary rock if seen on the ground. Those shown here are highly evolved and probably much younger than the oldest meteorites we find.

The one on the right is the famous **ALH84001** meteorite that was collected in a glacial outwash in the Allen Hills of Antarctica in 1984. It became famous, and brought some fame to McGill in 1996, when it was "***discovered***" that structures inside this meteorite seemed to show "***nanofossils***". We know that this meteorite was splashed off **Mars** some 30 million years ago.

Meteorites – Stony: Chondrite



Chondrites form from small beads of glassy rock materials cemented together. The beads are called **chondrules**, clearly seen in the right-most image.

They are glassy because they have cooled too quickly to form a crystalline structure; they may have formed of molten materials splashed from energetic collisions between asteroid-sized bodies or, perhaps, drops from the equivalent of a “rain” in the proto-solar nebula.

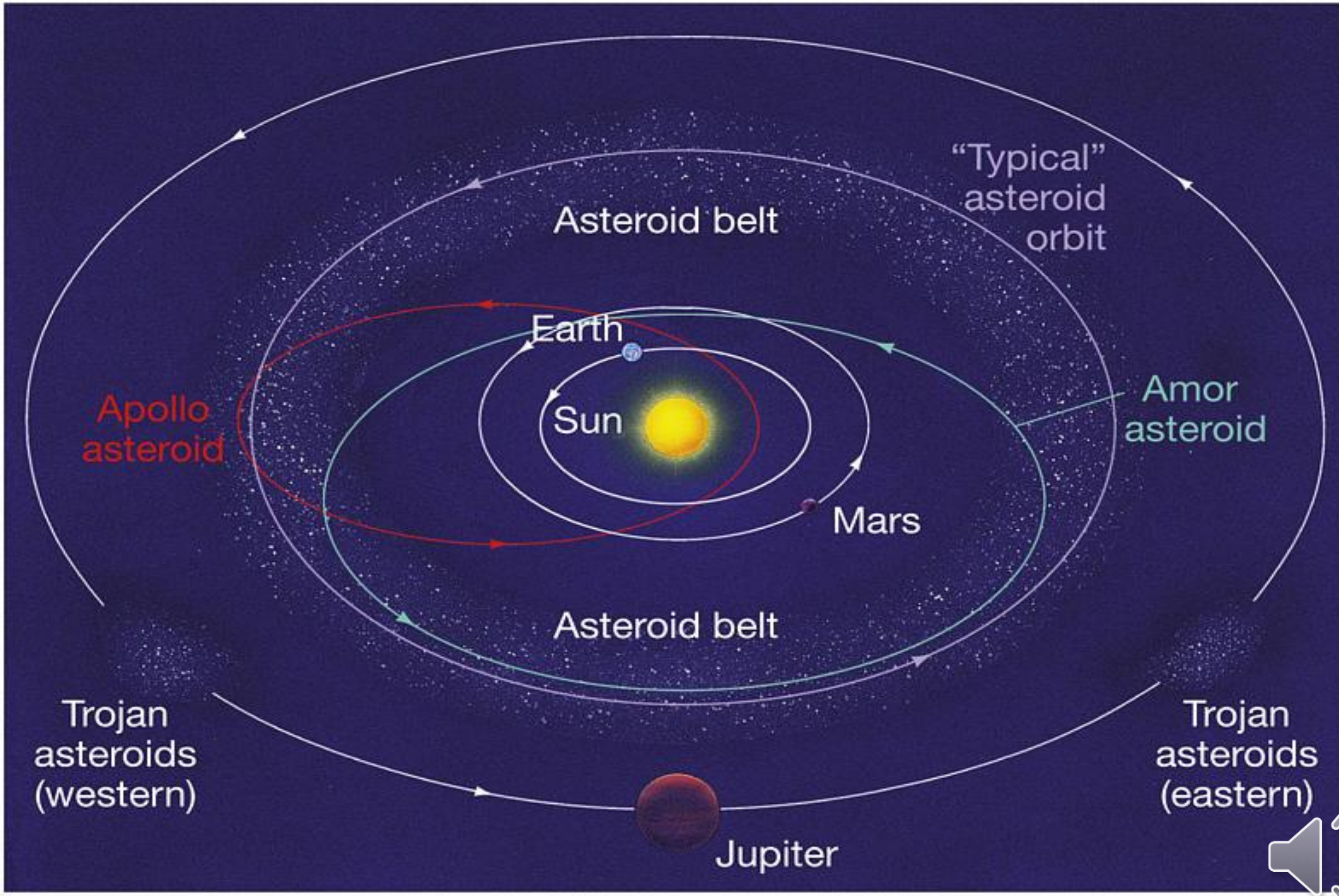
A Carbonaceous Chondrite: Tagish Lake Meteorite



Carbonaceous chondrites contain substantial organic material, namely carbon. Carbon, combined with other elements, namely **N**, **P**, **S** and **O** is often found already formed into organic molecules, the base amino acids and sugars necessary to the construction of **RNA** and **DNA** molecules.

The building blocks of life are contained in these meteorites. Perhaps they only need fall into empathetic environments that form primitive life.

Orbits of Asteroids

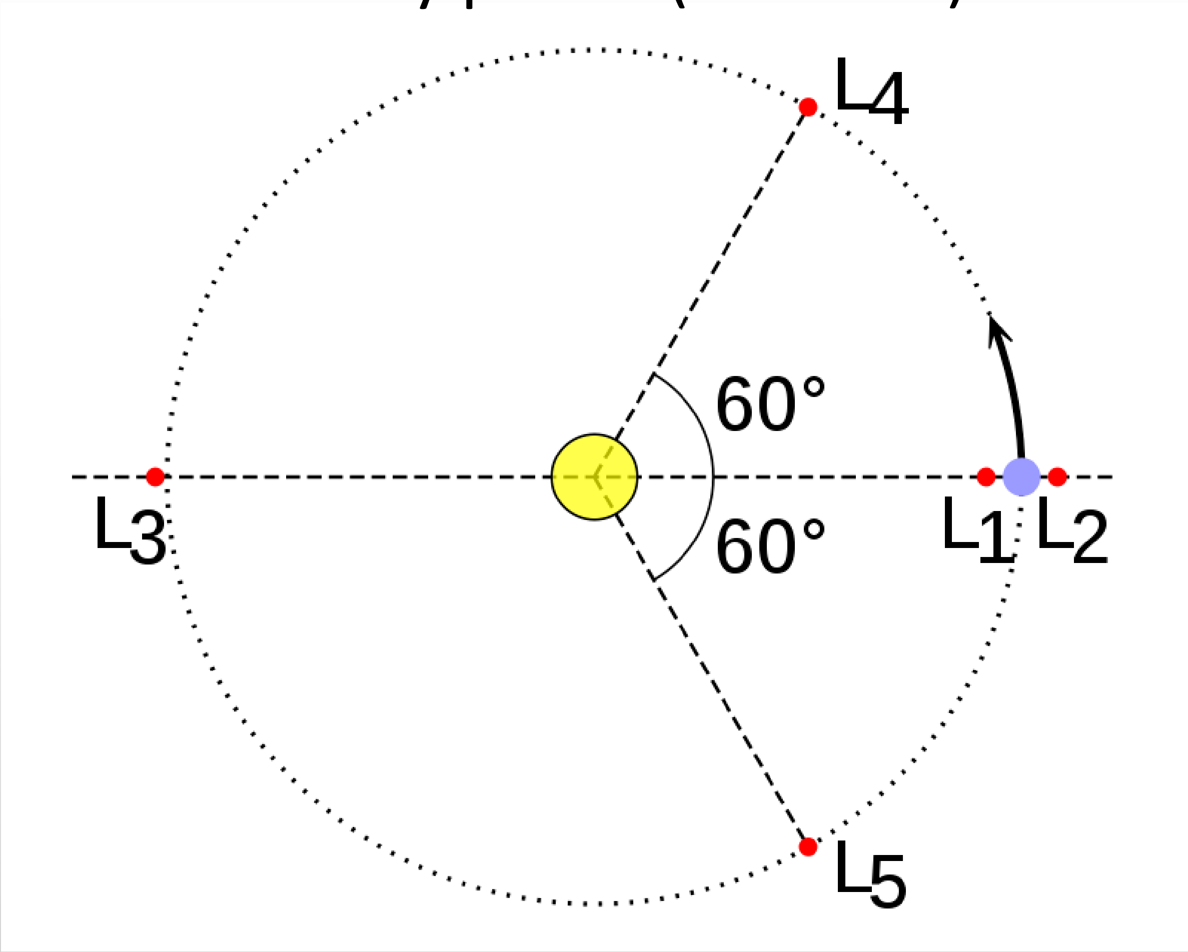


Orbits of Asteroids

- **Main belt**: orbit between Mars and Jupiter near the ecliptic plane in relatively low eccentricity orbits.
- **Apollos and Atens**: orbits cross Earth distance (1AU)
- **Trojans**: orbits are guided by Jupiter
- **Amors**: approach near Earth but don't cross Earth's orbital distance

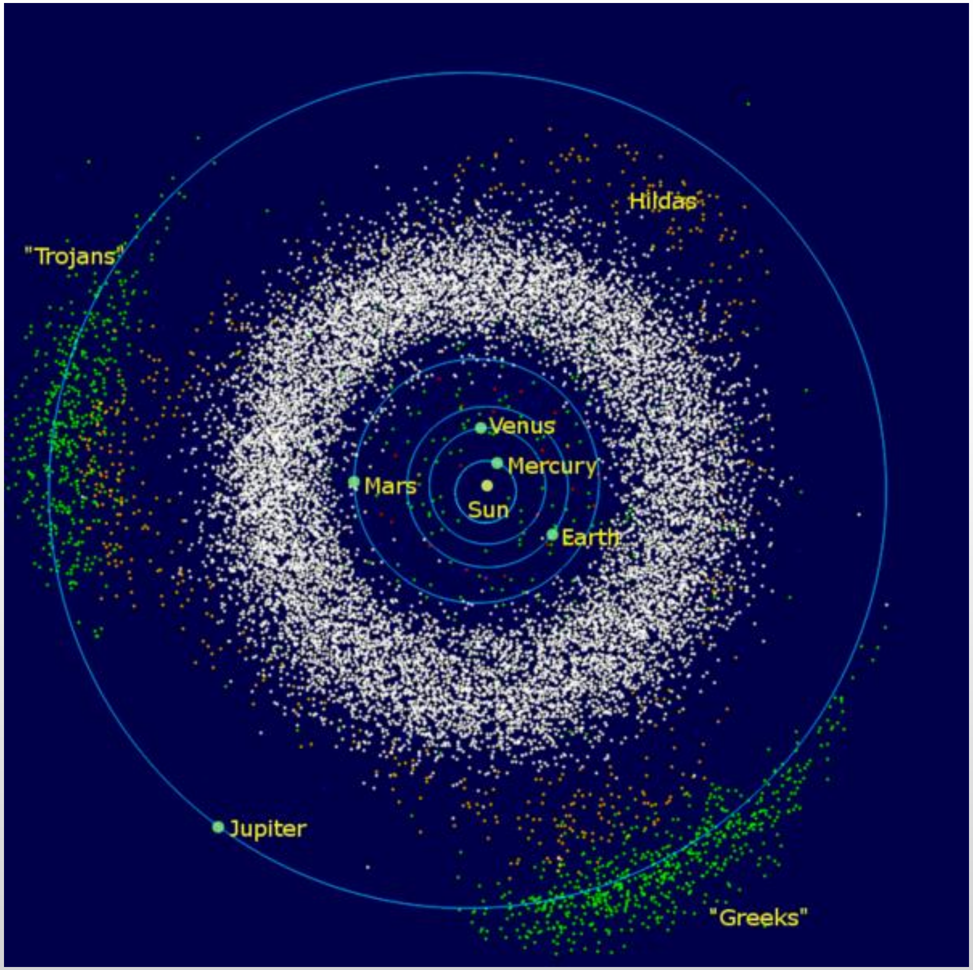
Orbits of Asteroids

Lagrangian gravitational stability points (2 bodies)

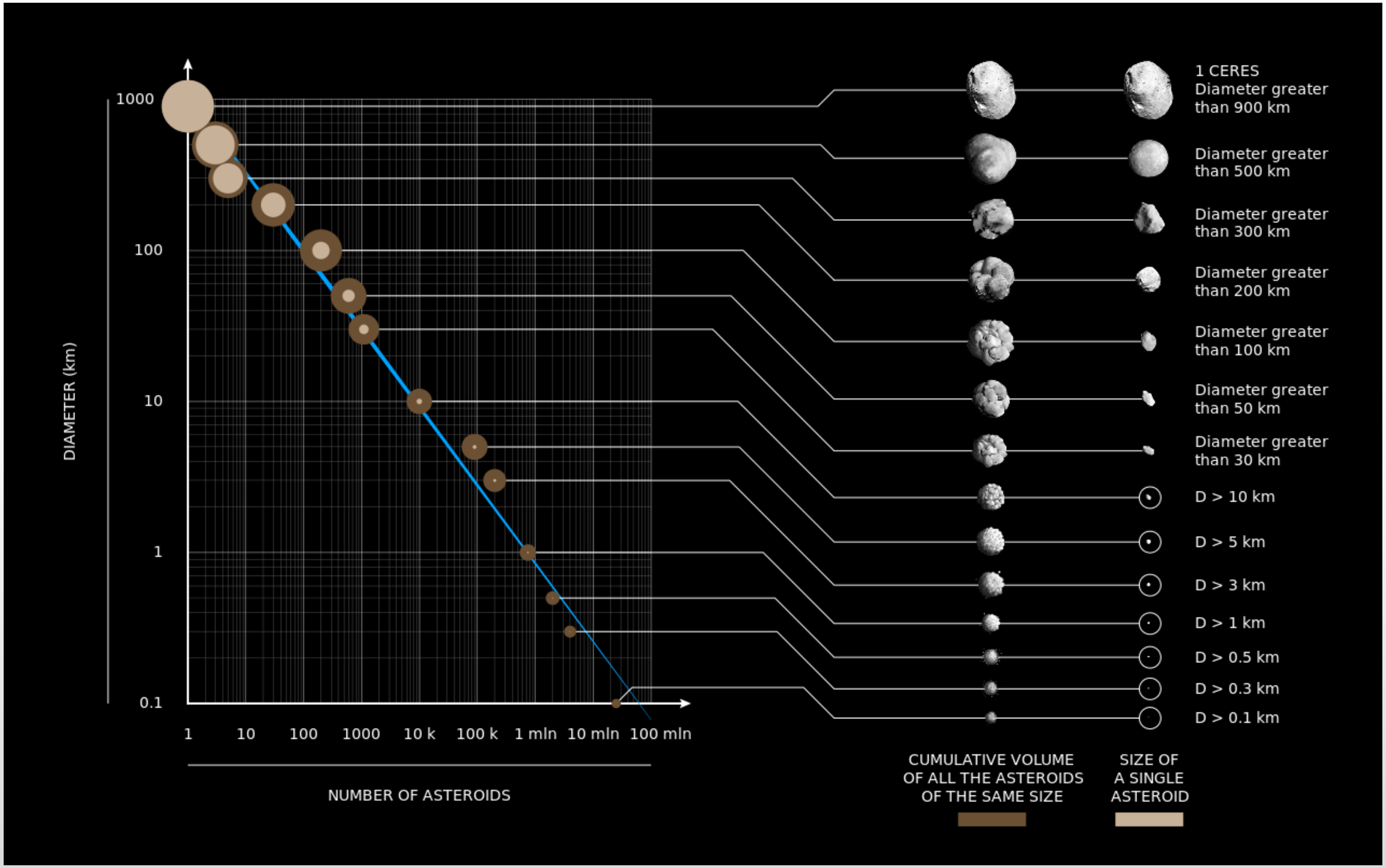


Orbits of Asteroids

Jupiter's Trojans



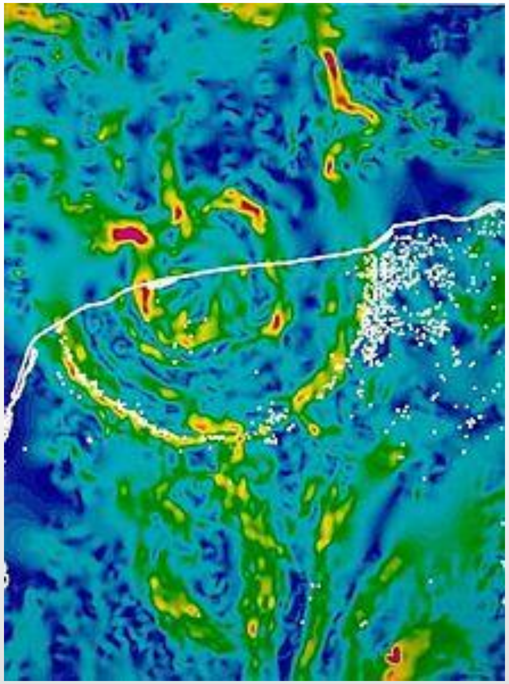
Asteroids size and number



https://commons.wikimedia.org/wiki/File%3AAsteroids_by_size_and_number.svg

Asteroidal Impacts

Chicxulub impactor: 65.5 million years ago, an asteroid at least 10km in diameter struck the Earth on the northern edge of the Yucutan Pennisula. It left a crater 100km in diameter, a hole punched in a platform of carbonate rocks.

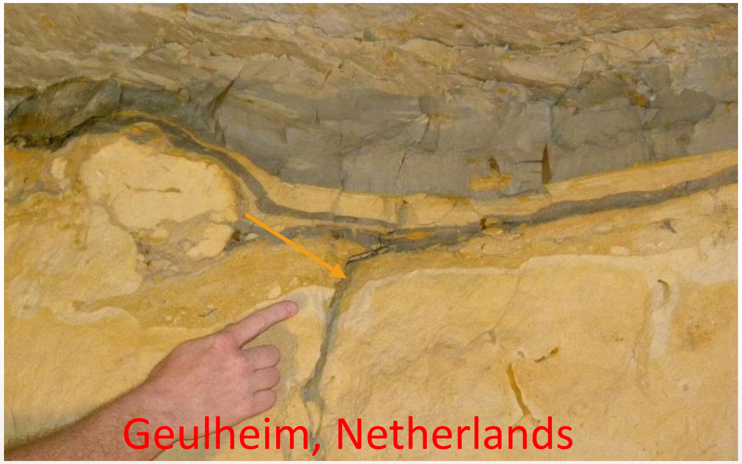


Molten rock fragments were sprayed into the atmosphere, falling worldwide to light fires in all the forests and lands of Earth. It vapourized the carbonates filling the atmosphere with a high concentration of **CO_2**. The age of the dinosaurs ended.

This was the great ***K/Pg*** (previously designated ***K-T***) ***extinction event*** that eliminated most of land-animal life.

Chicxulub Event

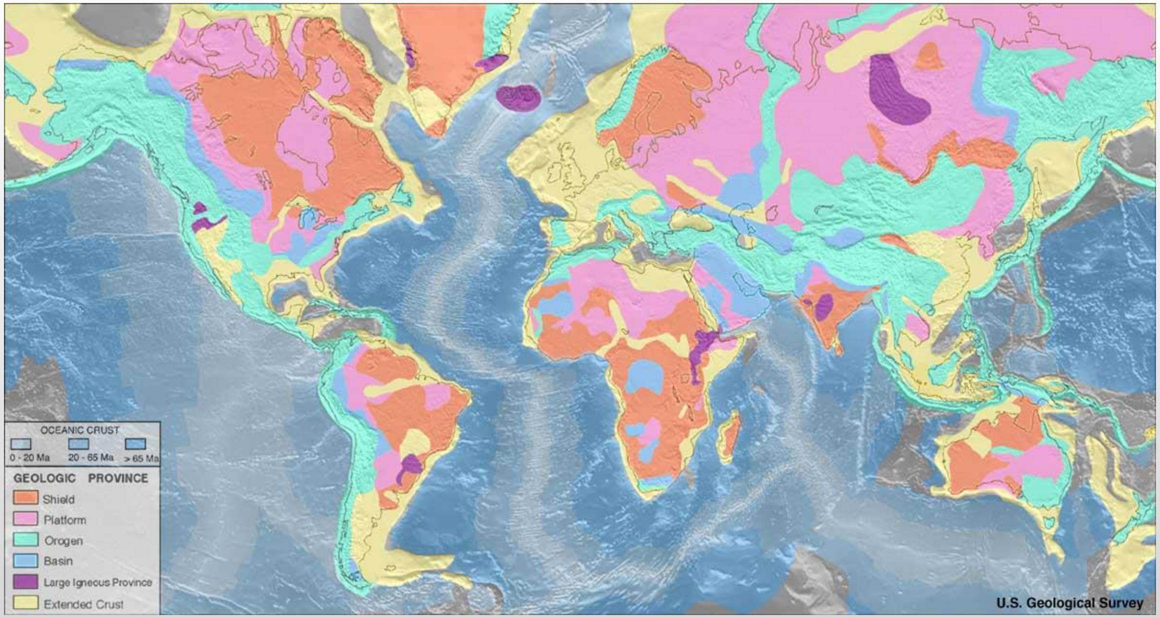
Evidence of the global scale of the Chicxulub Event: a globally distributed layer of sediments with anomalous **Ir** (iridium).



Images from: https://en.wikipedia.org/wiki/Cretaceous-Paleogene_boundary

Deccan Traps?

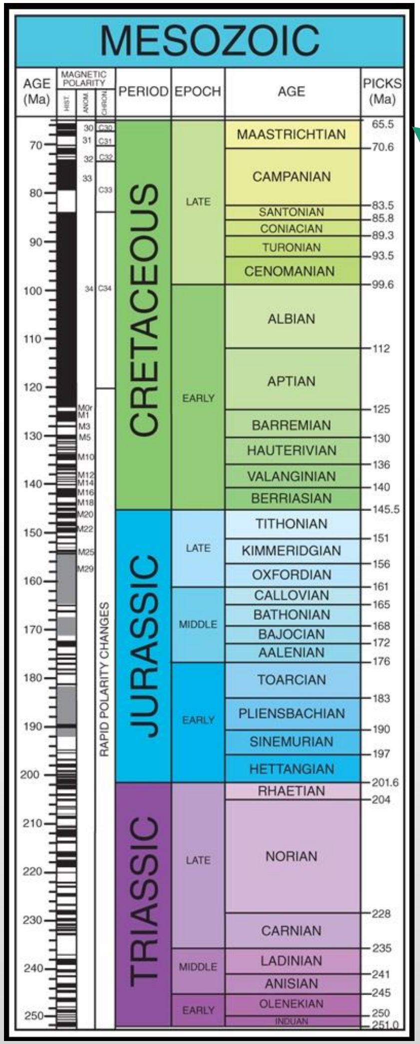
A massive volcanic eruption in what is now India about 250,000 years before the cataclysmic Chicxulub asteroid impact may have played a role in the **extinction** of **dinosaurs**, say scientists who have dated rocks from the [Deccan Traps], east of Mumbai.



From: [USGS], via Wikimedia Commons

“Geological Clock”

Age of the Dinosaurs

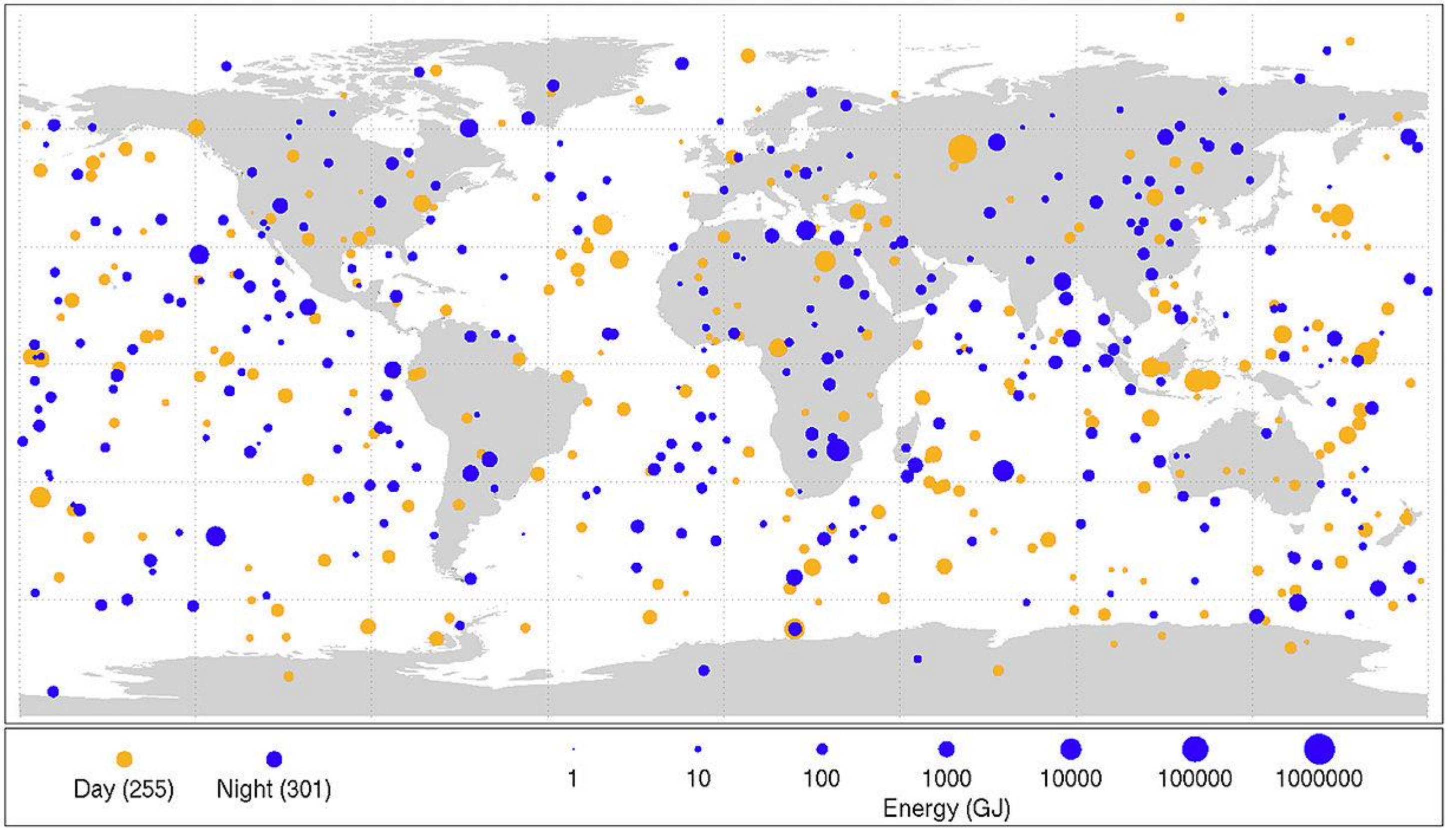


Chicxulub impactor and Deccan volcanism: within a few centimetres of the K/Pg boundary, we find no fossils of the great dinosaurs.

Siberian flood volcanism may have ended the Permian period with the greatest single extinction in the geological record

Bolide events (1994-2013)

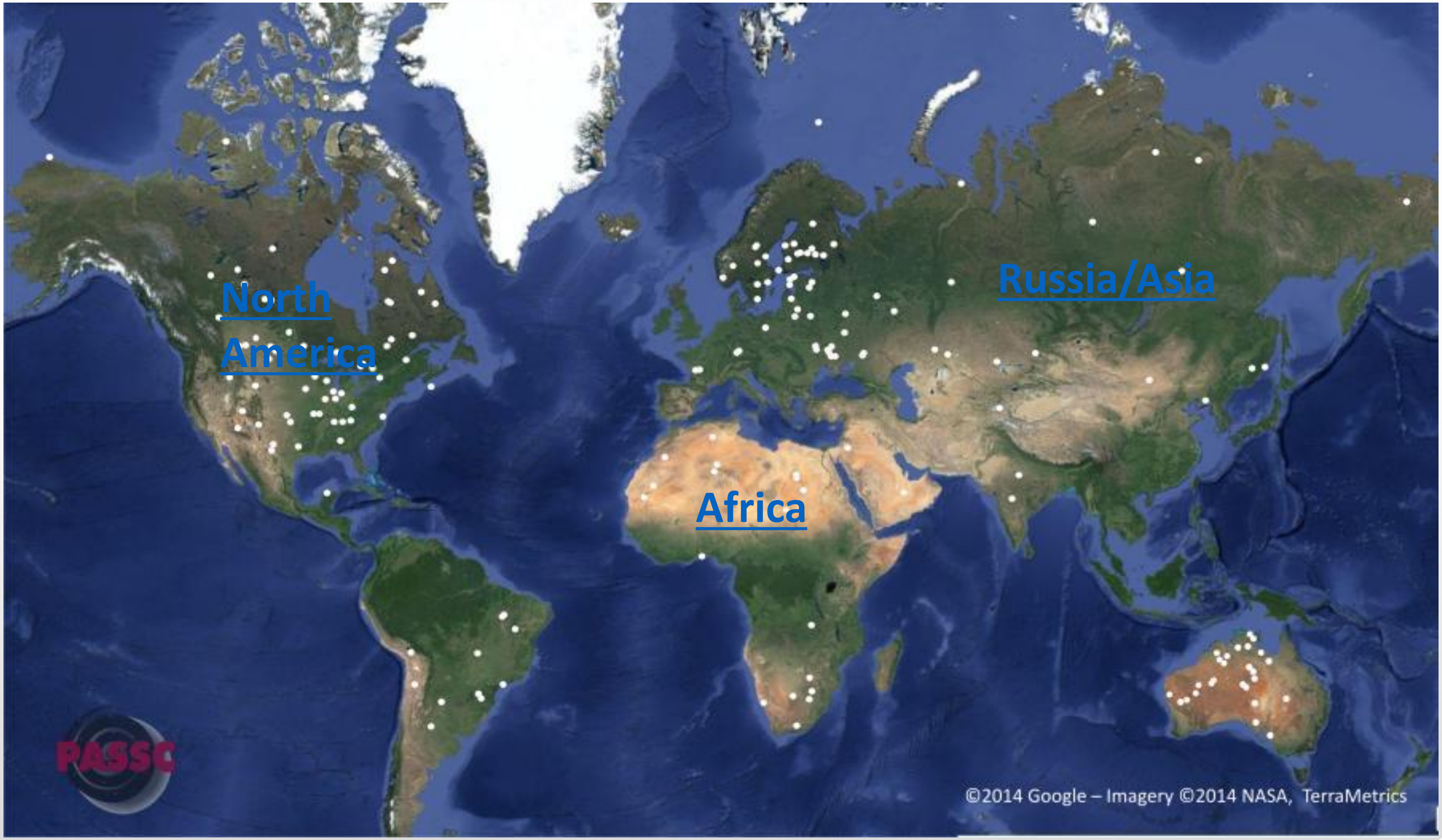
(Small asteroids that disintegrated in the Earth's atmosphere)



By NASA/Planetary Science [Public domain], via Wikimedia Commons

$$Energy\ equivalence\text{: } 1000000\ GJ\ \approx 250\ kton\ nuclear\ explosion$$

A history of large impacts



http://www.passc.net/EarthImpactDatabase/New%20website_05-2018/Index.html

Comets too? Tunguska Event

On the morning of 30 June 1908 an explosion over the sparsely populated Eastern Siberian Taiga flattened 2,000 km^2 of forest but caused no known human casualties. It may have been a comet strike.

Comets are made of low density dusts and ice but because their orbits are so eccentric, they may pass by (or strike) Earth with incredible speeds, up to 80000 km/hr.

Photo by Leonid Kulik

Even though they may not carry much mass, the energy they bring to collision is high because of their high impact speeds.

Tunguska Event

June 30, 1908, 7:14 a.m., central Siberia—Semen Semenov, a local farmer, saw “the sky split in two. Fire appeared high and wide over the forest.... From ... where the fire was, came strong heat.... Then the sky shut closed, and a strong thump sounded, and I was thrown a few yards.... After that such noise came, as if . . . cannons were firing, the earth shook ...”

Scientific American June 2008

Chelyabinsk Event (2013): Video of event

Some recent Comets

Hale-Bopp

Some recent Comets

Hyakutake

Some recent Comets

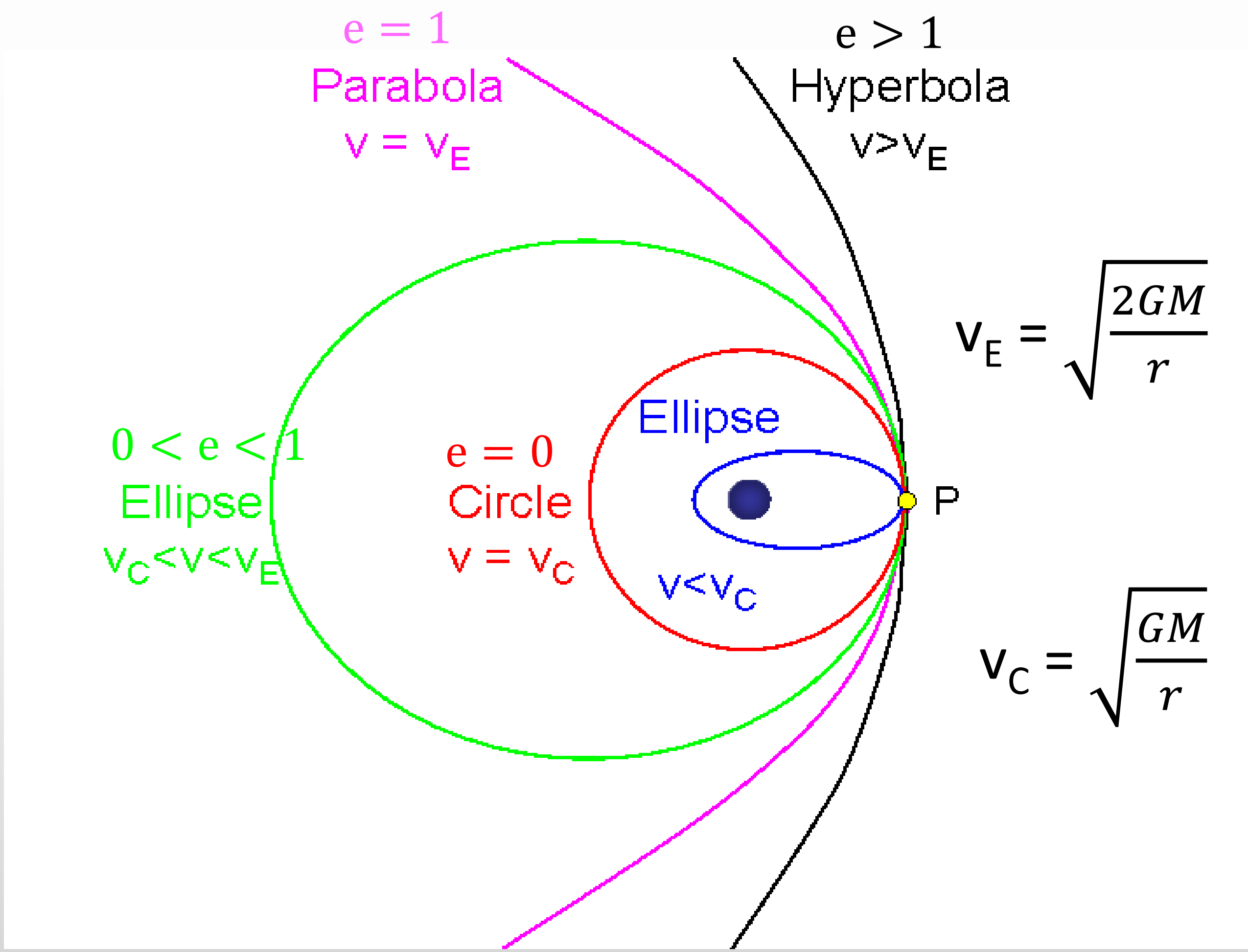
Halley's comet as imaged by Giotto probe in 1986

Some recent Comets

Some recent Comets

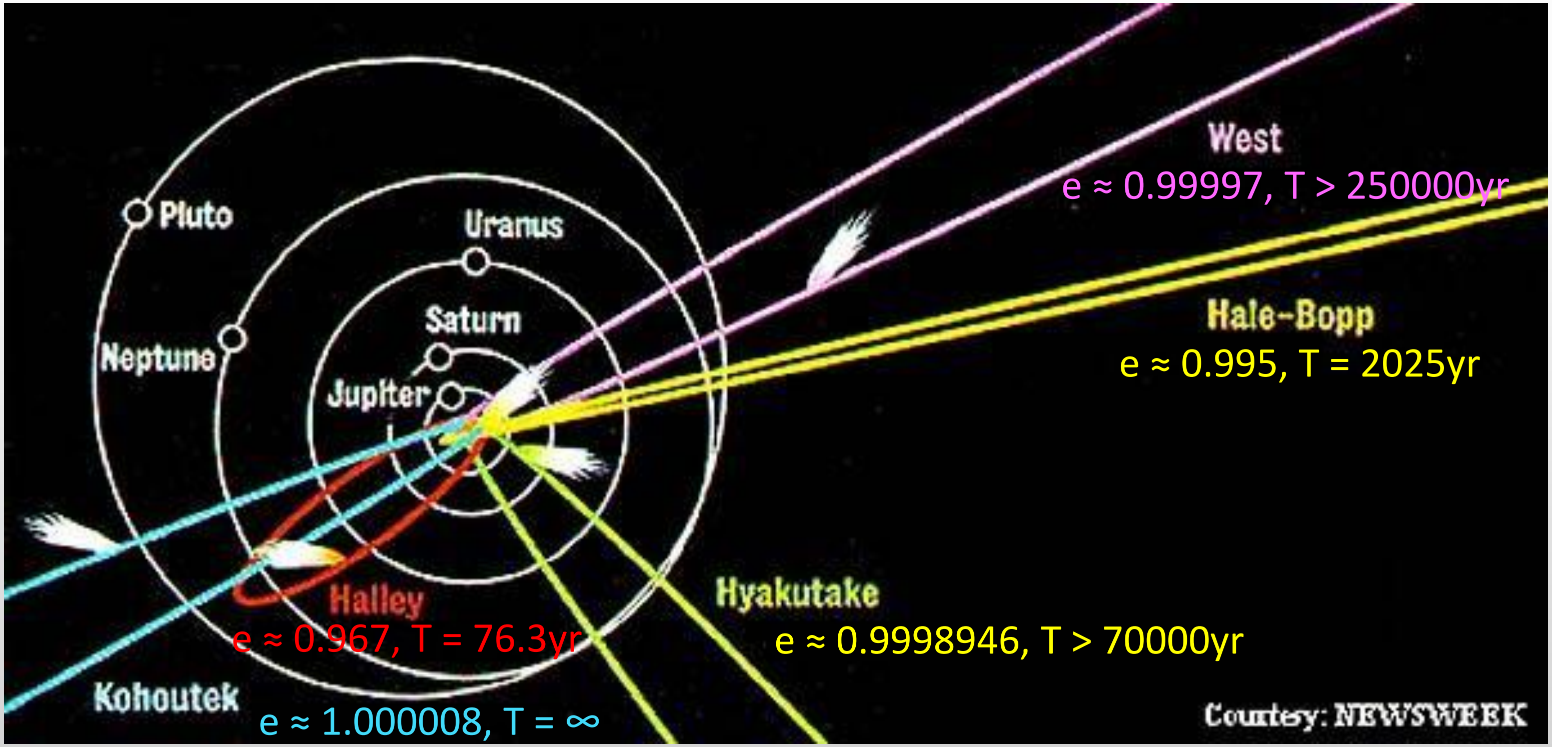
- Hale-Bopp (1997) Comet of the century
- Hayakutake (1995)
- Halley's (1910 and 1986)
- Kohoutek (1973)

Orbits and eccentricity



Orbits of Comets

Halley's comet (1910 and 1986) has a relatively short, 76-year, period orbit confined to the Solar System. Most of the recent spectacular comets enter the inner regions of the Solar System on highly eccentric (some on nearly parabolic) orbits.



Meteor showers – comet debris

- **Perseid shower** (August): Earth's orbit takes us through the debris-filled orbital path of comet Swift-Tuttle in July-August each year. Peak shower: August 11, 12.
- **Leonid shower** (November): The debris path of comet Temple-Tuttle. Peak shower: November 17,18
- **Draconid shower** (October): The debris path of comet Giacobini–Zinner. Peak shower: October 21±
- **Quadrantid shower** (January): Unknown extinct comet. Peak shower: January 1,3.

On asteroid risks

Chapman and Morisson (1994) presented a paper to the US congress that provided an evaluation of risk of asteroid impact catastrophes.

Their comparative estimates of death by asteroid impacts:

TABLE 3 Chances of dying from selected causes (USA)

Cause of death	Chances
Motor vehicle accident	1 in 100
Murder	1 in 300
Fire	1 in 800
Firearms accident	1 in 2,500
Asteroid/comet impact (lower limit)	**1 in 3,000**
Electrocution	1 in 5,000
ASTEROID/COMET IMPACT	**1 in 20,000**
Passenger aircraft crash	1 in 20,000
Flood	1 in 30,000
Tornado	1 in 60,000
Venomous bite or sting	1 in 100,000
Asteroid/comet impact (upper limit)	**1 in 250,000**
Fireworks accident	1 in 1 million
Food poisoning by botulism	1 in 3 million
Drinking water with EPA limit of TCE*	1 in 10 million

* EPA, Environmental Protection Agency; TCE, trichloroethylene.

On asteroid risks

Chapman and Morisson (1994) presented a paper to the US congress that provided an evaluation of risk of asteroid impact catastrophes.

Their presentation supported the creation and maintenance of the **Sentry** search. Continual monitoring of NEOs (Near Earth Objects) might give us some lead time in the future concerning possible impacts.

As of today, the object **29075 (1950 DA)**, a kilometer sized body, presents the greatest risk of a future impact currently estimated at 1.2 chances in 10000 in year 2880.