The KT Extinction!

Just to clarify... what does KT mean?

Refers to the Cretaceous-Tertiary boundary... The ‘K’ comes from the german word for Creta = Kreide = Chalk

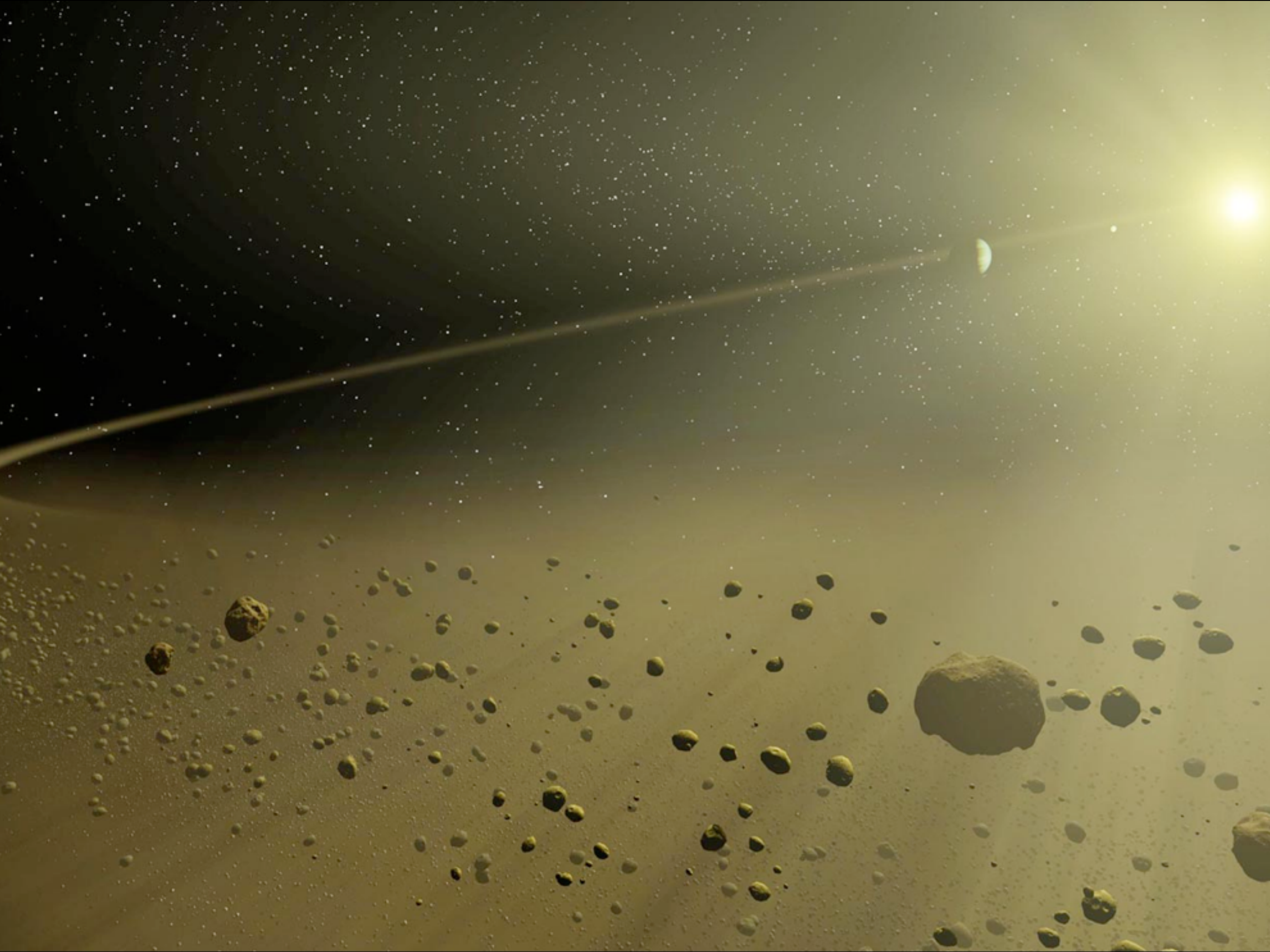
Now people say K-Pg for Cretaceous-Paleogene…

Cretaceous

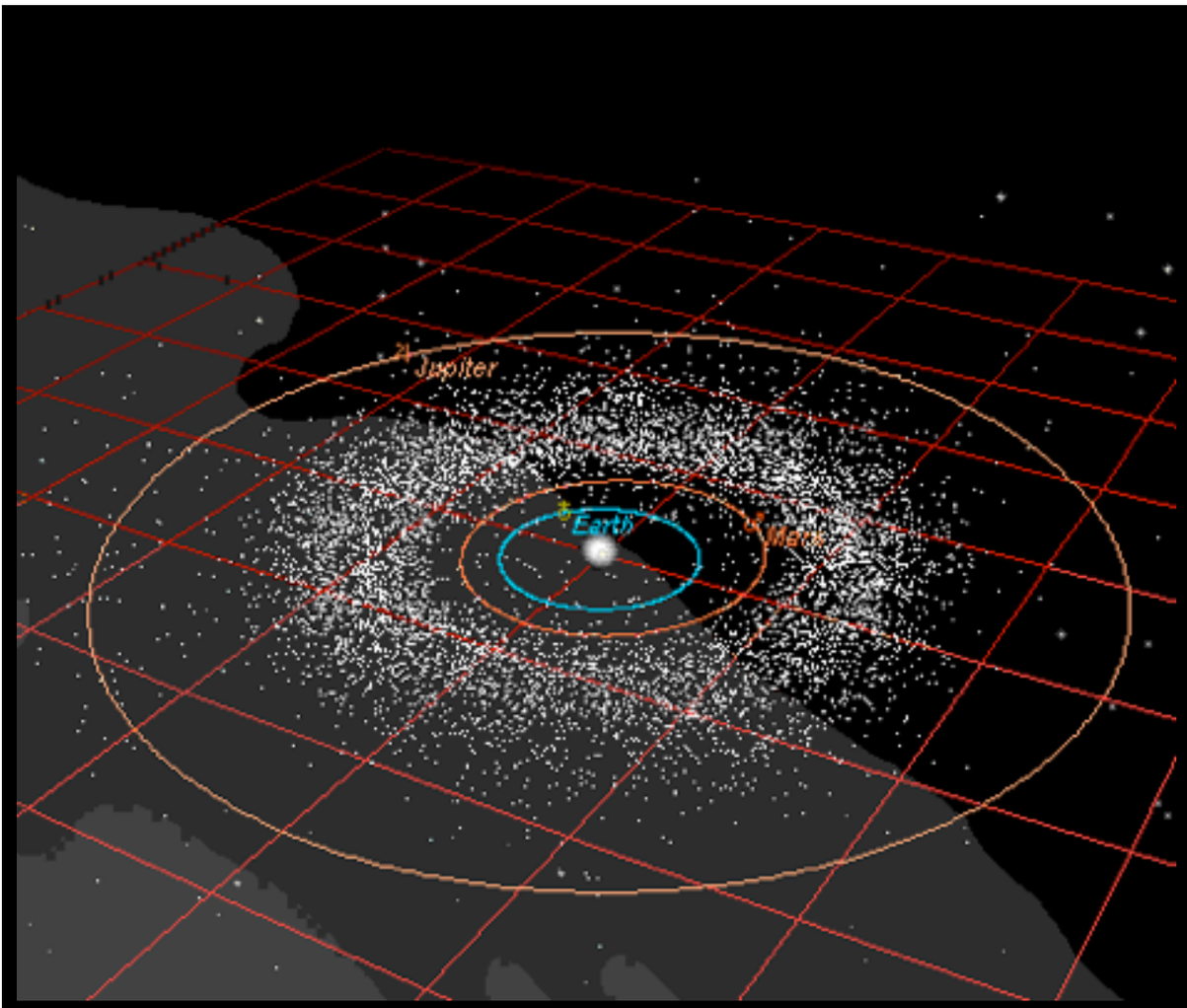
Paleogene

Mesozoic

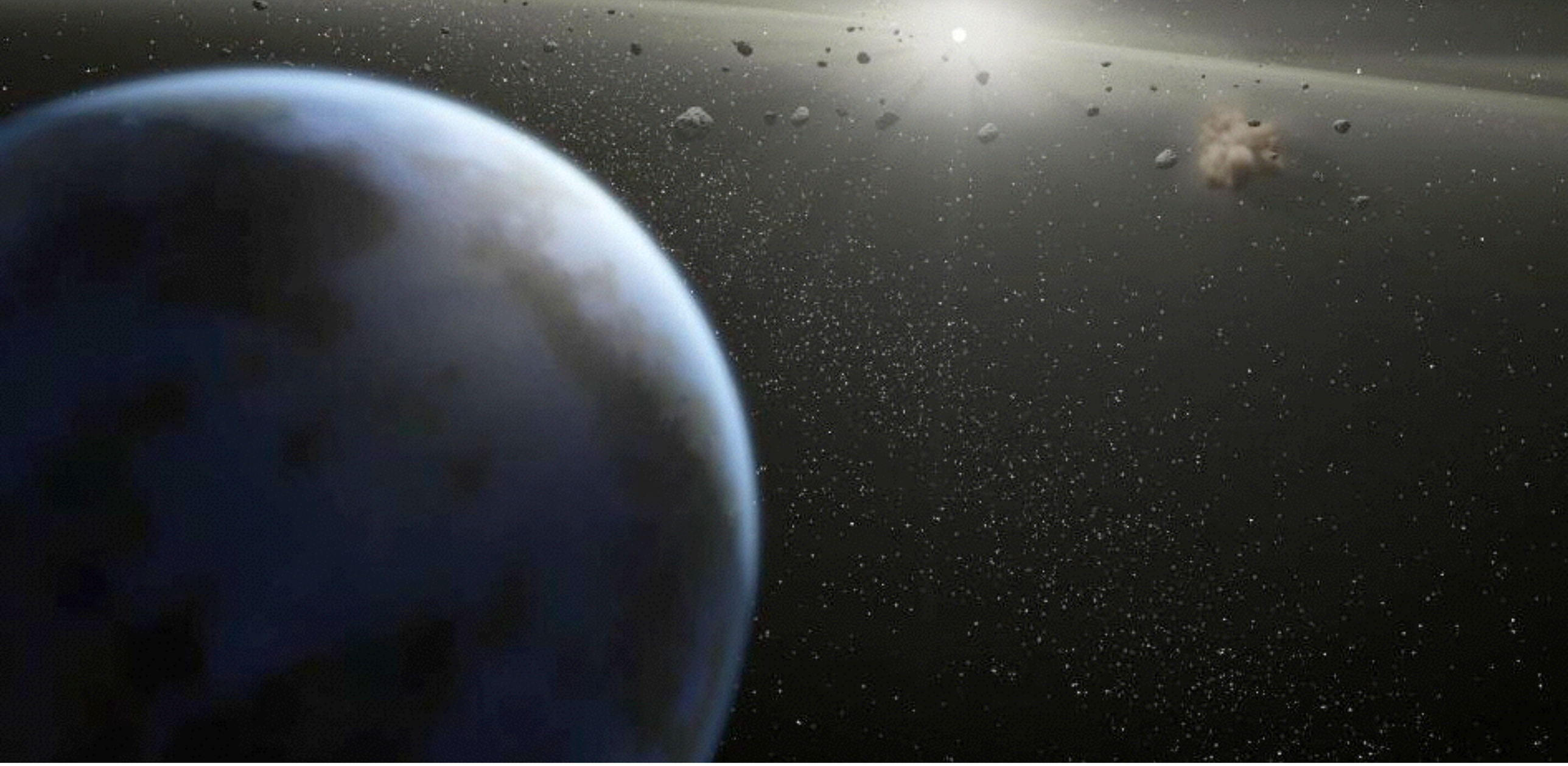
Cenozoic



Bolides!



Asteroid: A rocky or metallic minor planet, or planetoid
Comet: an asteroid that sublimates as the comet warms up
Meteorite: A natural object from outer space that survives an impact with Earth



The Asteroid Belt

Has been around since the first few million years of solar system formation

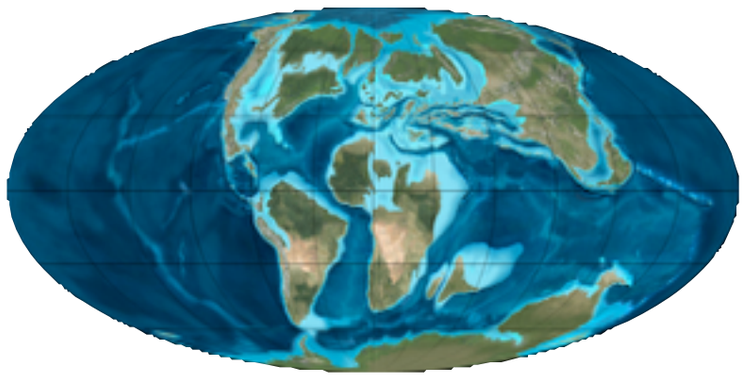
Much of the original primordial material has been lost (0.1% of original mass left)

12,000 have names; 96,000 have numbers...

700,000 to 1.7 million are larger than 1 Km

Harbor a small population of comets with water-ice. May have been the source of Earth's oceans

Latest Cretaceous: 65.5 Ma



Life at the KT boundary

Oceans

Fish & Sharks: Not devastated; the record is not detailed enough to know what happened here.

Plesiosaurs/Pliosaurs: Harder to tell... certainly disappeared around the KT

Mosasaurs: Extinction occurred abruptly at KT

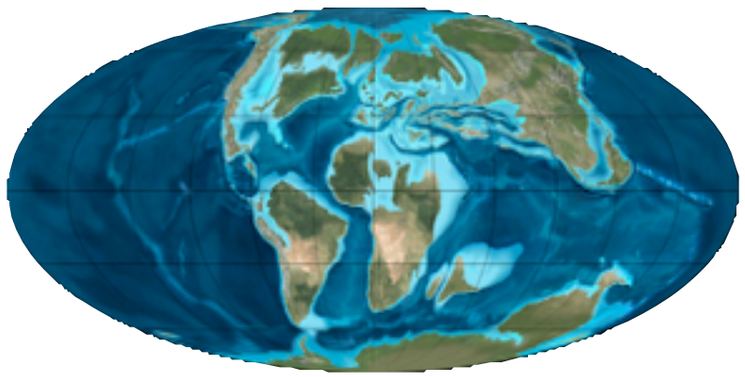
Ichthyosaurs: Disappeared *well before* the KT event

Ammonites: Extinction occurred abruptly at KT

Bivalves: 65% went extinct within the last 10 Ma of the Cretaceous, but the record is not fine enough to known exactly when or how

Latest Cretaceous: 65.5 Ma

Life at the KT boundary



Oceans

Foraminifera: Abrupt extinction... only a few species crossed over.

Calcareous nanofossils: As abrupt as Foraminifera

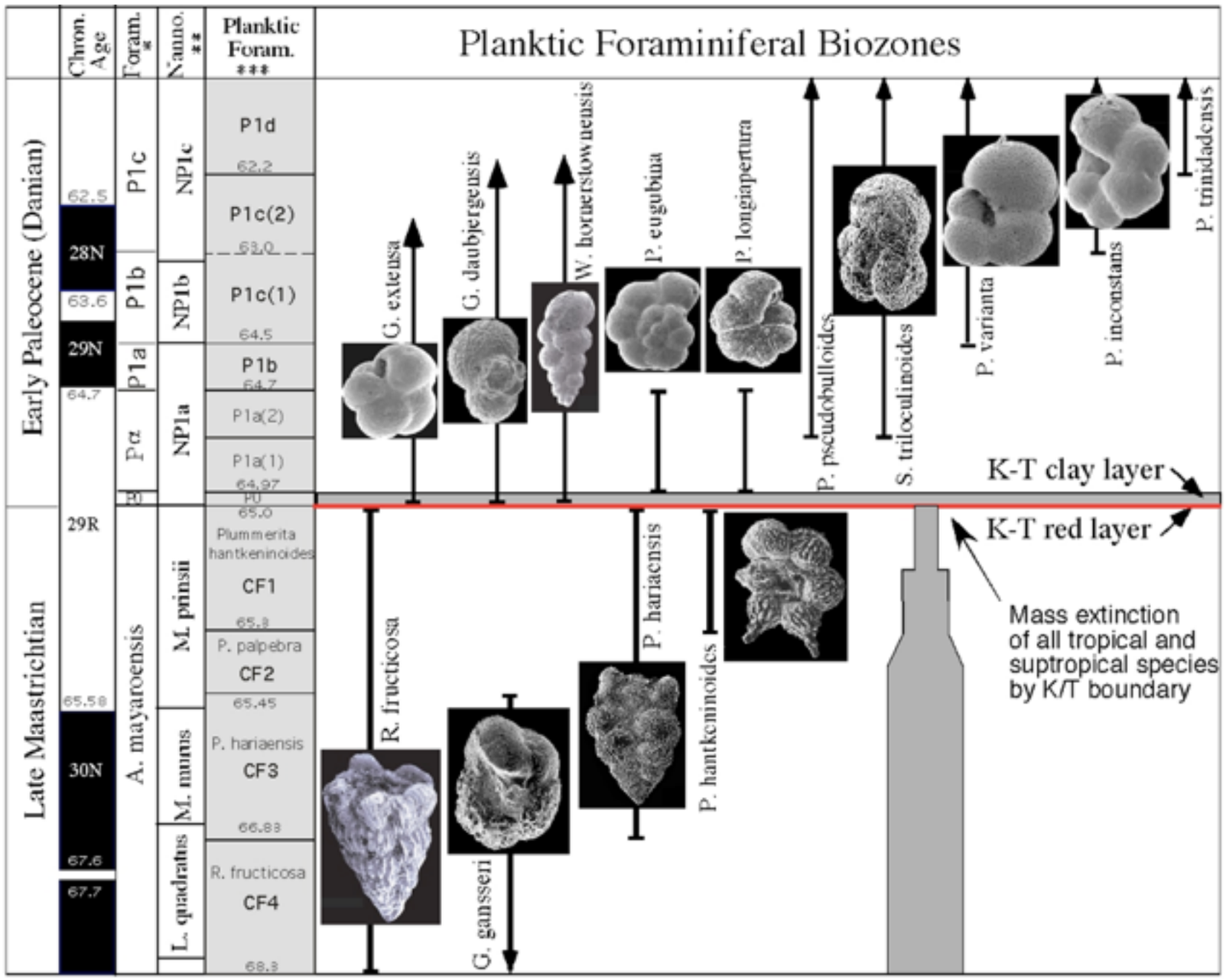
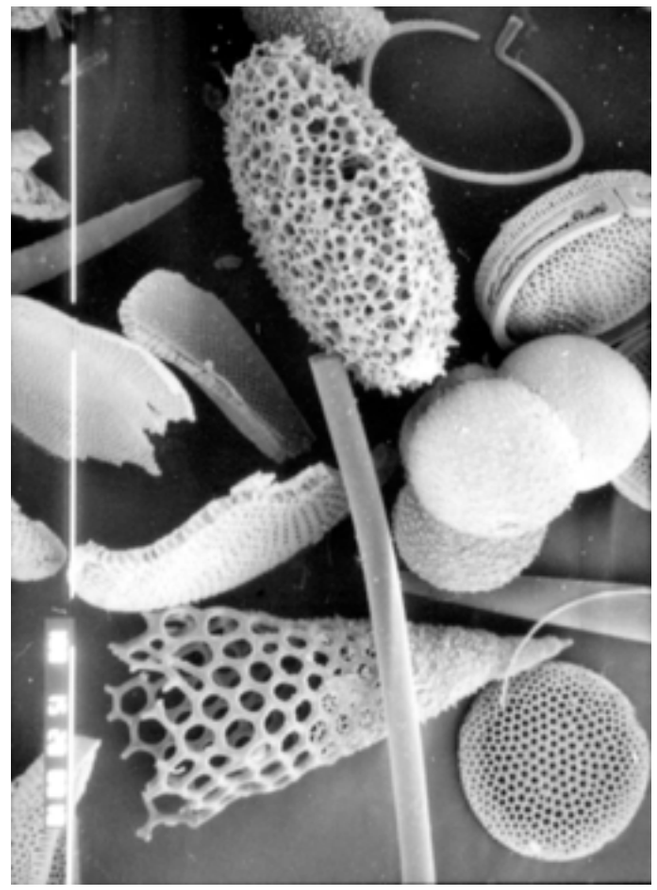


Figure 2



Gradual or Catastrophic?

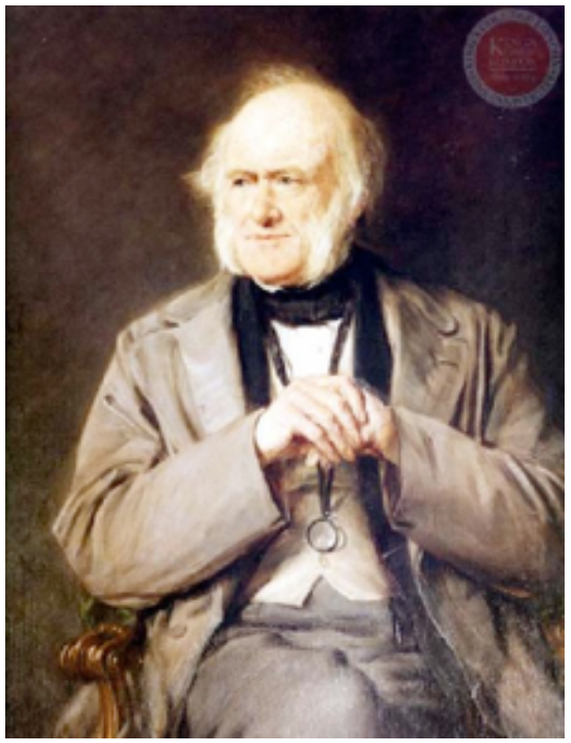
Gradualist scenario:

The world was changing slowly over a period of many years

This was the dominant hypothesis regarding the KT event until the early 1980s

Main evidence:

- Non-Dinosaurian terrestrial vertebrates show continuity across the KT boundary
- Dinosaurs declined for 10 million years prior to the KT boundary



Charles Lyell: studied molluscan assemblages that showed very gradual changes through time...
Greatly influenced Charles Darwin's idea of gradual changes in animals through time
GRADUALIST

Georges Cuvier: studied invertebrate and vertebrate fossils of the Paris Basin and observed **abrupt** changes between organic remains preserved in sedimentary series
CATASTROPHIST

Charles won the day and remained the dominant Father of Geology and Paleontology well into the 20th century. Catastrophism fell by the wayside.

Uniformitarianism Prevailed

Until Team Alvarez came around in the late 1970s

Helen Michel Frank Asaro Luis Alvarez
Walter Alvarez

Grubbio Outcrop, Italy

Lower beds contained Cretaceous marine organisms

Upper beds contained Exclusively Tertiary marine organisms; no mixing

Separated by a thin layer of clay

Expanded

FACIAL HAIR TYPES


Hollywoodian


Mutton Chops


A la Souvarov


French Fork


Ducktail


Fu Manchu


Old Dutch


Dali


Handlebar and Chin Puff


Van Dyke


Friendly Mutton Chops


Balbo


Rap Industry Standard


Sparrow


Klingon


Federation Standard


Short Boxed Beard


Goatee


Chin Curtain


Hulihee


The Zappa


Soul Patch


Handlebar and Goatee


The Winnfield


Petit Goatee


Franz Josef


Anchor


Napoleon III Imperial


Copstash Standard


Pencil

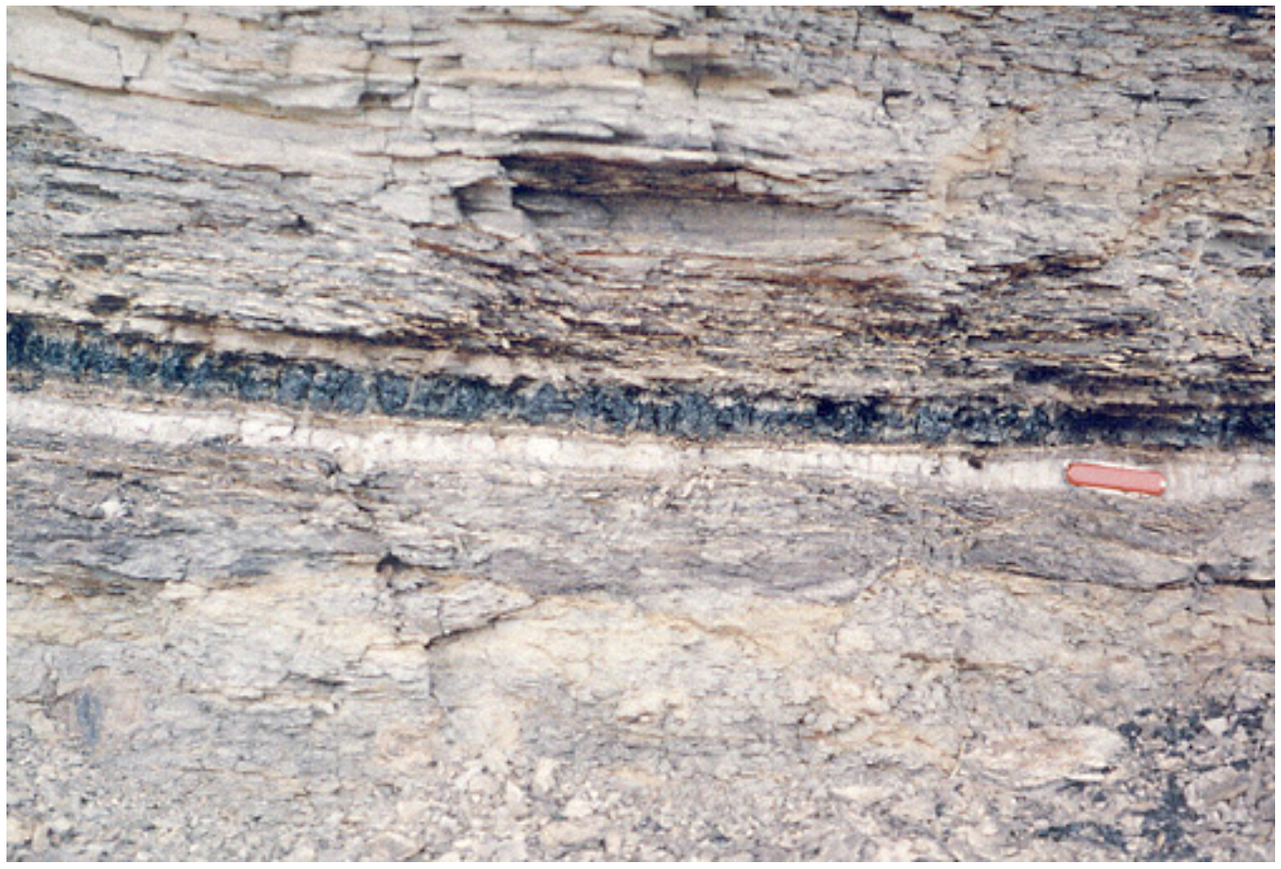

Super Mario

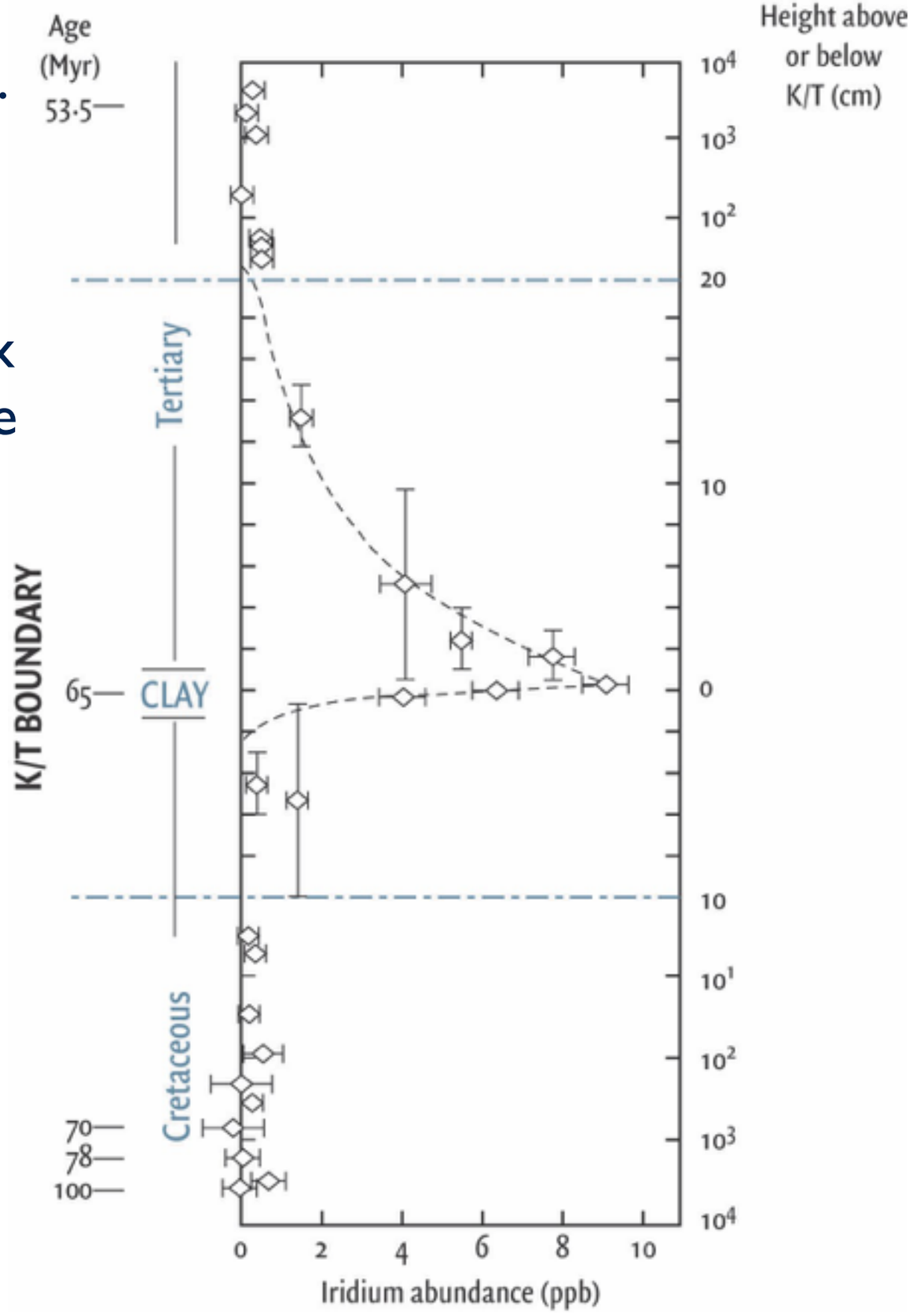

Handlebar

The Iridium Spike

Team Alvarez analyzed the upper, lower, and clay layers for Trace Elements (Rare elements). The ratios of different elements can give you clues to where the soils came from.

They found that the Clay layer contained 10^4 x the amount of Iridium than you'd expect in the Earths Crust!



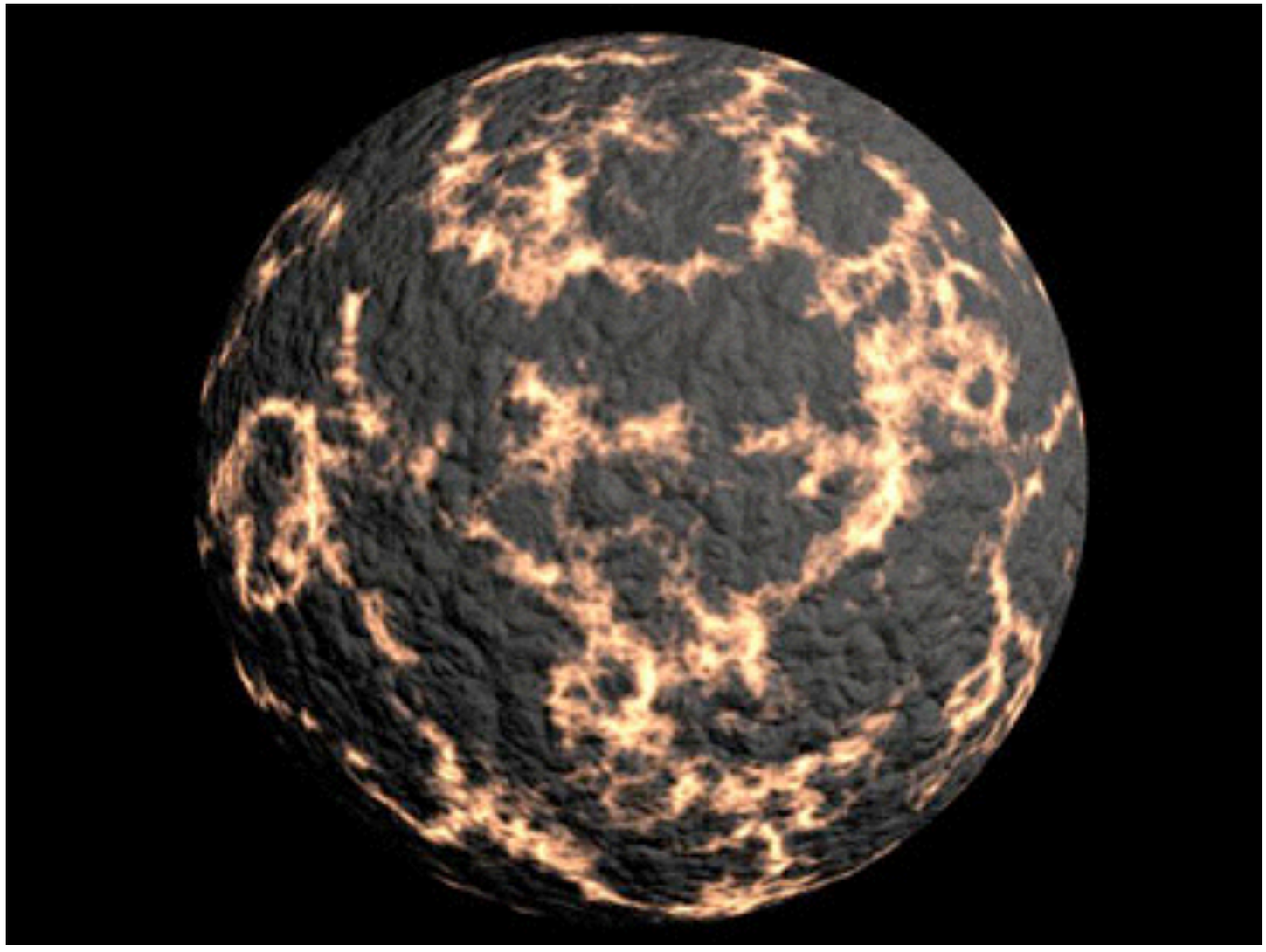


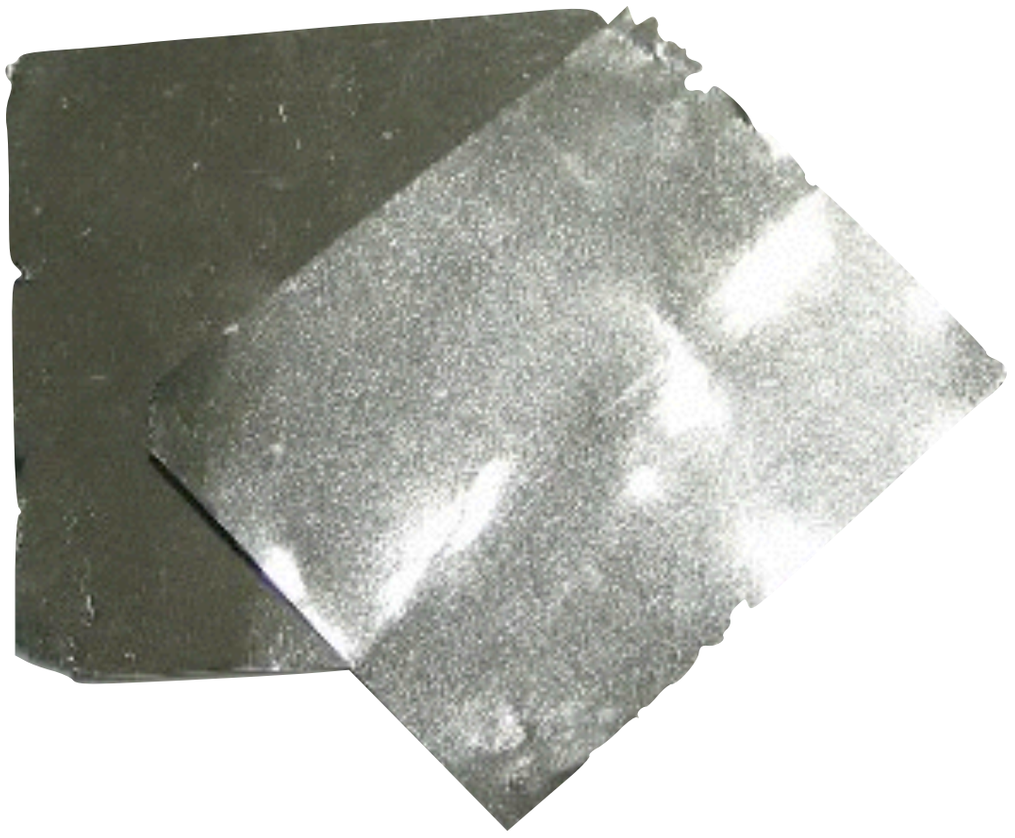
The Iridium Spike

Iridium is rare in the Earth's crust relative to the rest of the Solar System

When Earth was periodically heated during it's formation, molten iron (being heavier than other elements) sank to the Earth's core, scrubbing out the platinum group elements, which include Iridium.

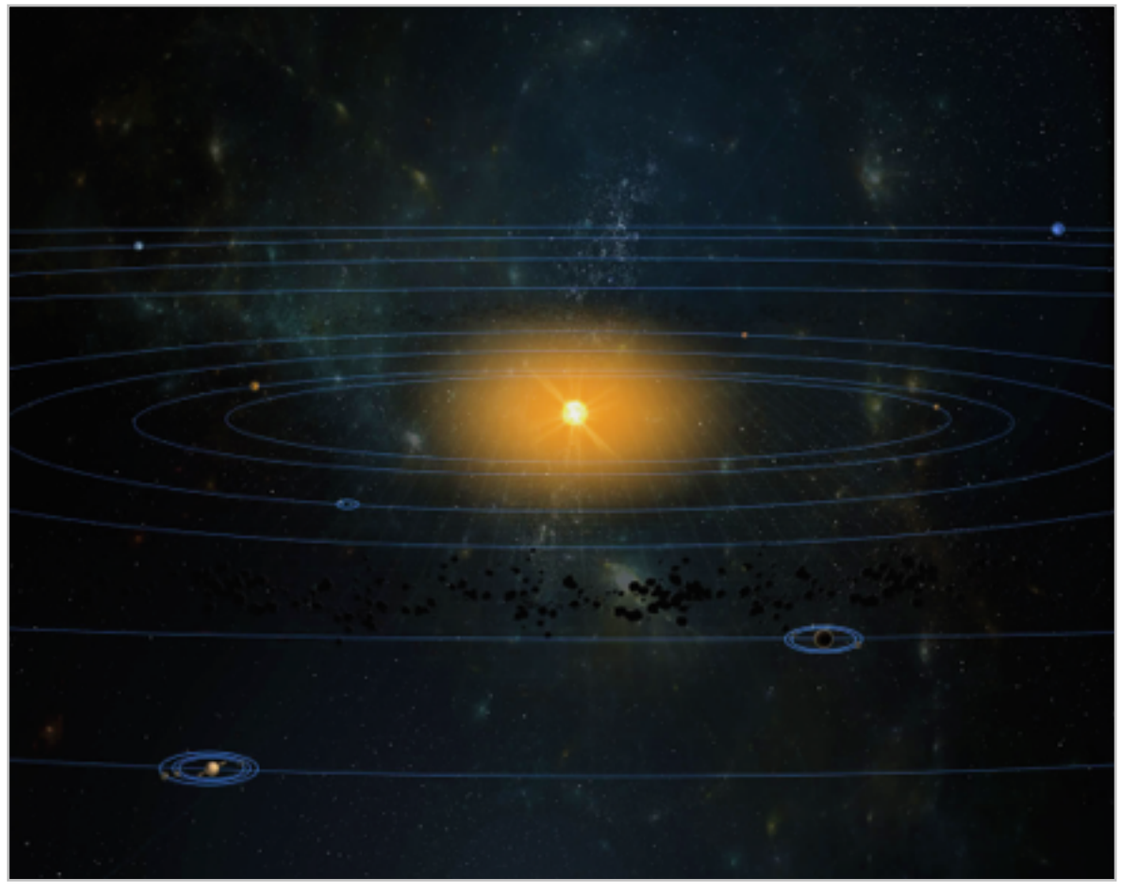
So the Earth has plenty of Iridium... it's just 'downstairs'.





The Iridium Spike

Crust



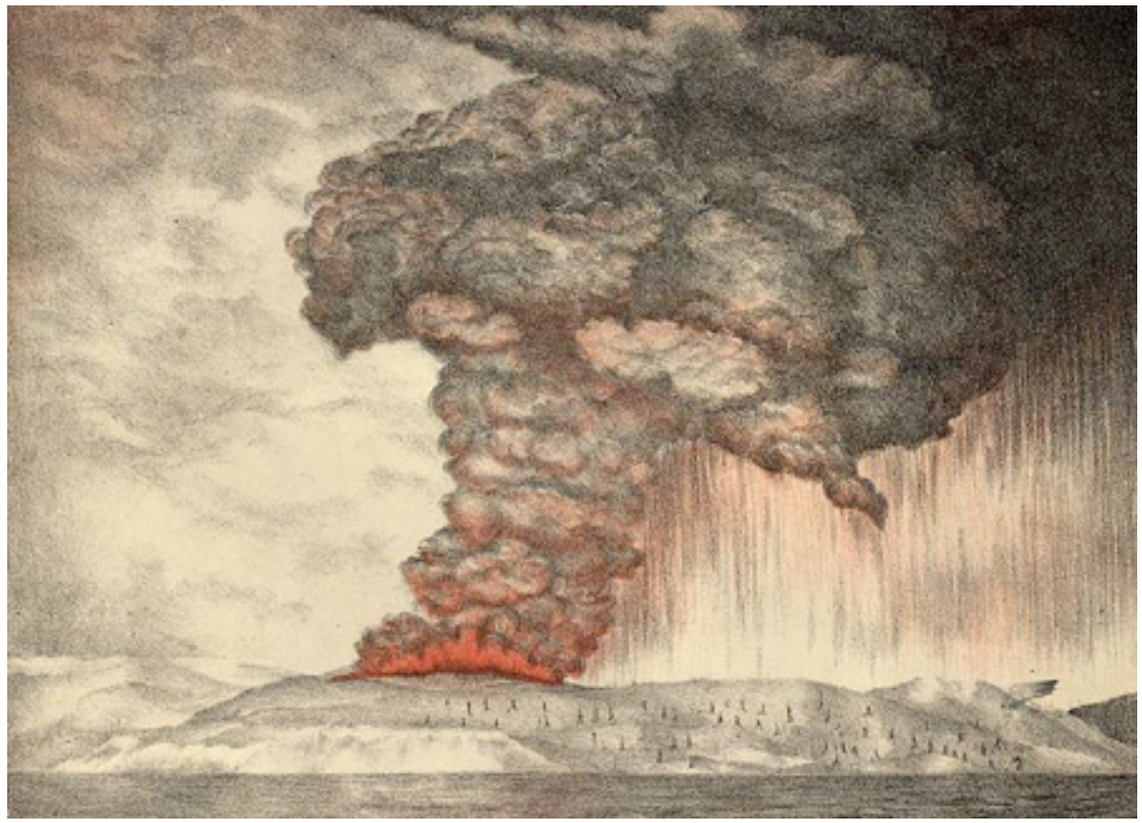
Universe

The Iridium Spike

Team Alvarez checked the Iridium Anomaly against Iridium results from the same layer in Denmark and New Zealand... the results were consistent!!

From this, they conjectured that the Earth was hit by an object from outer space...

No one knew anything about the physics of colliding large objects... how much devastation could an impact bring about? They based their analysis on studies of large terrestrial events such as massive volcanic explosions



Krakatoa

The Iridium Spike

After a back-of-the-envelope calculation:

Surface density of Iridium

Surface Area of Earth's Crust

Mass of asteroid $M = \frac{s * A}{0.22 * f}$

Fraction of material Krakatoa ejected into upper atmosphere

Fractional abundance of Ir in asteroids

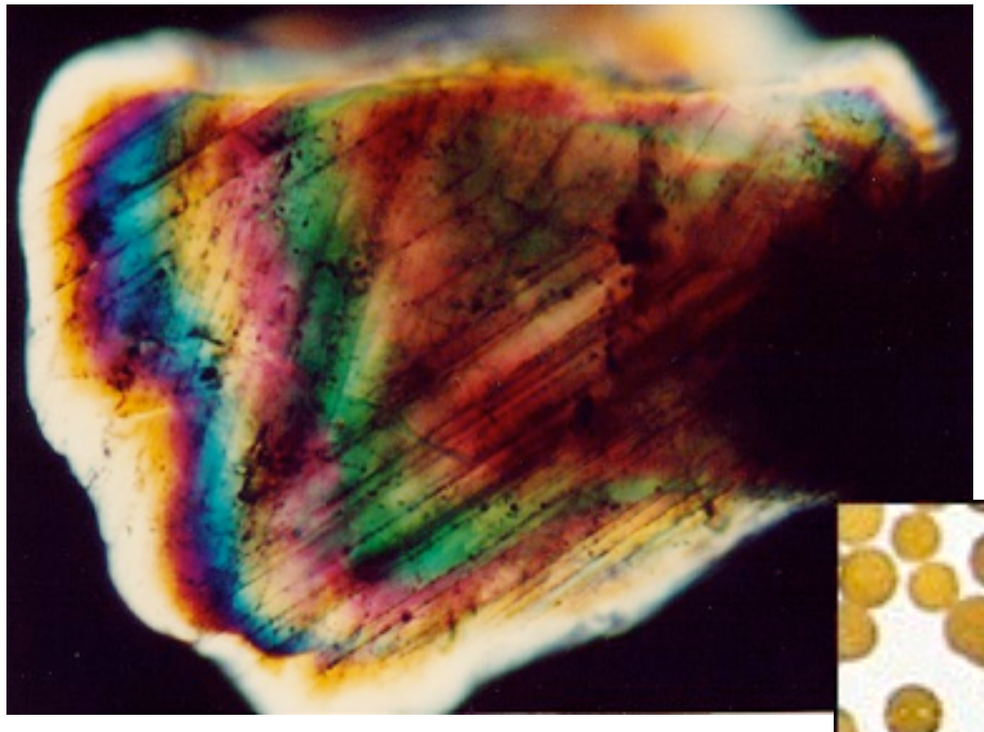
Mass of asteroid = 34 billion tonnes
Between 7 to 10 Km in Diameter...
Would have produced a crater 100-150 km wide

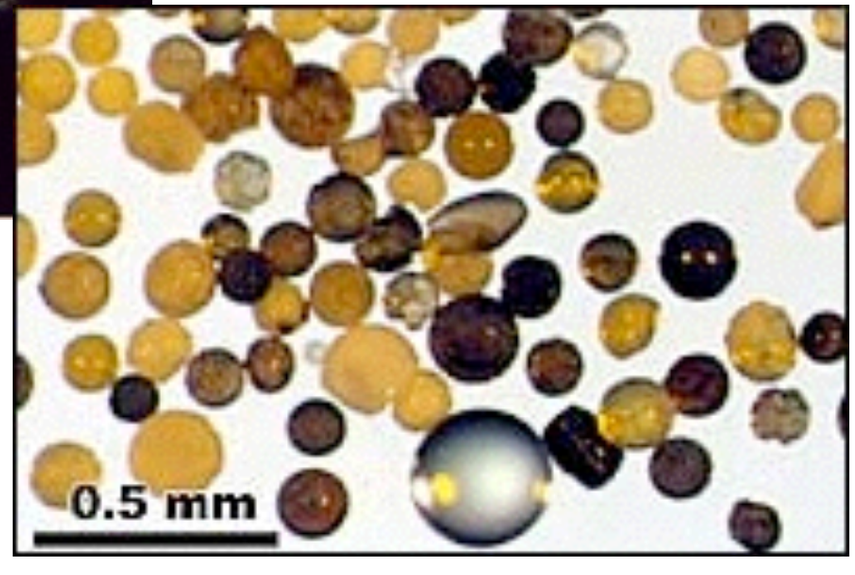
Other Evidence of an impact...

1) Shocked Quartz: Quartz grains with a unique structure: can only form under INTENSE heat, pressure

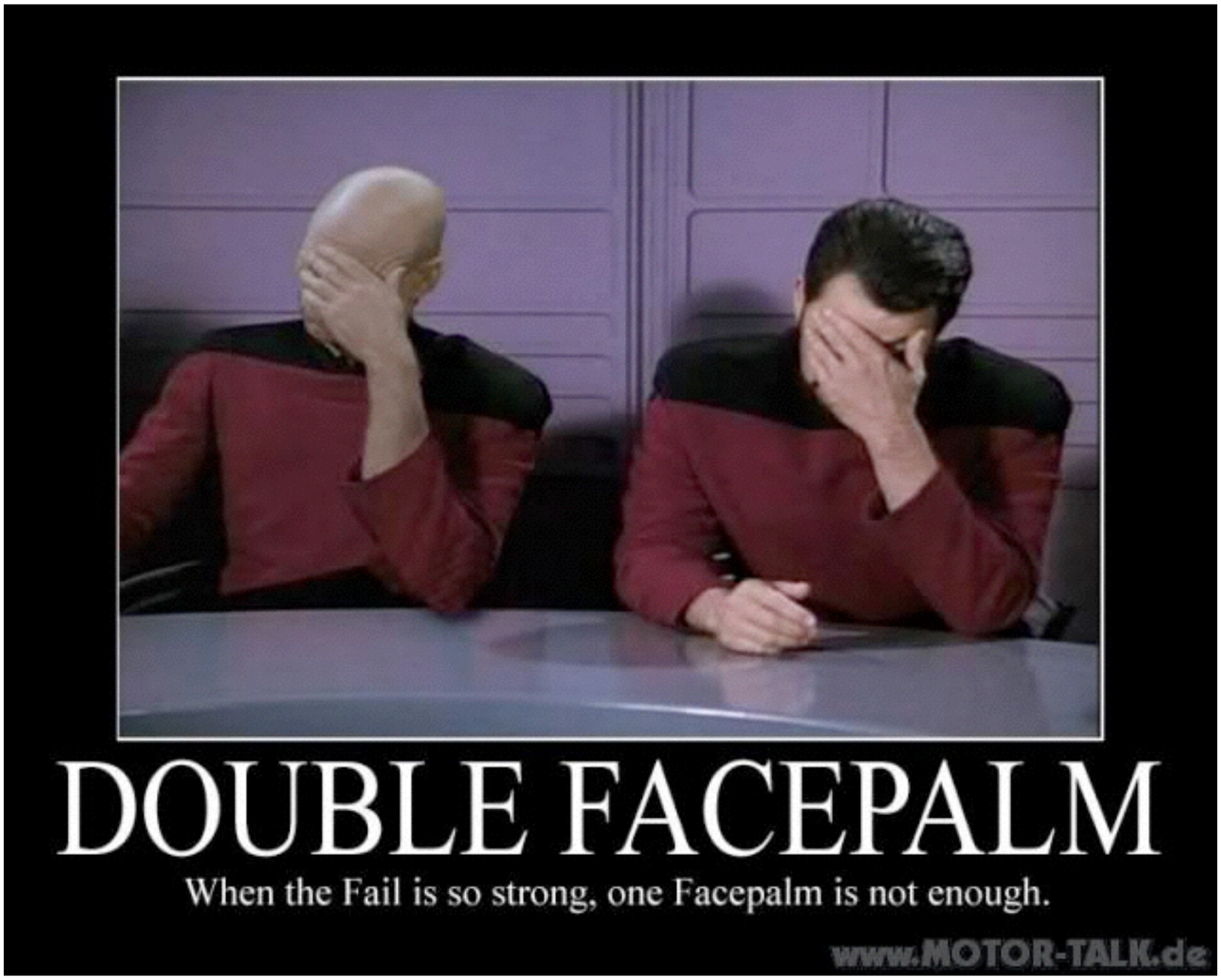
2) Melt spherules (Microtektites): Impacts eject droplets of molten rock into the atmosphere. Cools in a spheroid shape while in mid-air

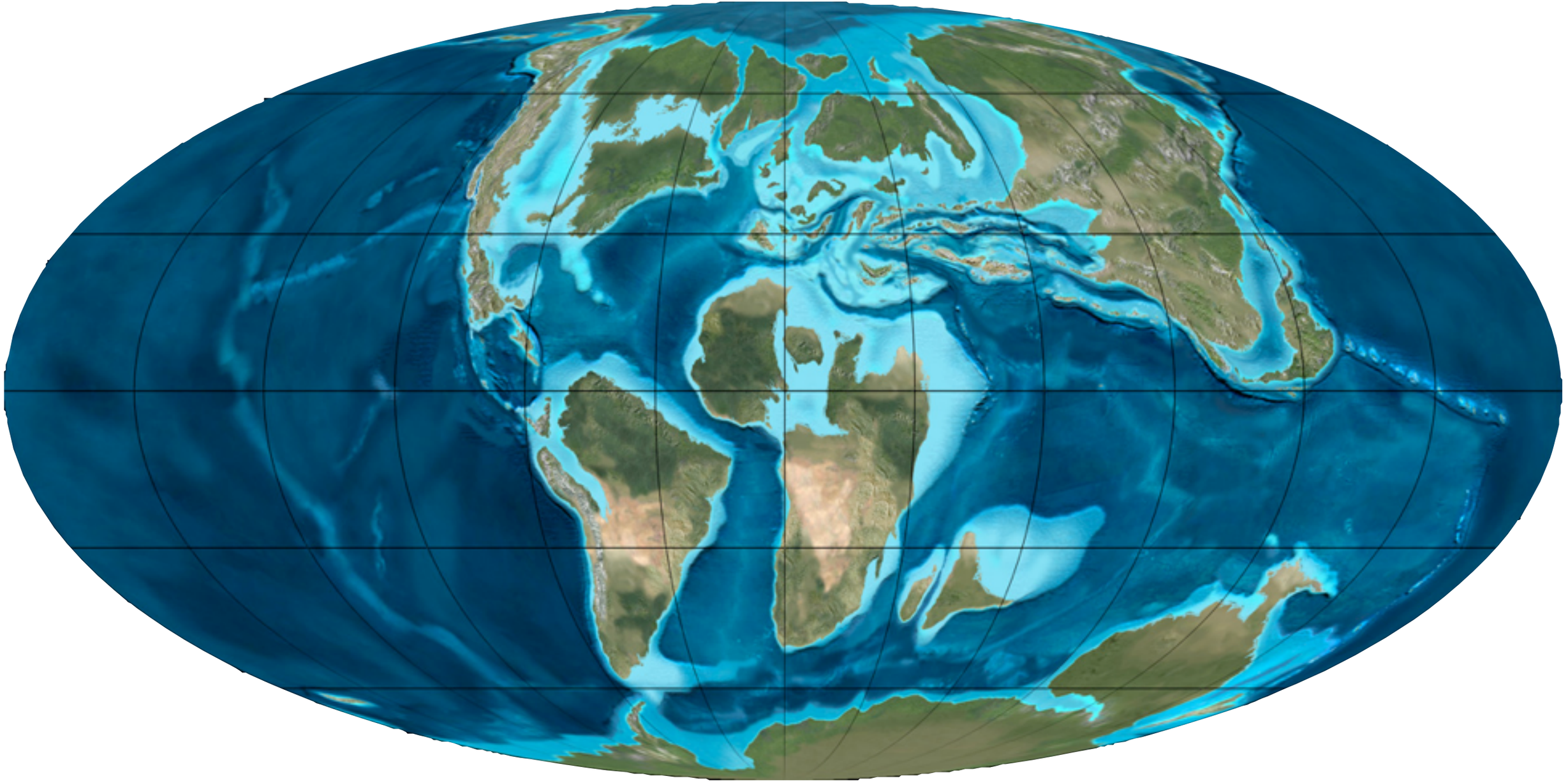
3) Graphite: Carbon... evidence of burning and intense heat. Debris is lifted into upper atmosphere and burns upon re-entry





Geologists *did not* like Physicists telling them what happened to Dinosaurs....

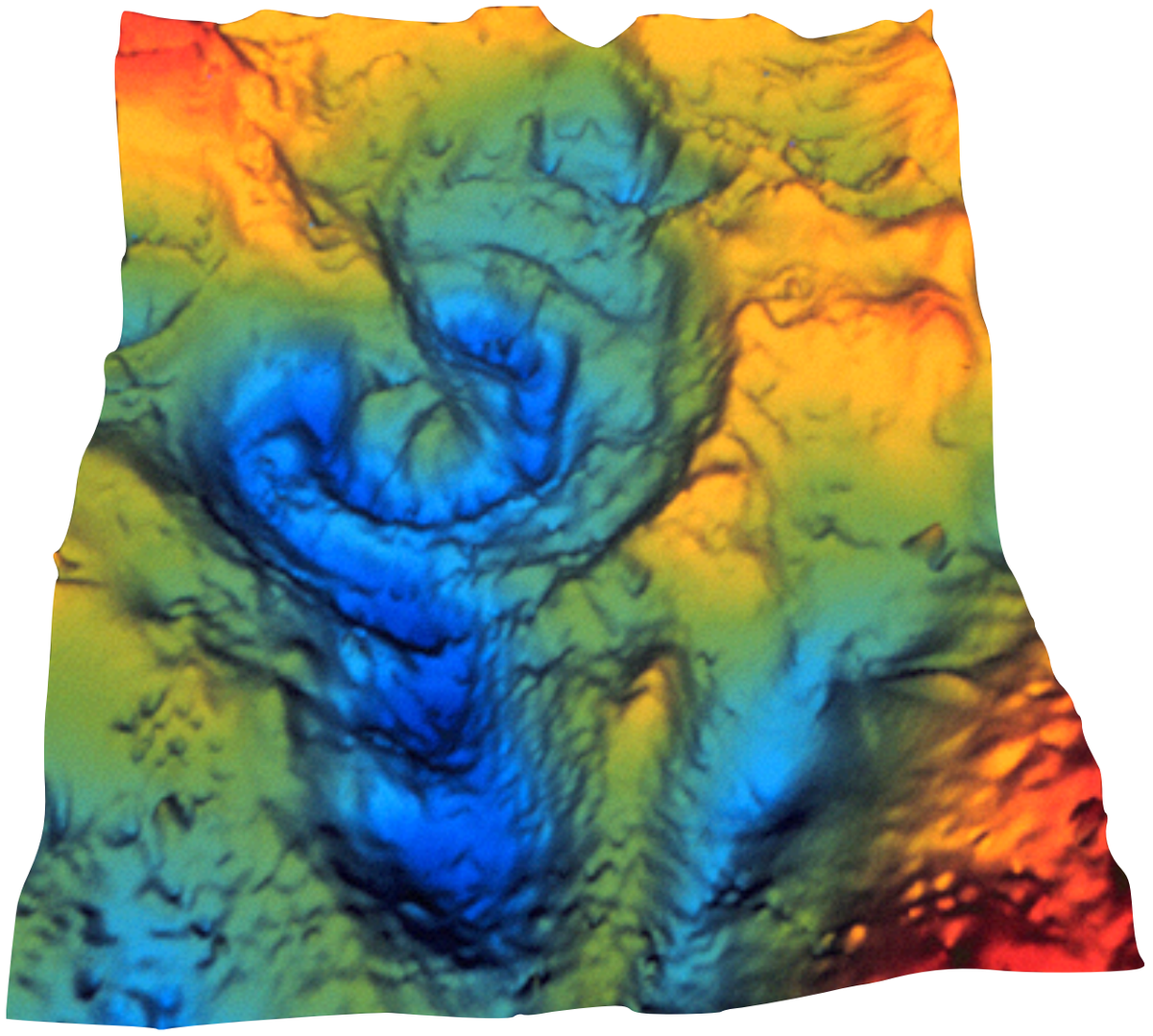




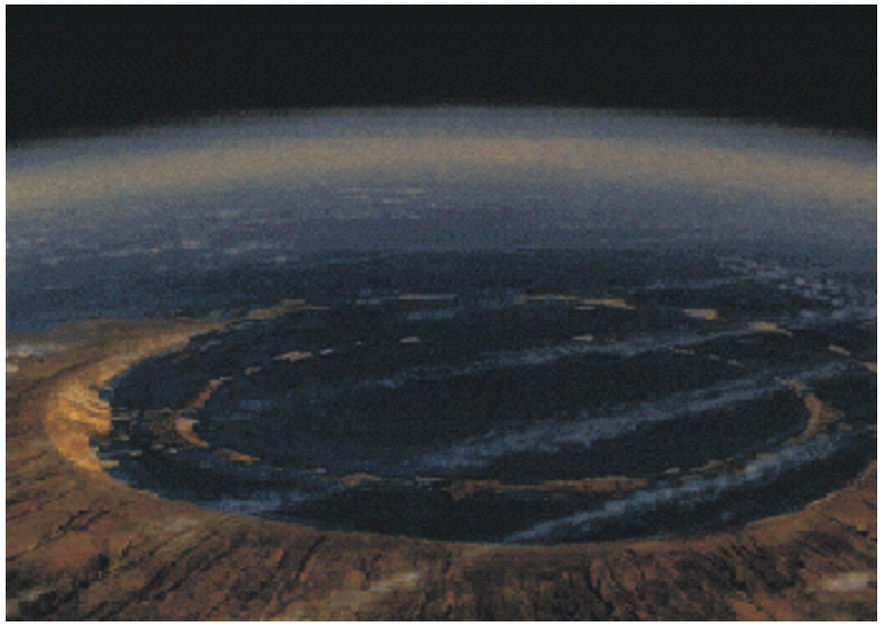
Where's the Crater?????

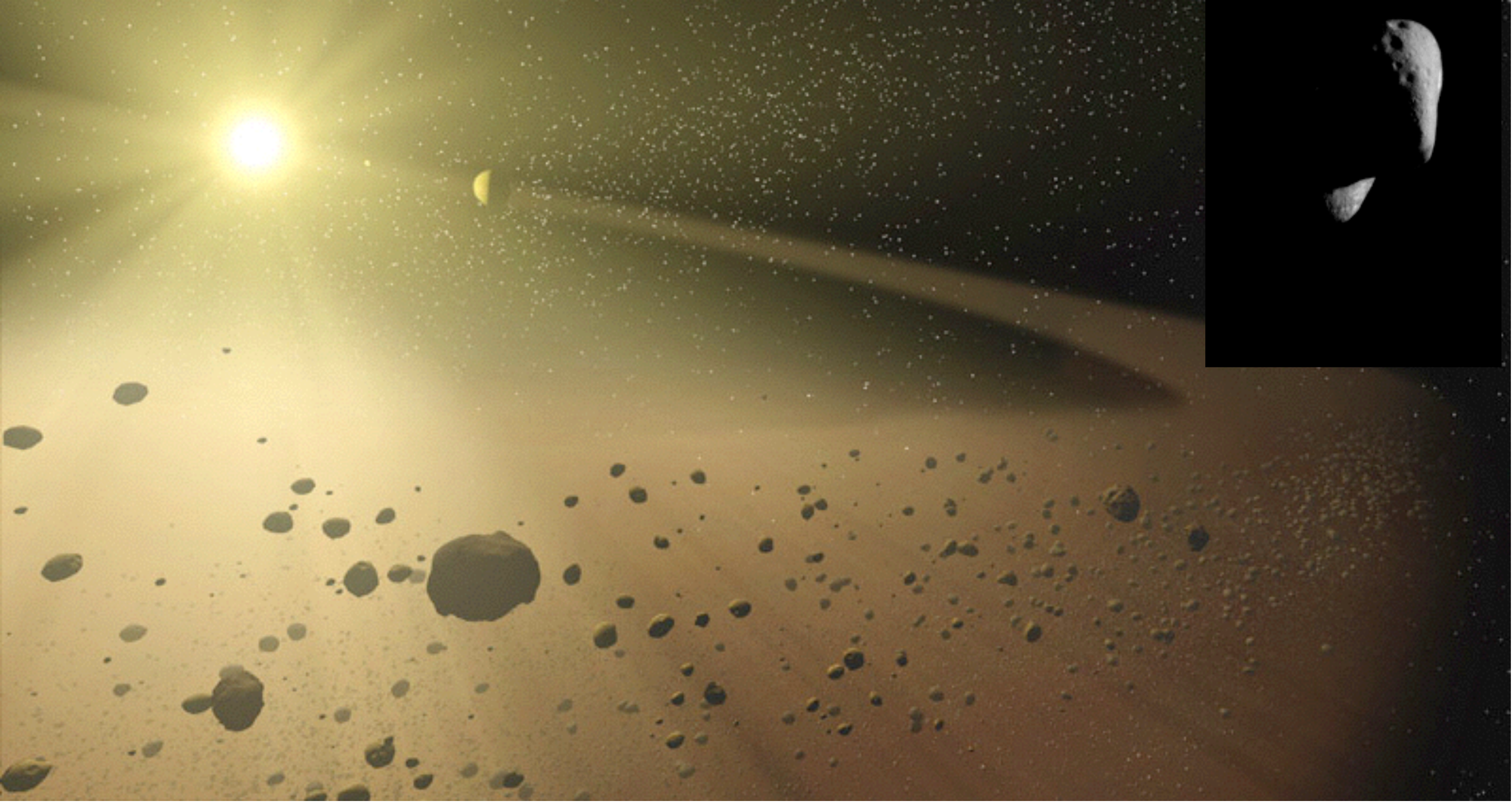
Most of the planet is water... if the impact occurred in the deep ocean, it's very likely evidence would be lost due to subduction of oceanic plates

Chicxulub Crater



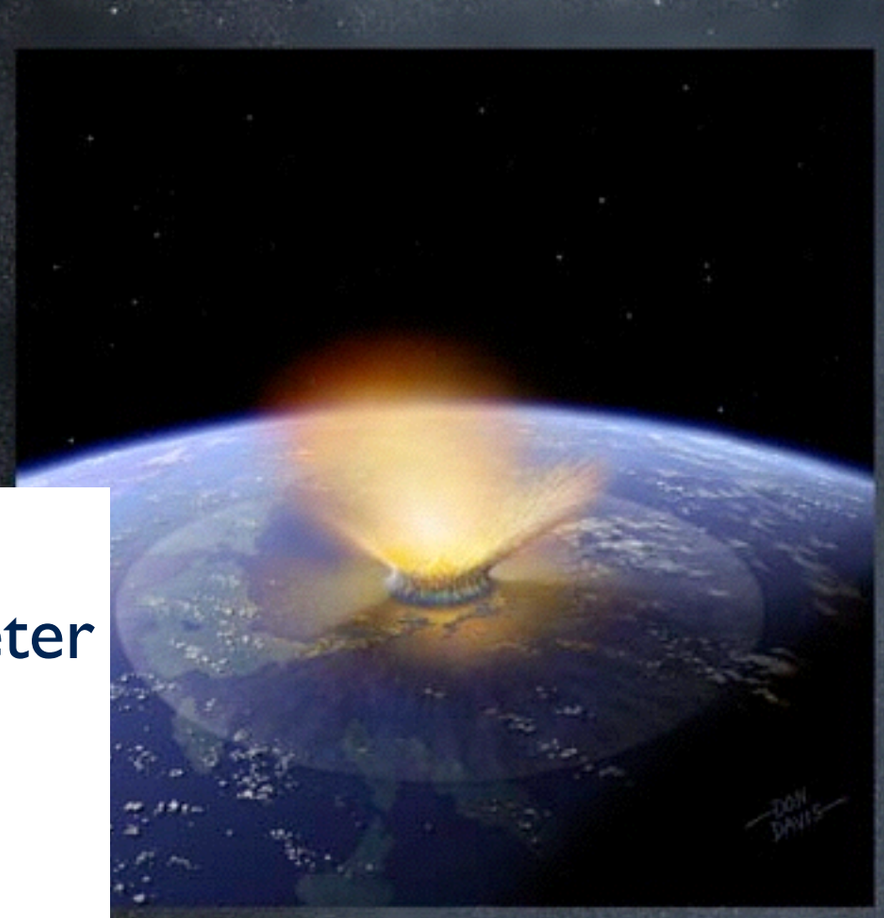
180 Km wide
People have known about it since 1981
In 1991, Drill cores revealed shocked quartz
Large quantities of microtektites were found in Haiti and the Caribbean in general
Sedimentary evidence of tidal waves rushing inland
Dated to 65.5 Ma... the nail in the coffin.



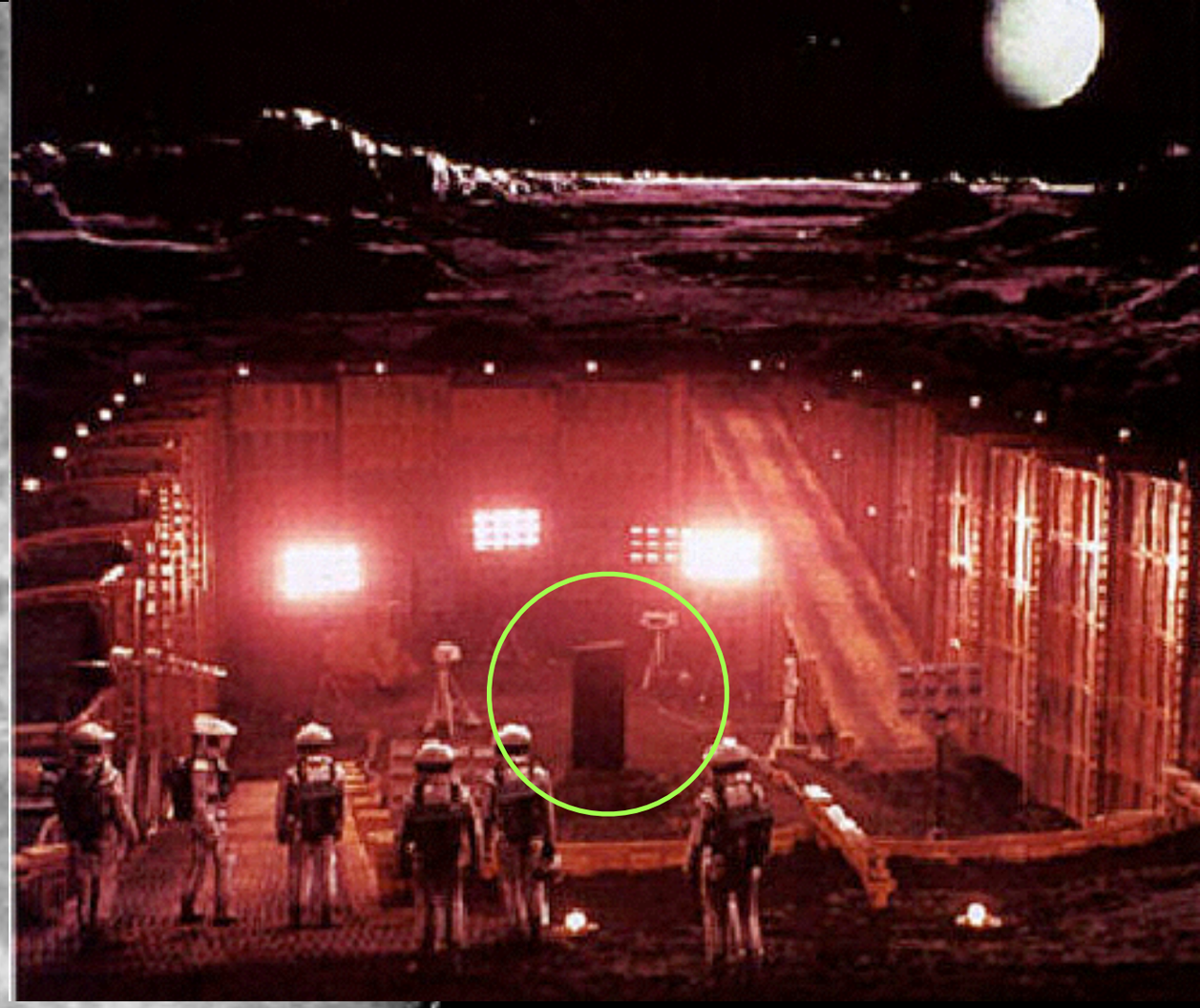


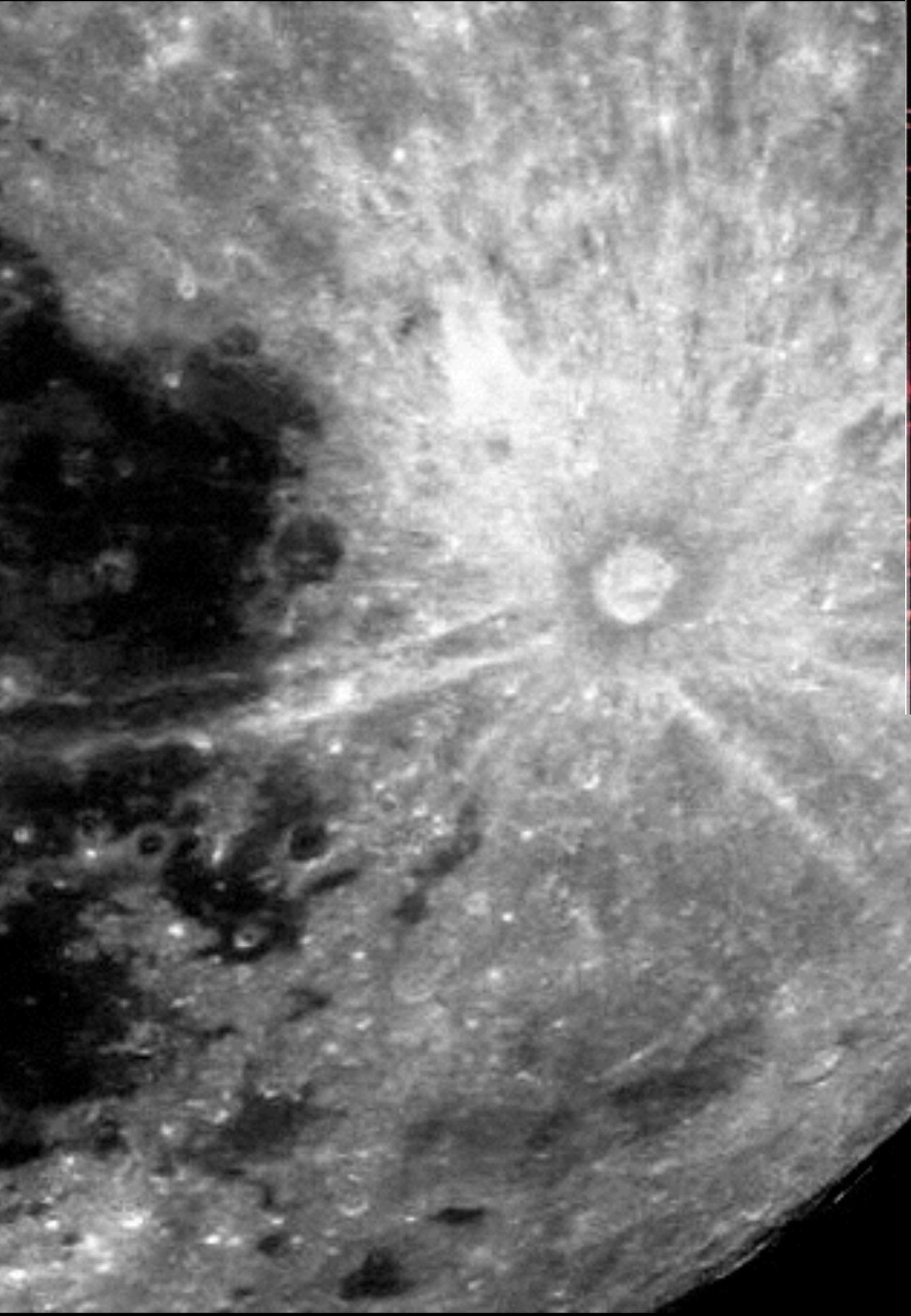
It's now incontrovertible that an impact occurred at the KT boundary.
It's also incontrovertible that this impact was large and devastating.
But more evidence is required to ensure that it is the elusive Dinosaur-Killer.

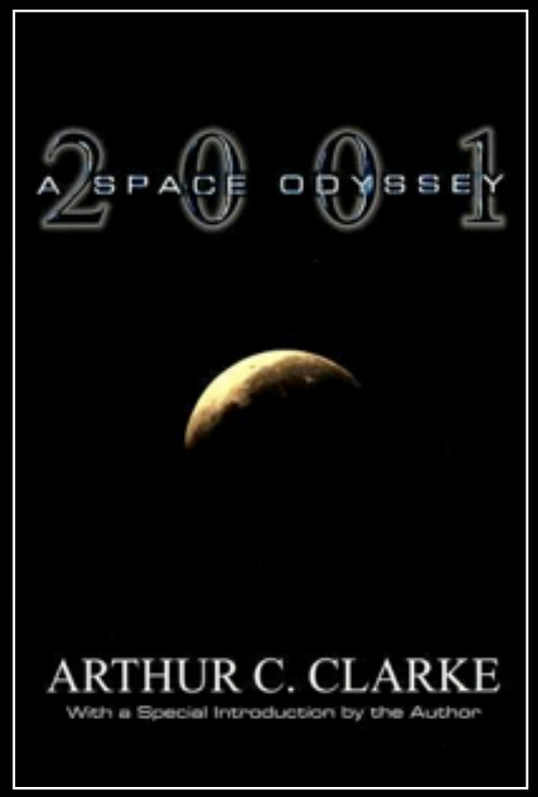
So what exactly happened?
To answer that, we have to take a step back...



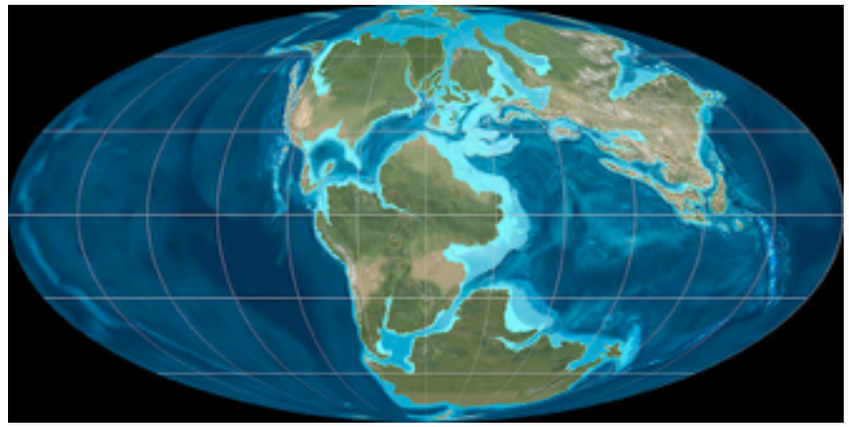
Planetoid *Baptistina*.
160 million years ago, *Baptistina*- at 170 Km in diameter struck another asteroid about 60 Km in diameter.
=> 2 large asteroids ca. 10 Km in diameter
One fragment hit the moon ~ Tycho crater (85 Km)





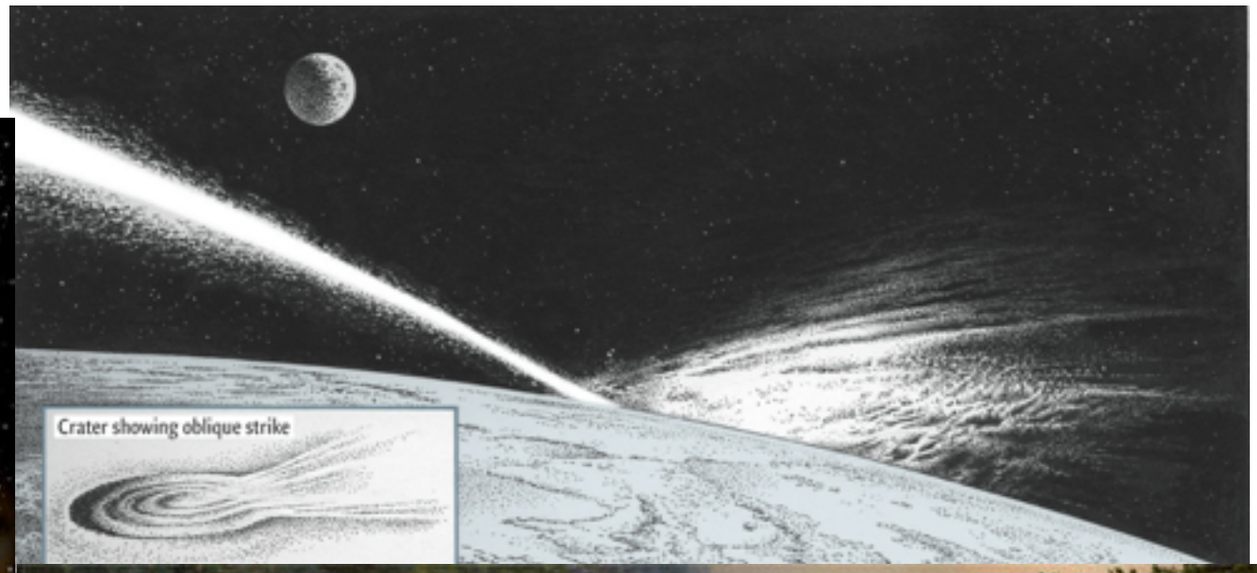

2001
A SPACE ODYSSEY
ARTHUR C. CLARKE
With a Special Introduction by the Author

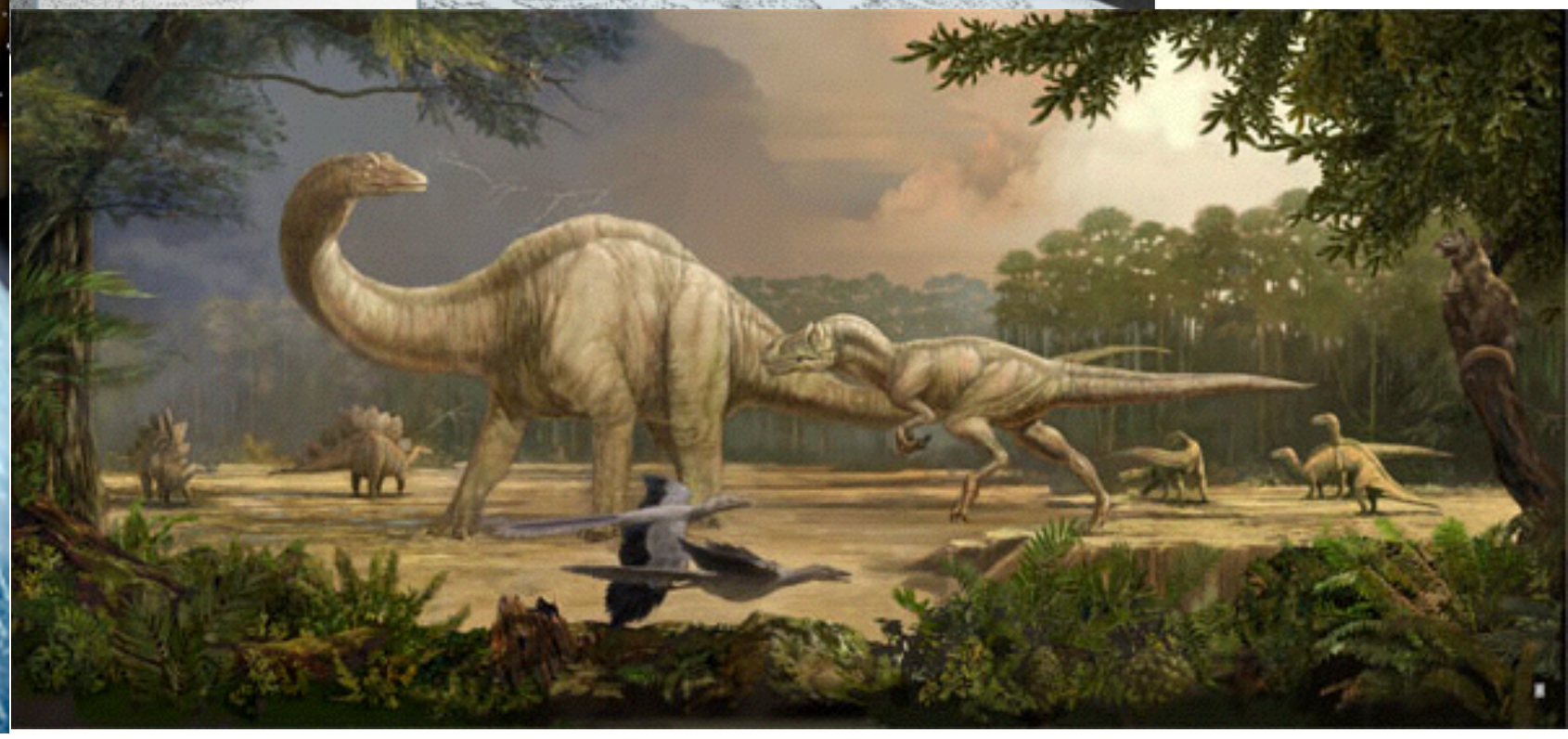
160 MA: the mid-Jurassic



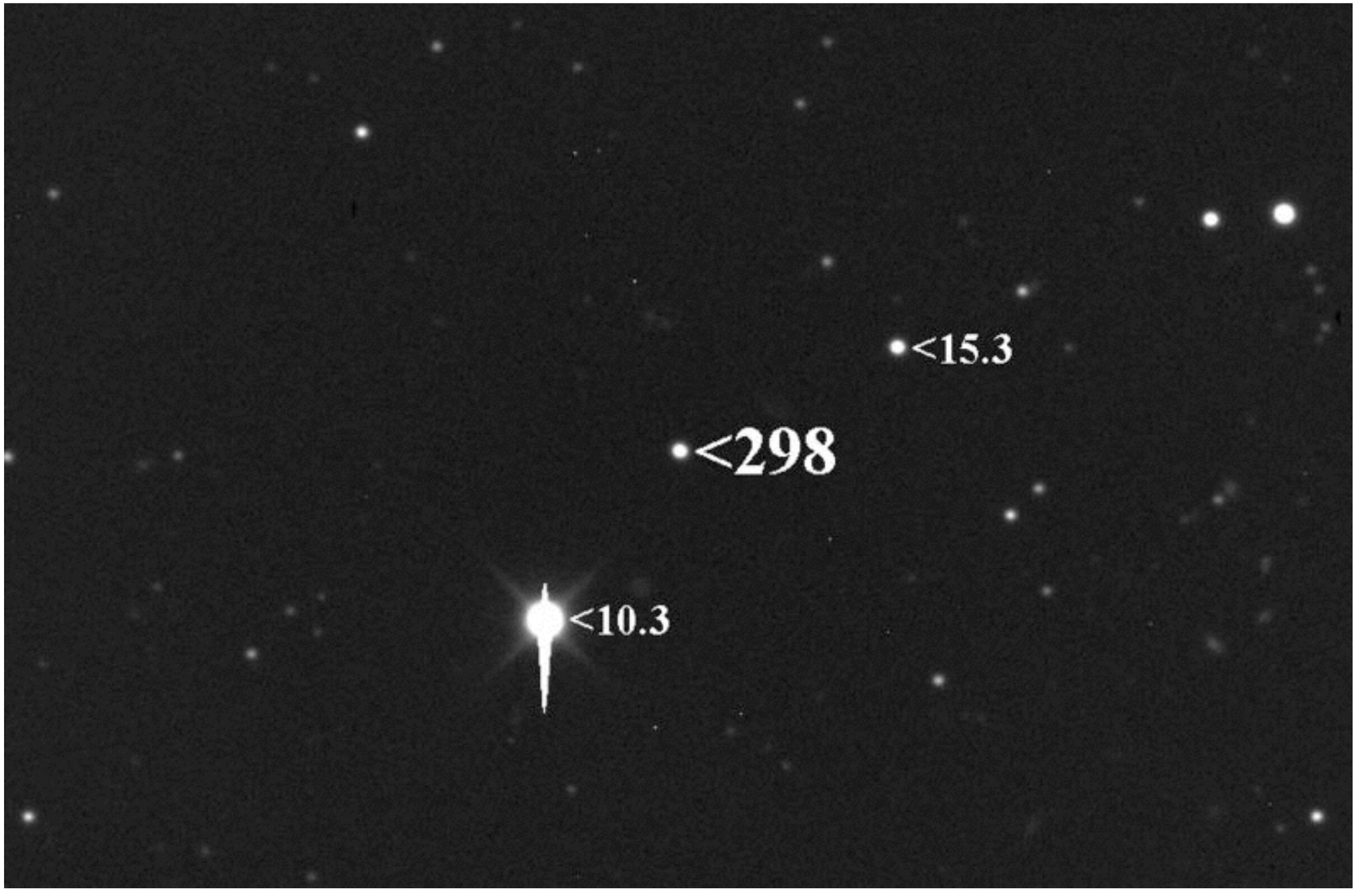
The collision of *Baptistina* occurred during a period of time when Dinosaurs were reaching the peak of their diversity. Their fate was sealed by the middle of the Jurassic

This also explains an accelerated impact rate over the last 100 million years





The remnants of Baptistina can still be observed in the asteroid belt.

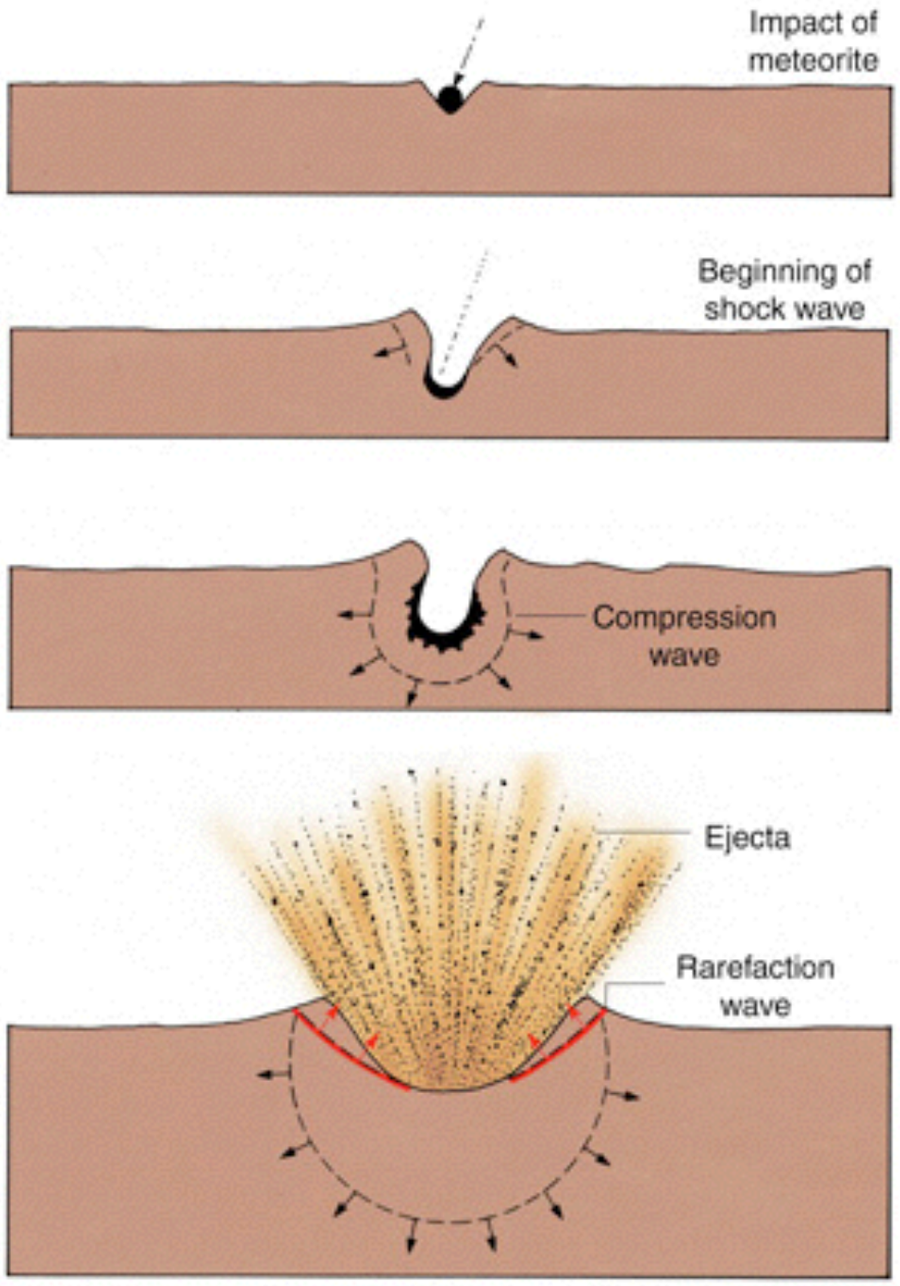


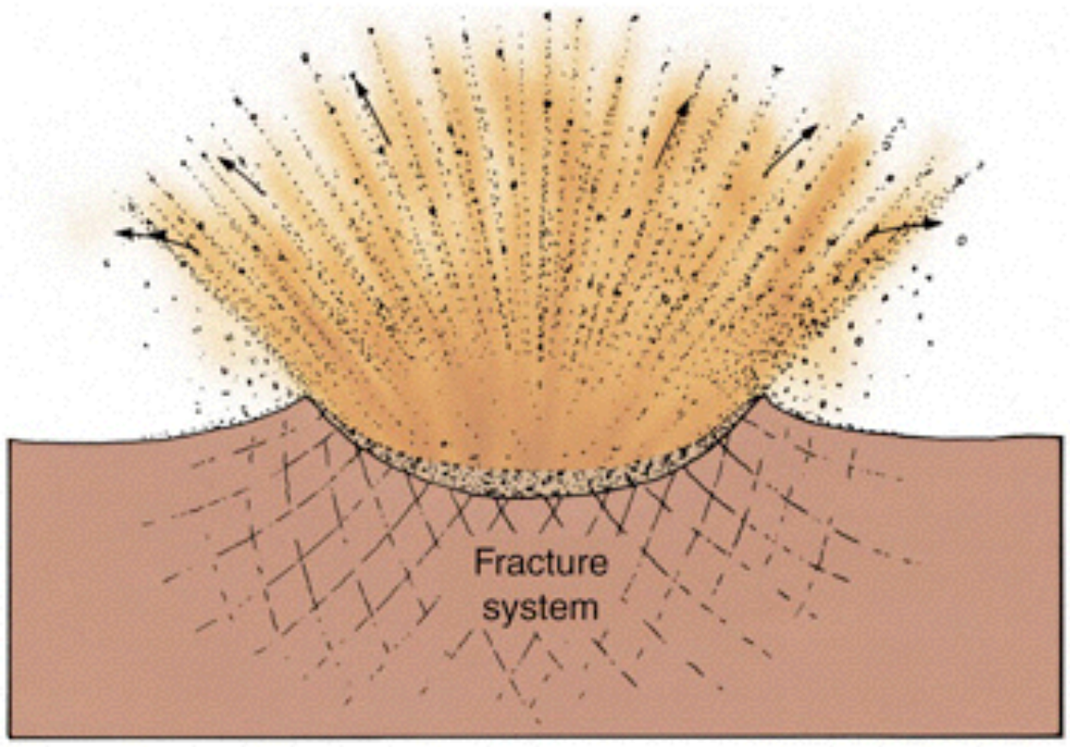
So what happened on impact?

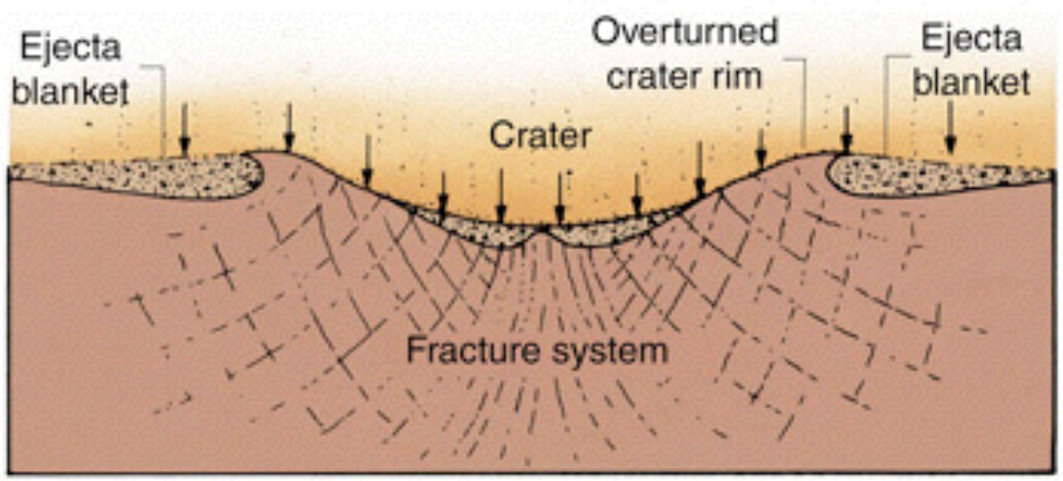
Asteroid or comet 10 Km in size struck at about 22 Km/s

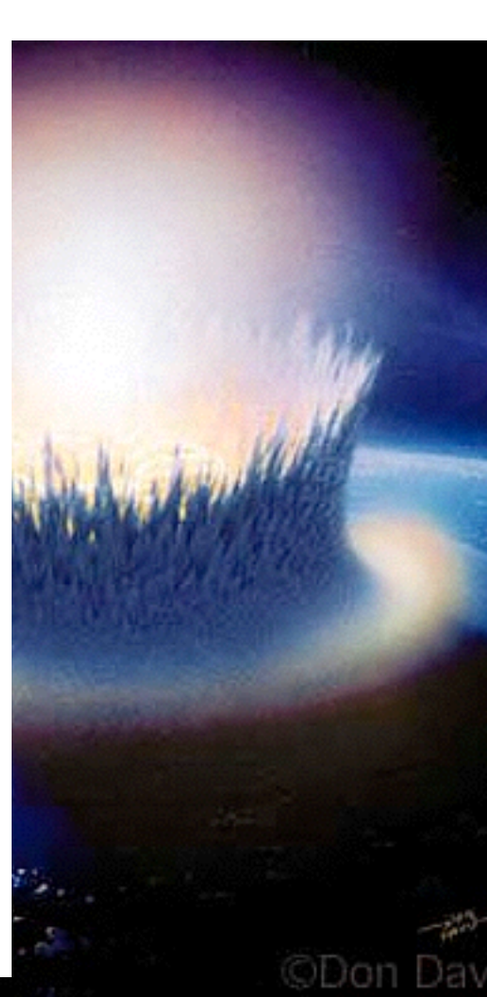
Blew a hole in the atmosphere 100 Km wide

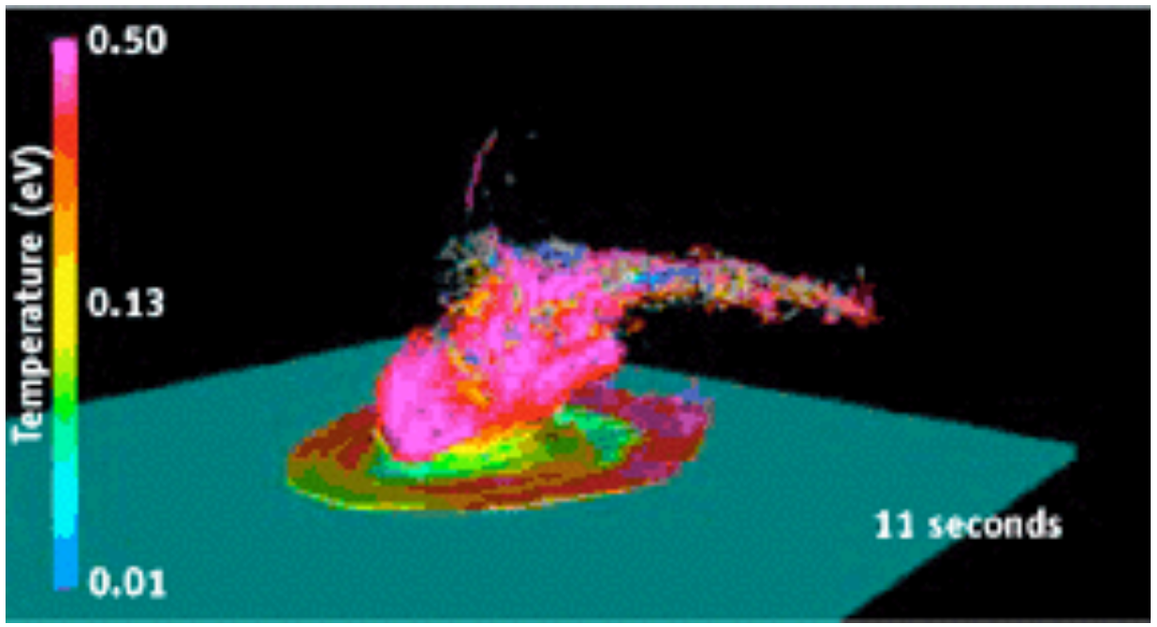
Flung enormous amts of dust, rock, and everything else into the upper atmosphere

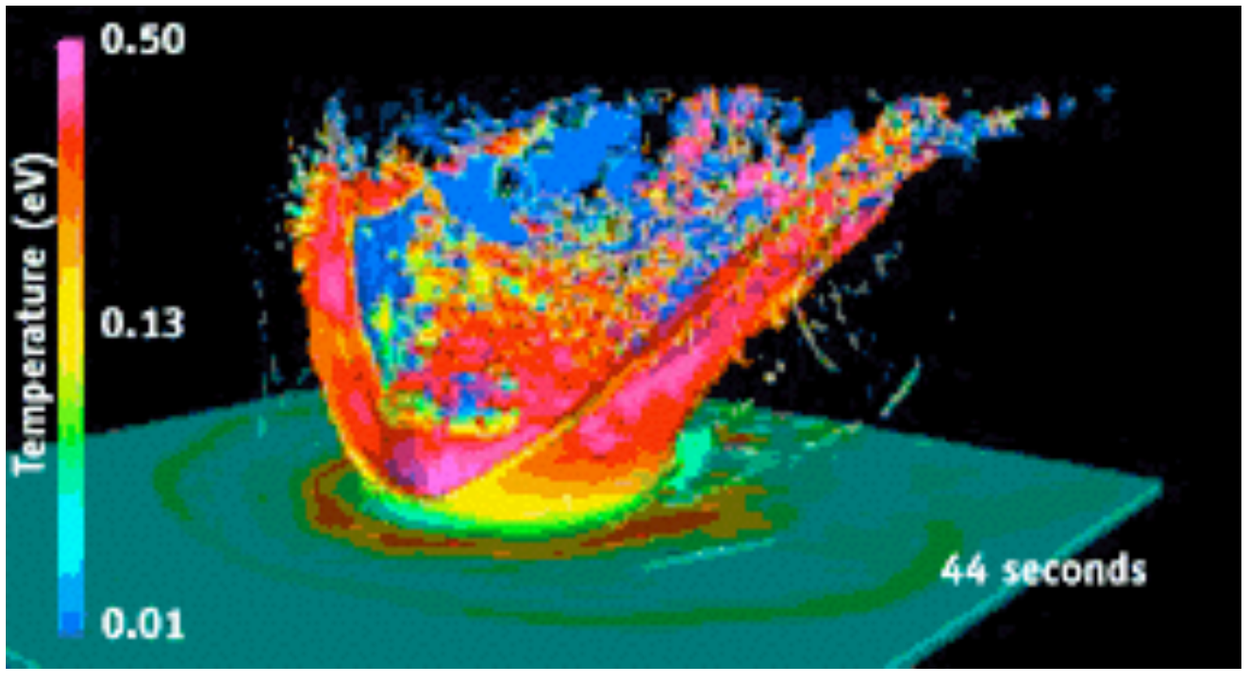









0.50
Temperature (eV)
0.13
0.01
11 seconds


0.50
Temperature (eV)
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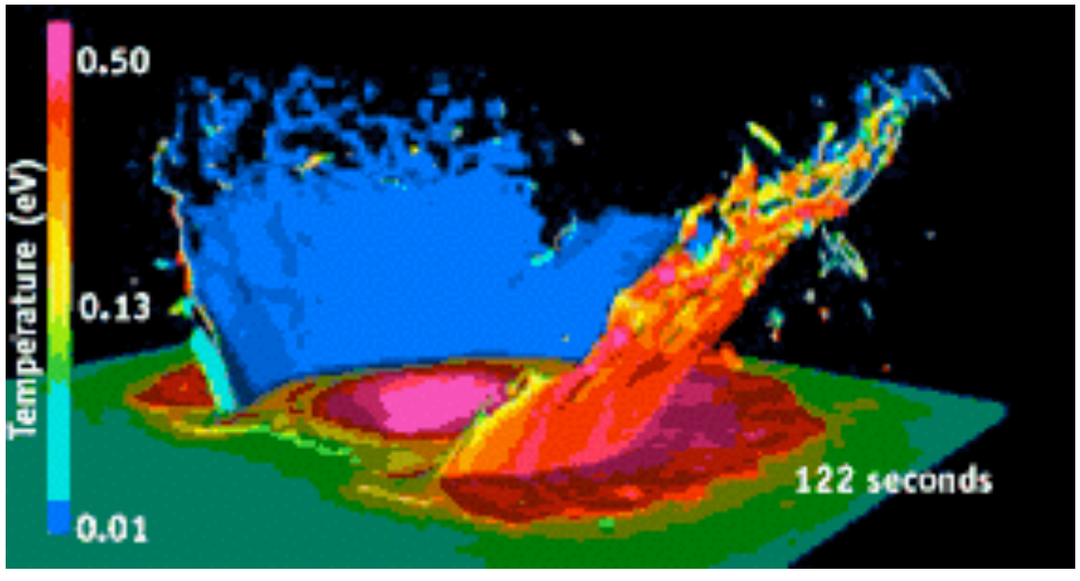
0.01
44 seconds


0.50
Temperature (eV)
0.13
0.01
122 seconds

So what happened on impact?

As the debris returns to earth, it burns up in the atmosphere, delivering intense IR radiation across the globe (and forming Microtectites)

This, with the blast wave caused by the impact, knocked down and burnt trees across 1000s of Kilometers

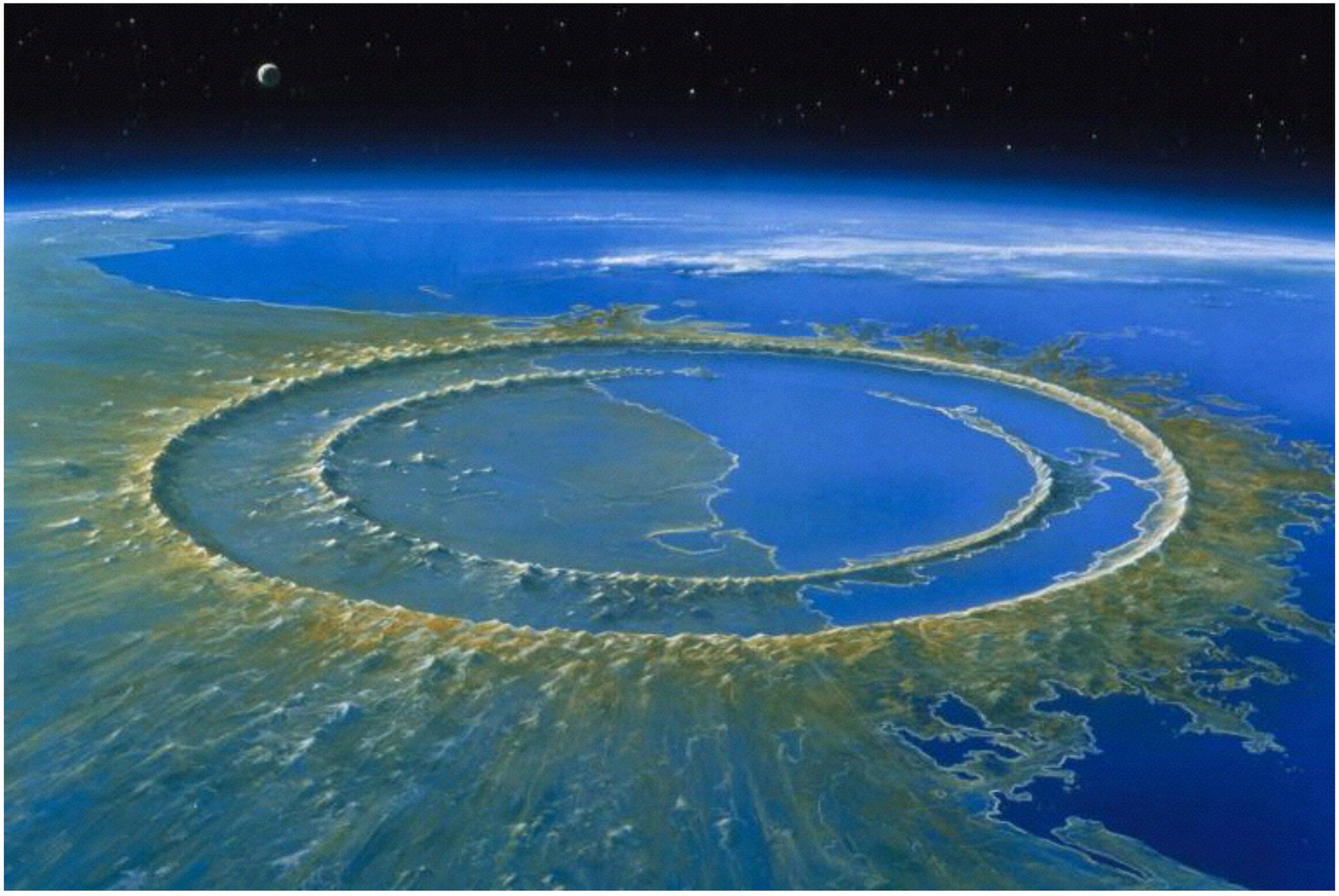
Rock at the site is shock-heated

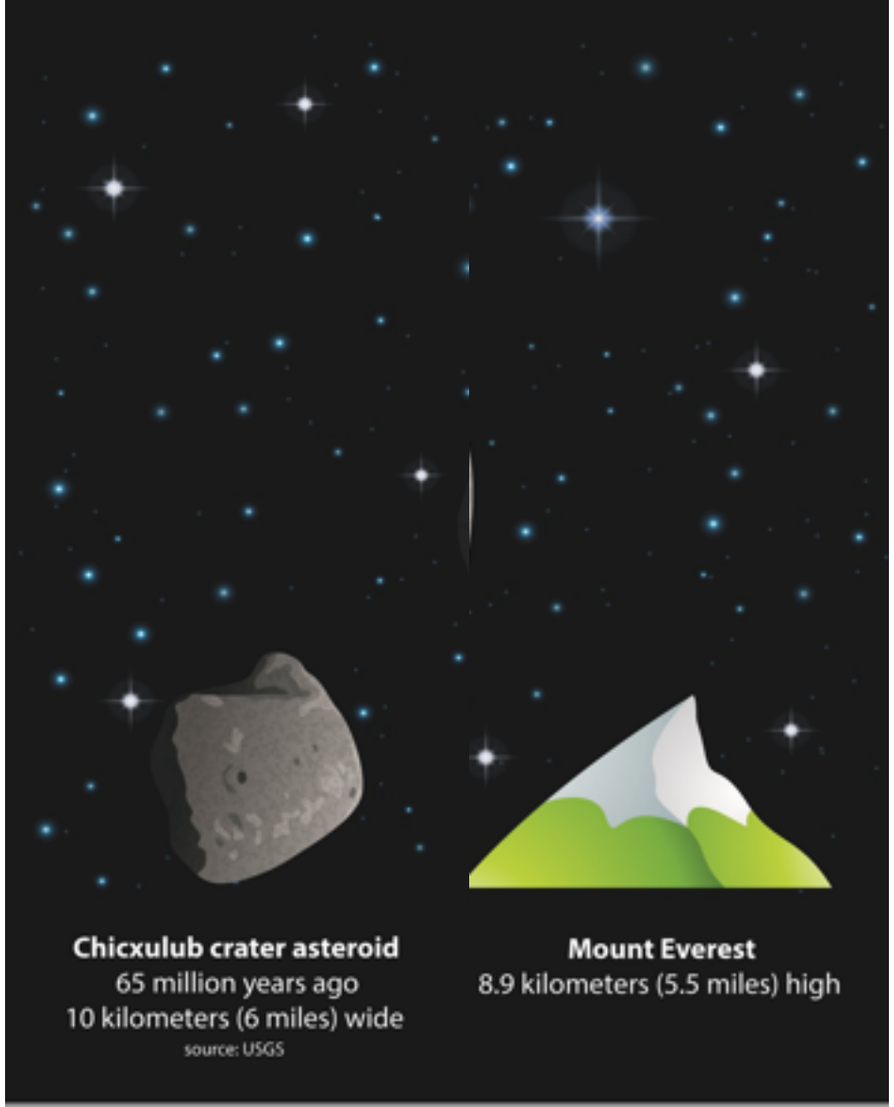
Tidal waves inundate the land for 100s of Km in all directions

Stratospheric dust encircles the Earth.

1,000,000 x Mt. St. Helens

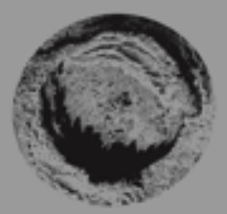
70 x the entire worlds nuclear arsenal





Chicxulub crater asteroid
65 million years ago
10 kilometers (6 miles) wide
source: USGS

Mount Everest
8.9 kilometers (5.5 miles) high



Chicxulub crater
65 million years ago
At least 150 kilometers (93 miles) wide
source: USGS

Island of Hawaii
122 kilometers (76 miles) wide
source: Hawaii economic data book

Short term consequences

All life near the impact is extinguished

Dust blocks out the sun, cooling the Earth for weeks or months

The average daytime surface temperature would drop to 10˚C (50˚F)

Photosynthesis could be shut down for a year

Short term consequences

As the bolide breaks through atmosphere, air is heated and Nitrous Oxides form. When dissolved in water, shells start dissolving...

Sulfur oxides were released from the seafloor => Acid Rain

Water ejected into the atmosphere would decrease Ozone

The News gets better!

Impact hit a carbonite shelf... releasing tons of CO_2 into the atmosphere

After short-term cooling, the world endures a decades-long greenhouse

Plants

Terrestrial plants underwent an instantaneous extinction event
79% of Angiosperms went extinct

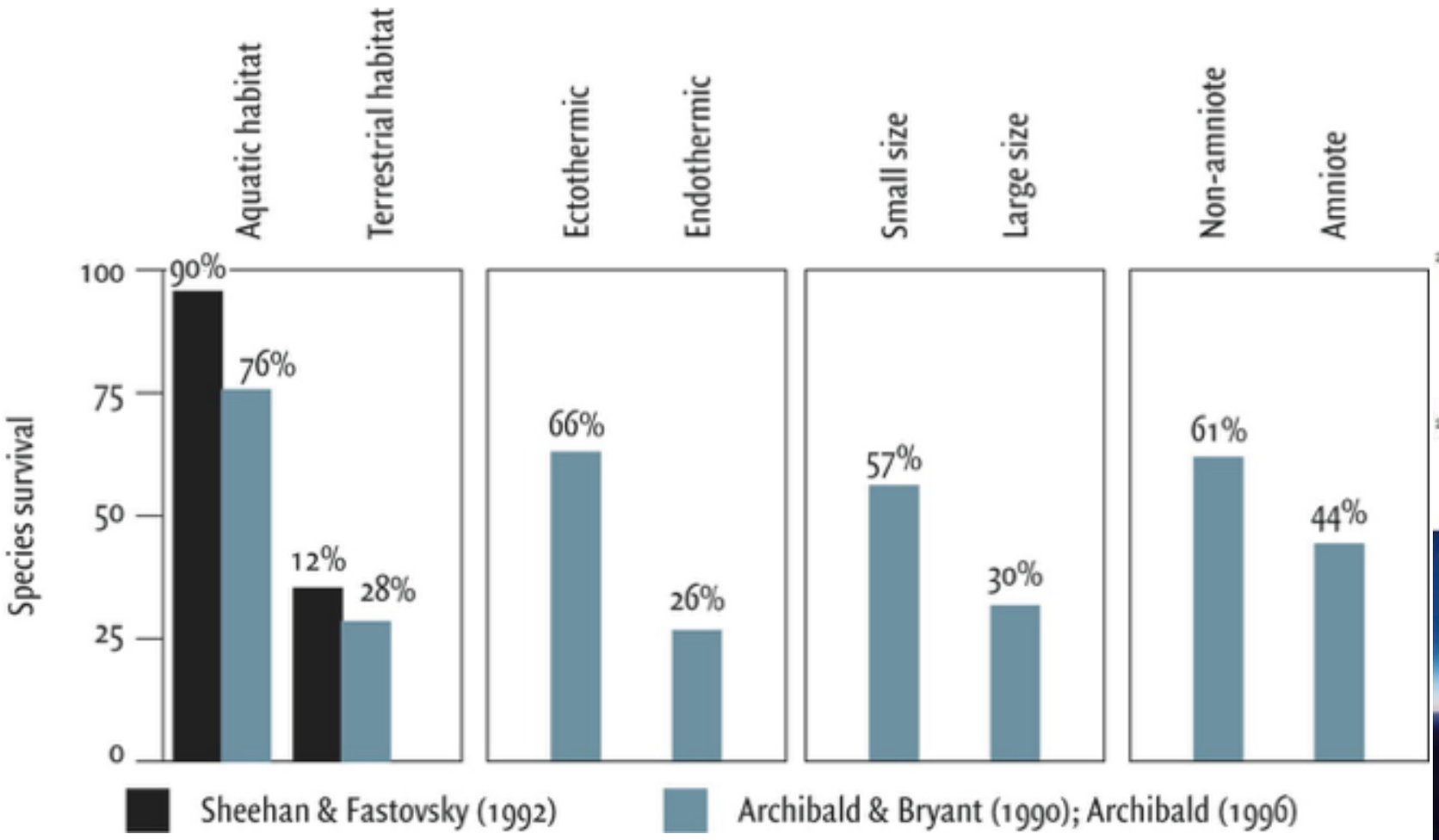
In some places, a fungus spike directly after extinction

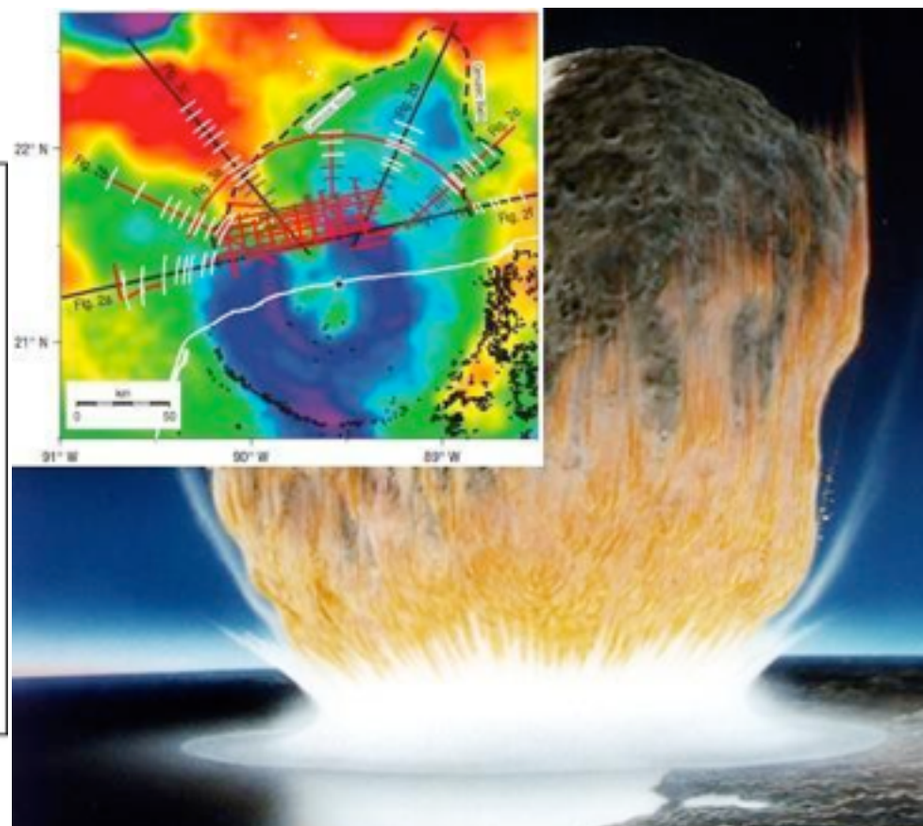
Global Fern spike soon afterwards

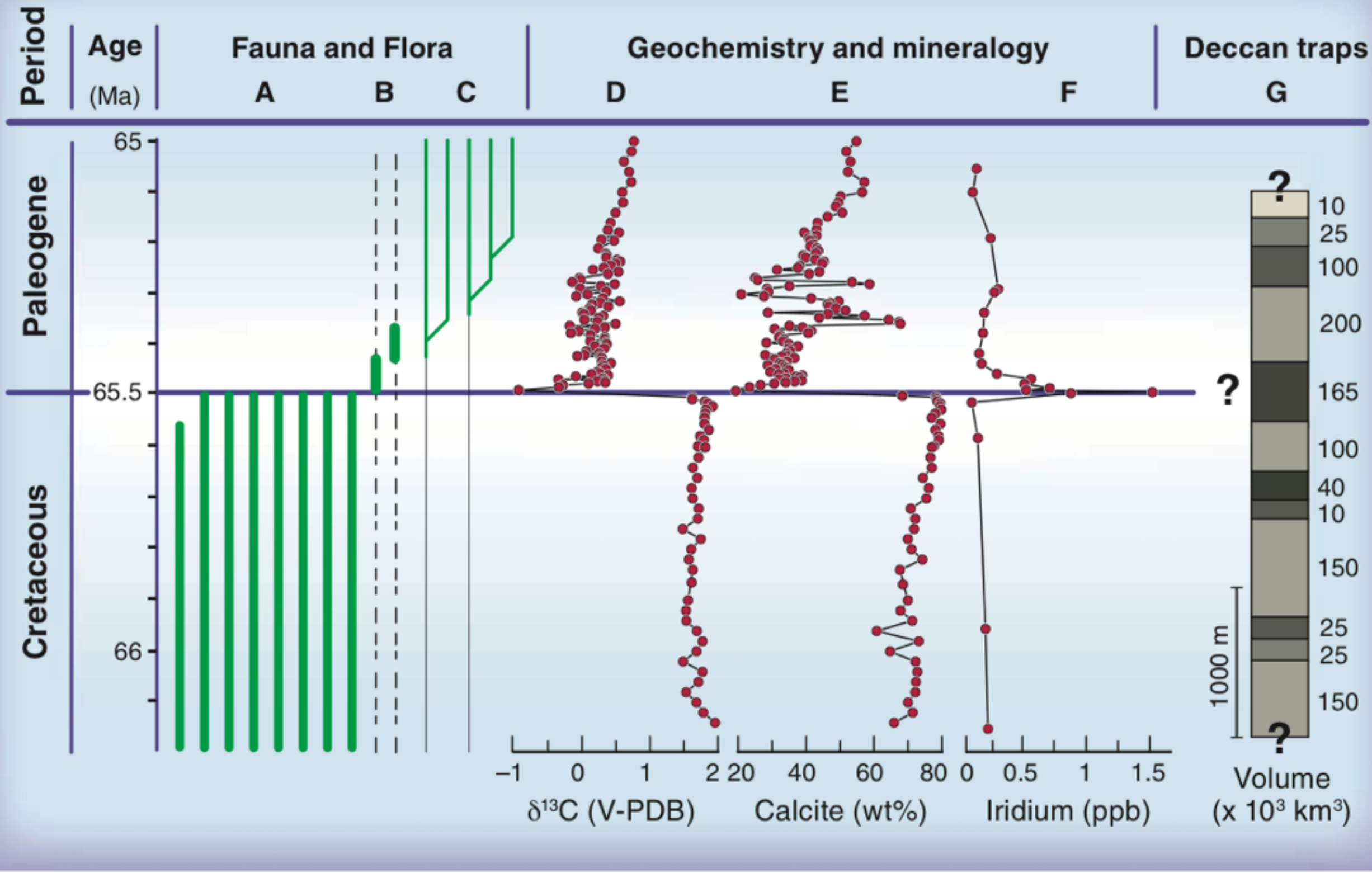
Animals

Dinosaurs, of course, are most famous victims
12-28% of fully-terrestrial vertebrates survive
BUT
76-90% of aquatically adapted organisms survive

Small vertebrates are favored
Ectotherms are favored
Non-amniotes favored







A) Massive extinction of species
B) Successive blooms of opportunistic species
C) Radiation of new species

Other explanations

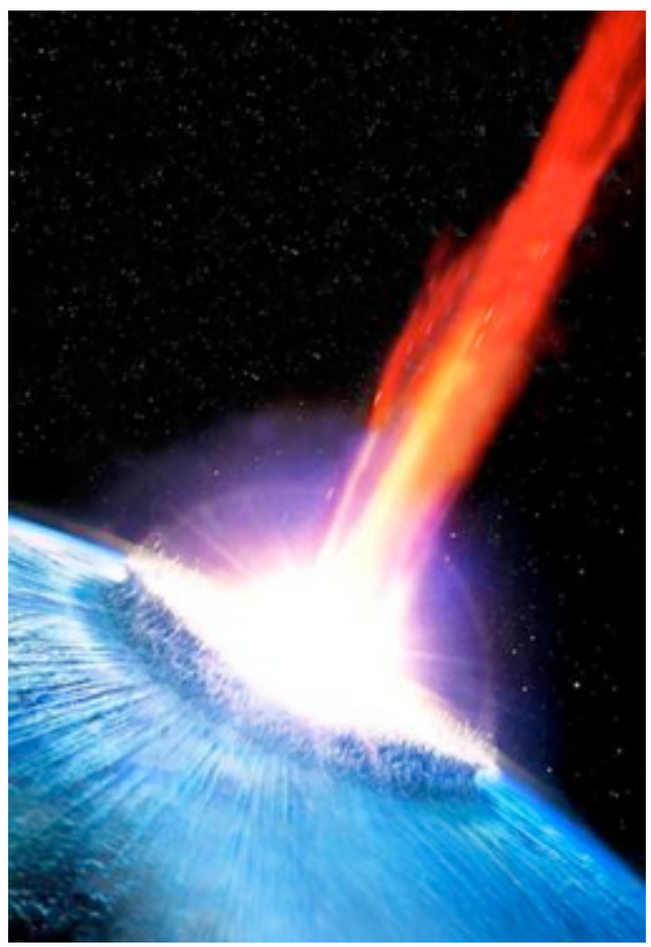
Volcanism: Could explain Ir spike, but not shocked quartz

And, you'd only expect a local Ir spike.

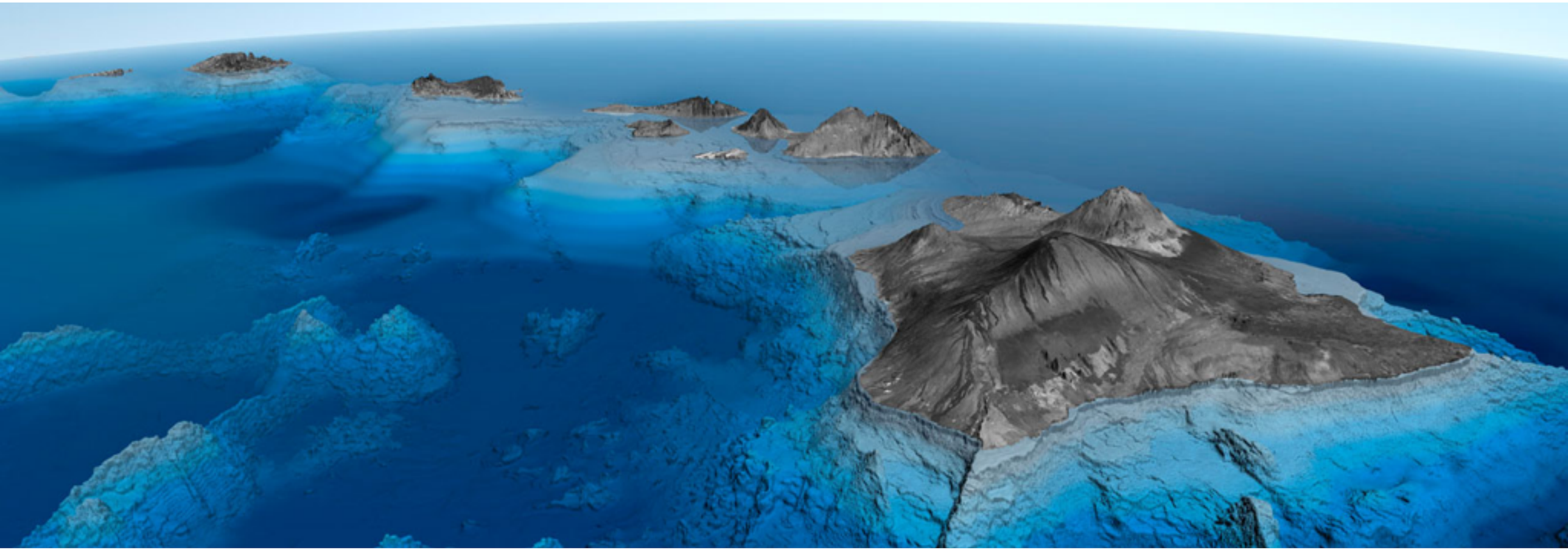
Deccan Traps: Certainly big and potentially devastating, but they were active before and after the KT without detectable effects on biota.

Clearly a bolide hit. Did it cause the mass extinction?

Because the most recent evidence does not suggest any decline in diversity or correlation of biotic turnover with climatic effects, it remains the most plausible scenario.



“The new analysis of the dinosaur family tree reveals that dinosaurs were disappearing even before the asteroid hit about 65.5 million years ago. Roughly **24 million years** before that impact, dinosaur extinction rates passed speciation rates, meaning that the animals were losing the ability to replace extinct species with new ones, the researchers said.” - LiveScience

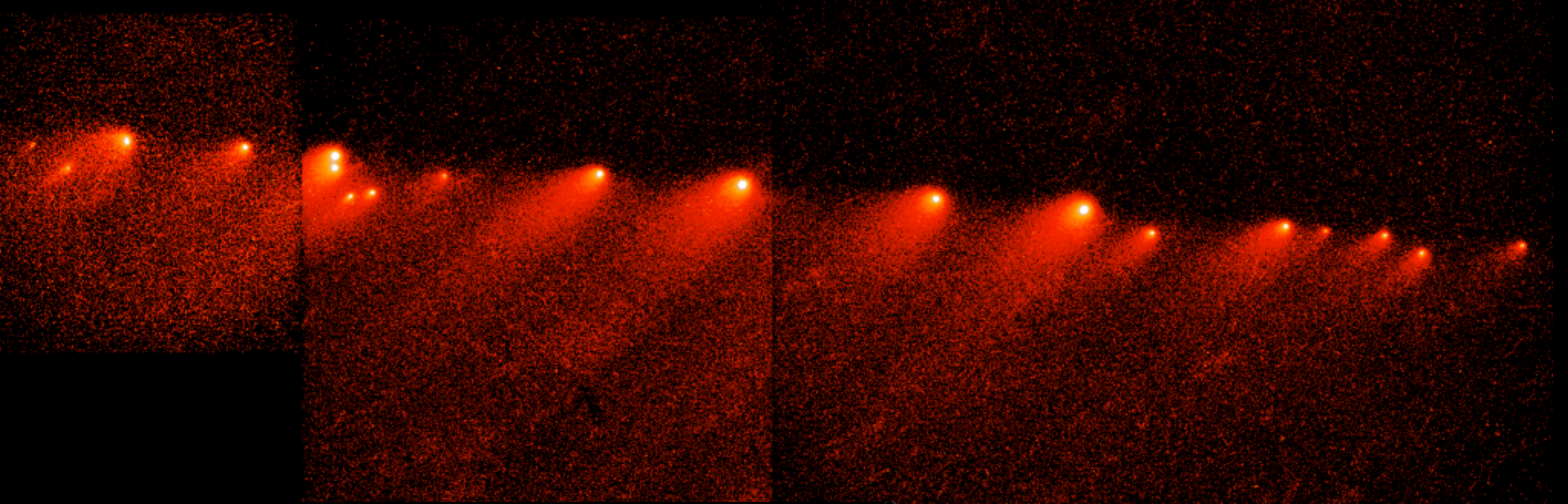


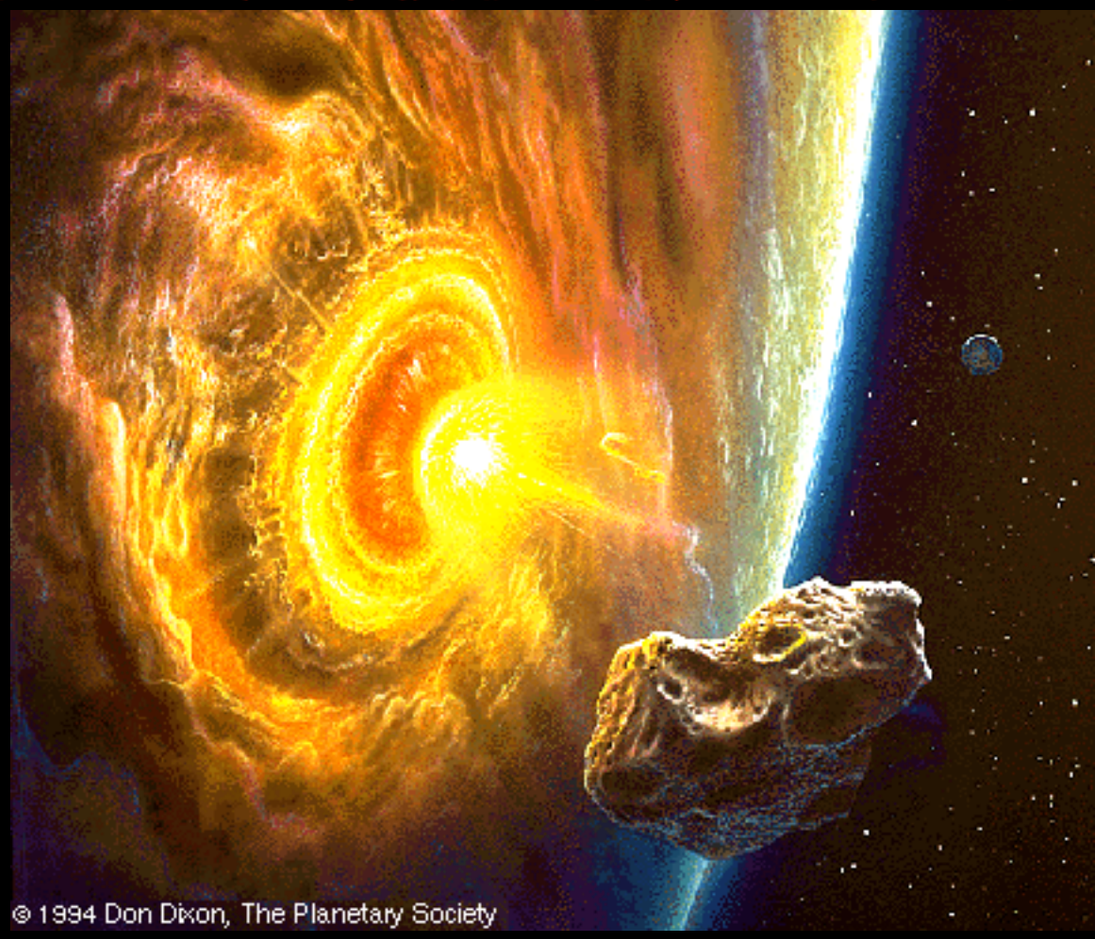
“It's unclear why the dinosaurs started going extinct so early, but there are clues as to why speciation increased during certain periods, the scientists said. One idea is that rising sea levels cut into the land, fragmenting dinosaur habitats and nudging the beasts to evolve separately into new species in different areas, the researchers said.” -LiveScience

Forget simulations...
We can study impacts in real time.

- In July 1994, the comet Shoemaker-Levy 9 was caught in Jupiter's massive gravity well.
- This collision is a rare opportunity to observe an impact event in real time.
- The impactor consisted of several fragments, the largest being ca. 1 Km wide
- But Jupiter's massive gravity greatly increased the velocity of the bolides... this resulting collision is believed to be of very similar magnitude to the KT event.


1024x1024 Near-Infrared Camera
University of Hawaii 2.2-meter telescope





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Okay. Up the Ante.

What if a 500 Km (300 mile) diameter bolide hit Earth?

That's 500 x the KT bolide

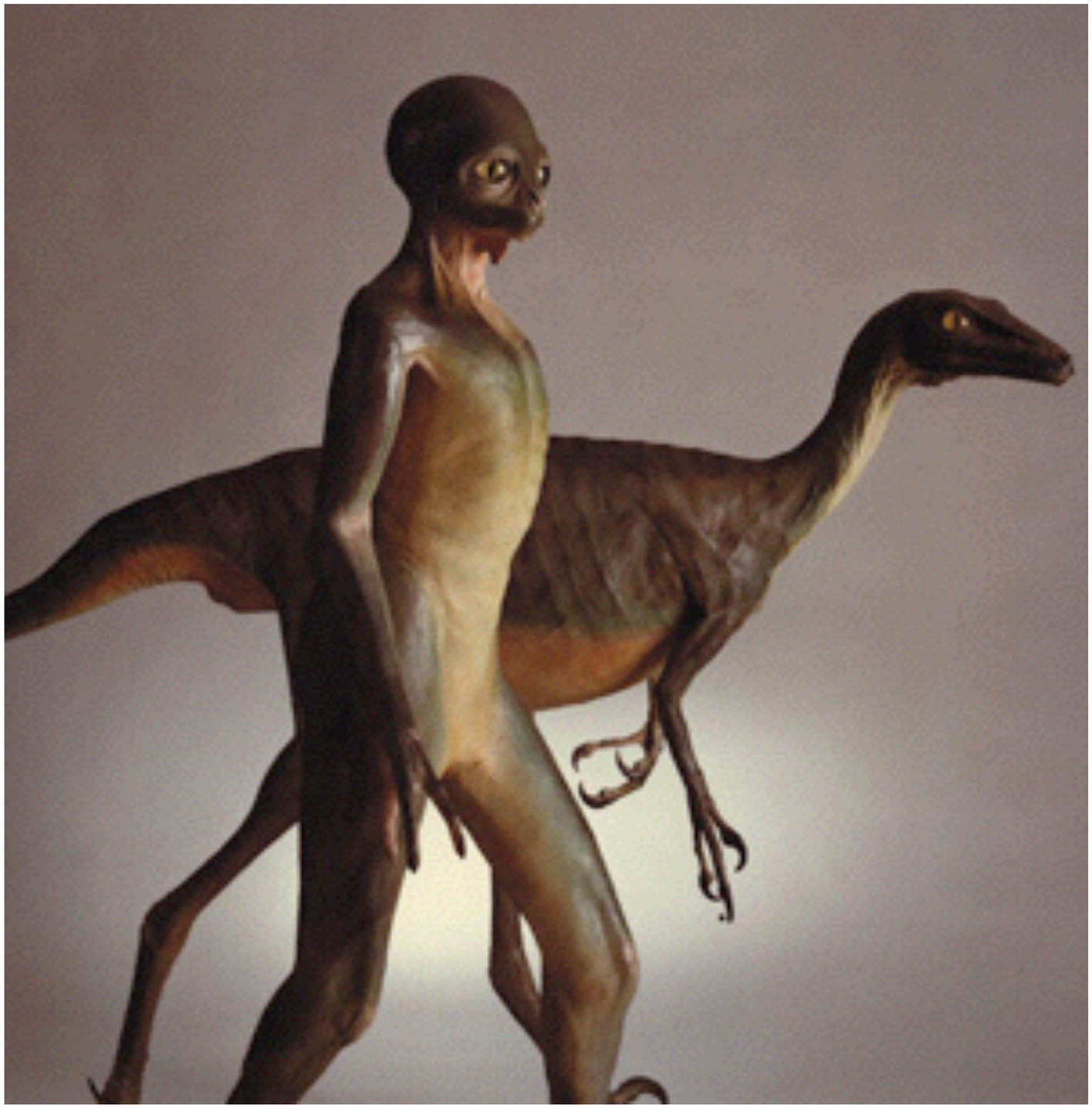
150 miles radius

200 asteroids known to be > 100 km diameter

700,000 to 1.7 million w/ diameter of 1 Km or more

Extinctions reset the clock.

We owe everything to the KT bolide impact




USGS

A Cenozoic extinction well on track to matching the Mesozoic extinction...

Thanks for a great quarter!