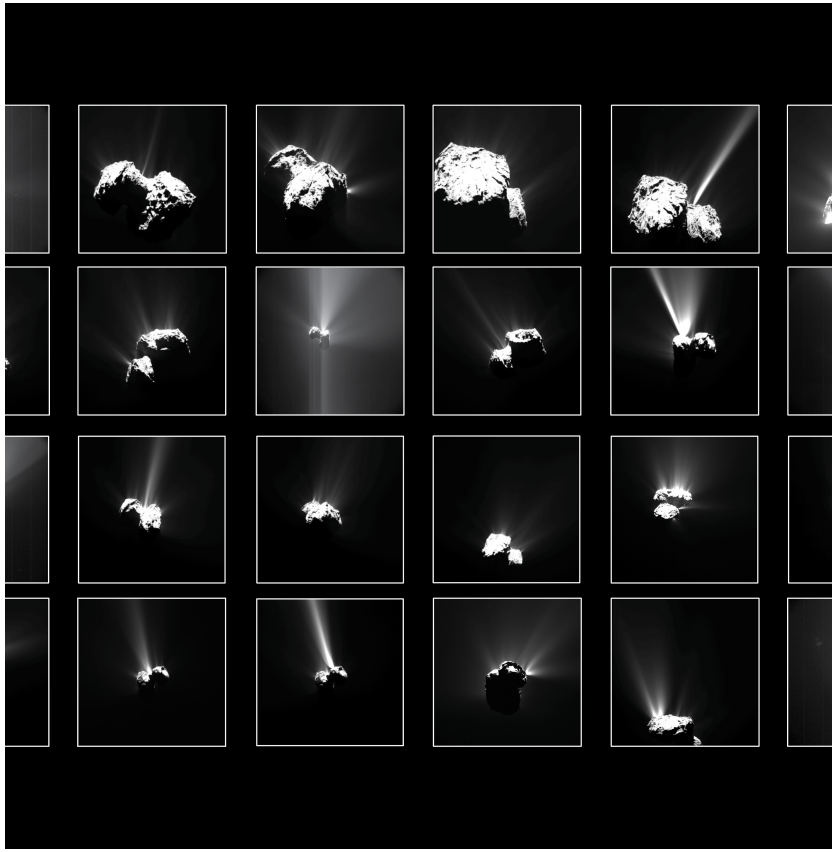
[21] The Impact Hazard (11/14/17)

Upcoming Items

1. Homework #10 due Tuesday, Nov 21.
2. Homework #11 will be due *Thursday*, Nov 30. Enjoy Thanksgiving!
3. Read Ch. 14.1–14.2 by next class and do the self-study quizzes.

Comet 67P/C-G Outbursts

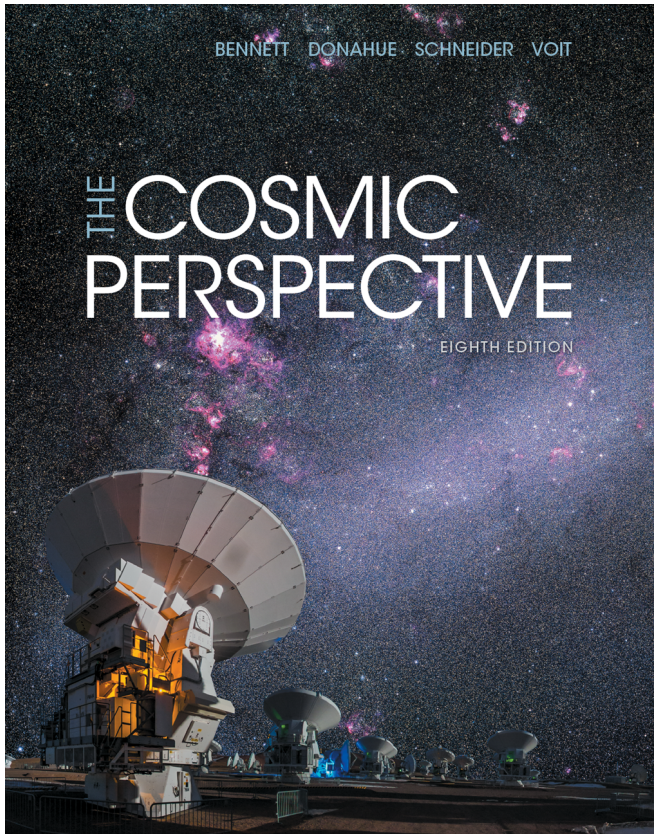


LEARNING GOALS

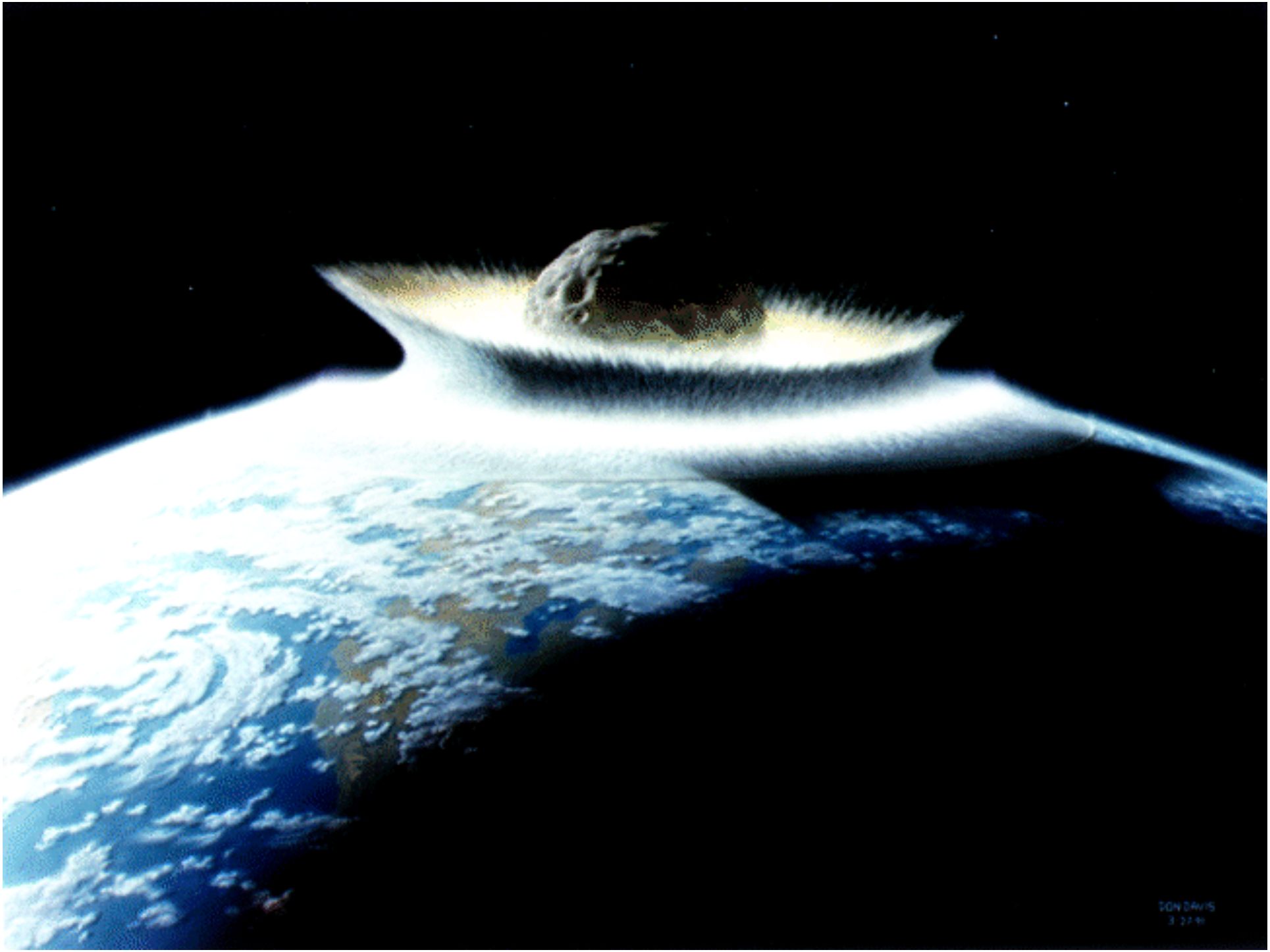
Ch. 12.5

By the end of this lecture, you should be able to…

- *interpret frequency vs. size impact data to evaluate the chance of a future small-body impact on Earth;*
- *discuss the relative threat of asteroids and comets in terms of frequency, impact energy, and likely advance warning;*

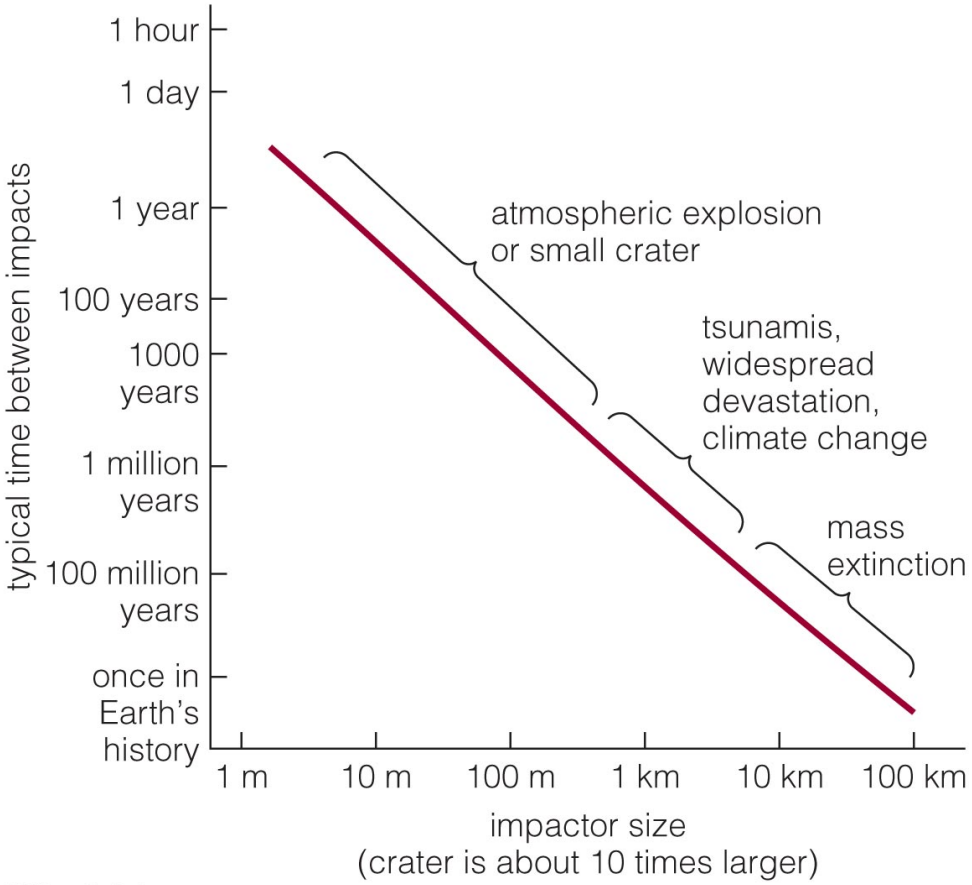


Any astro questions?


DON DAVIS

The Impact Hazard

- Comets and asteroids (modern-day planetesimals) continue to collide with the planets in our solar system.
  - Comet Shoemaker-Levy 9 impact on Jupiter.
  - Meteorite impacts on Earth, including Tunguska and Chelyabinsk.
  - Extinction-level events (a comet may have doomed the dinosaurs).
- It's not a matter of "if" we will be hit, but "when."
- Large impacts are rare, but small ones are still dangerous.
- Fortunately, we can often predict impacts in advance, and use technology to prevent the impact (in principle).
  - But don't necessarily believe what you see in the movies…
- Other planets like Jupiter can protect us from hazards. Or is that the net effect???



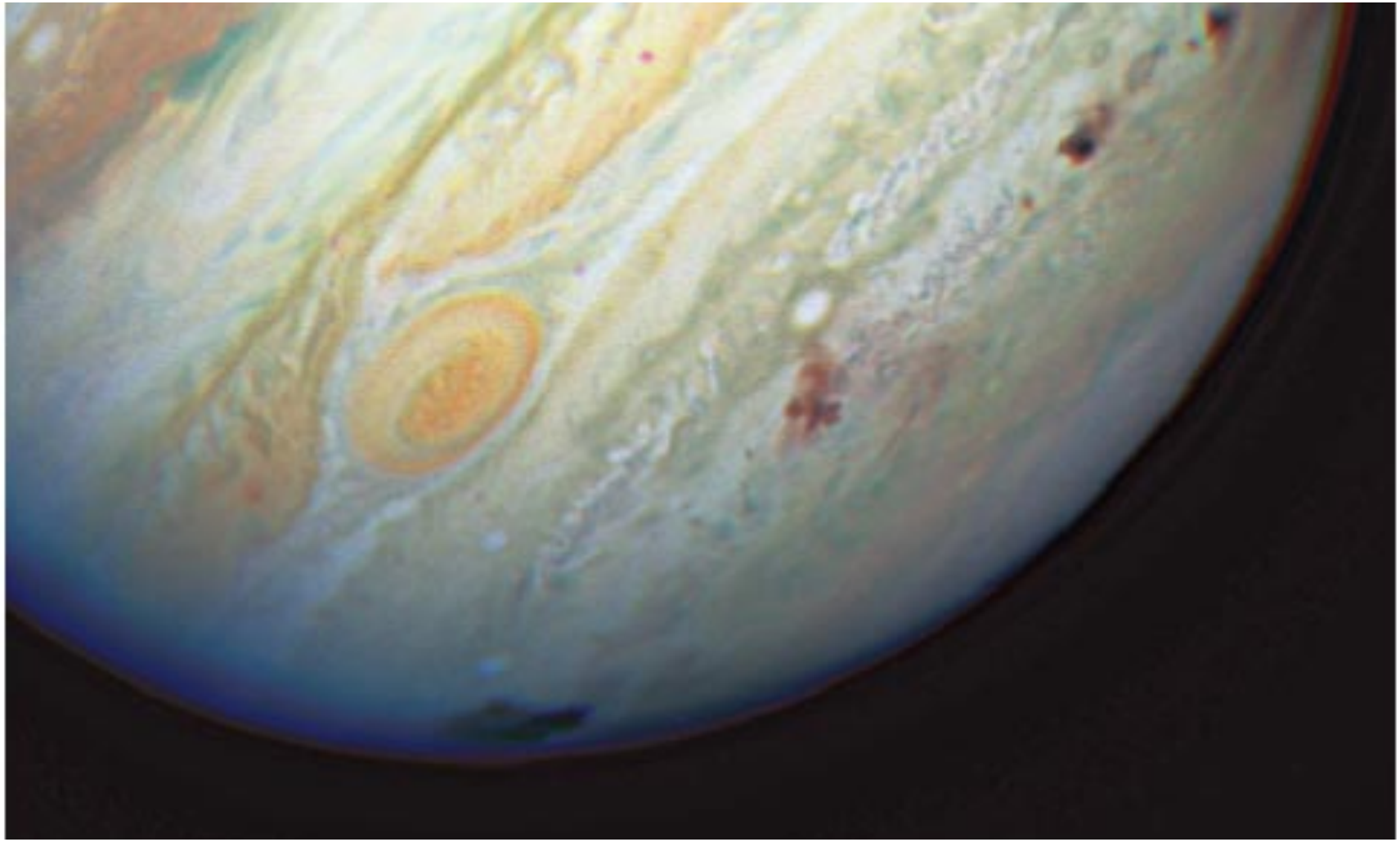
Note that Chelyabinsk (2013) had about a 20 m diameter.

Tunguska (1908), probably ~40 m diameter.

Group Discussion

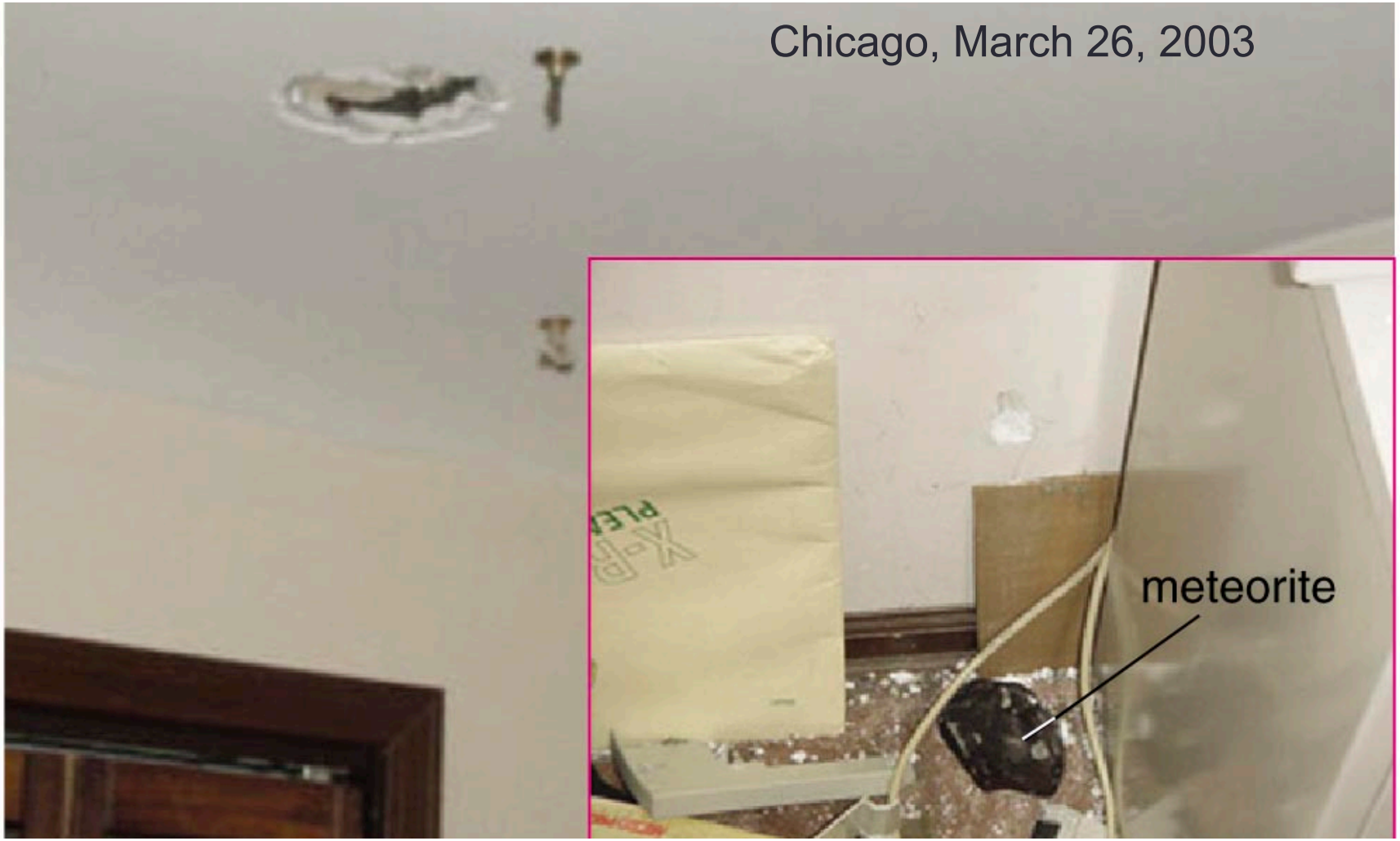
- List ways in which the threat of a particular impact on Earth could be mitigated. Consider different scenarios (e.g., impactor mass, warning time, etc.).

Impacts Happen: SL9 at Jupiter

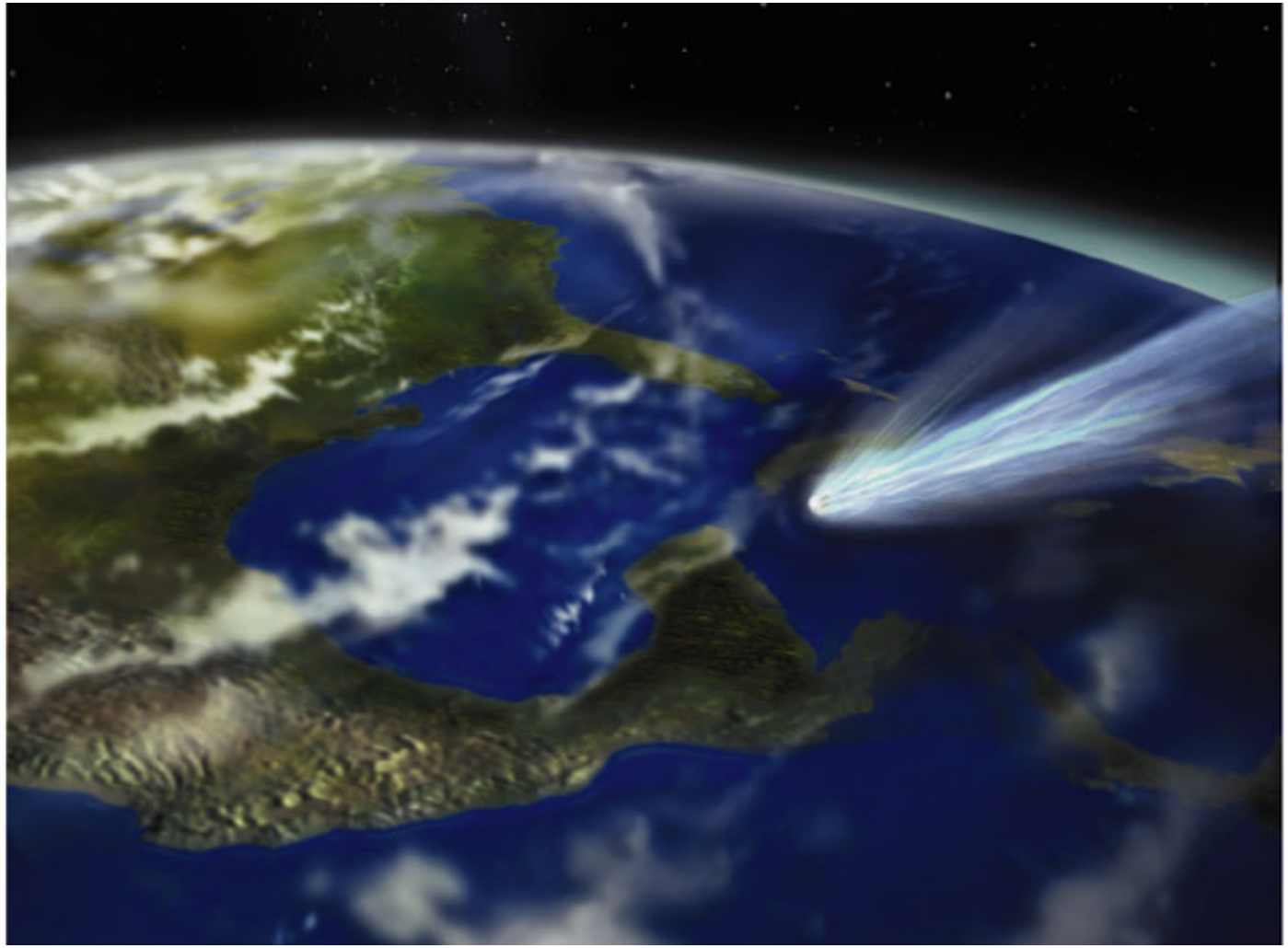


Peekskill, NY,
October 9, 1992

Meteorite Impact

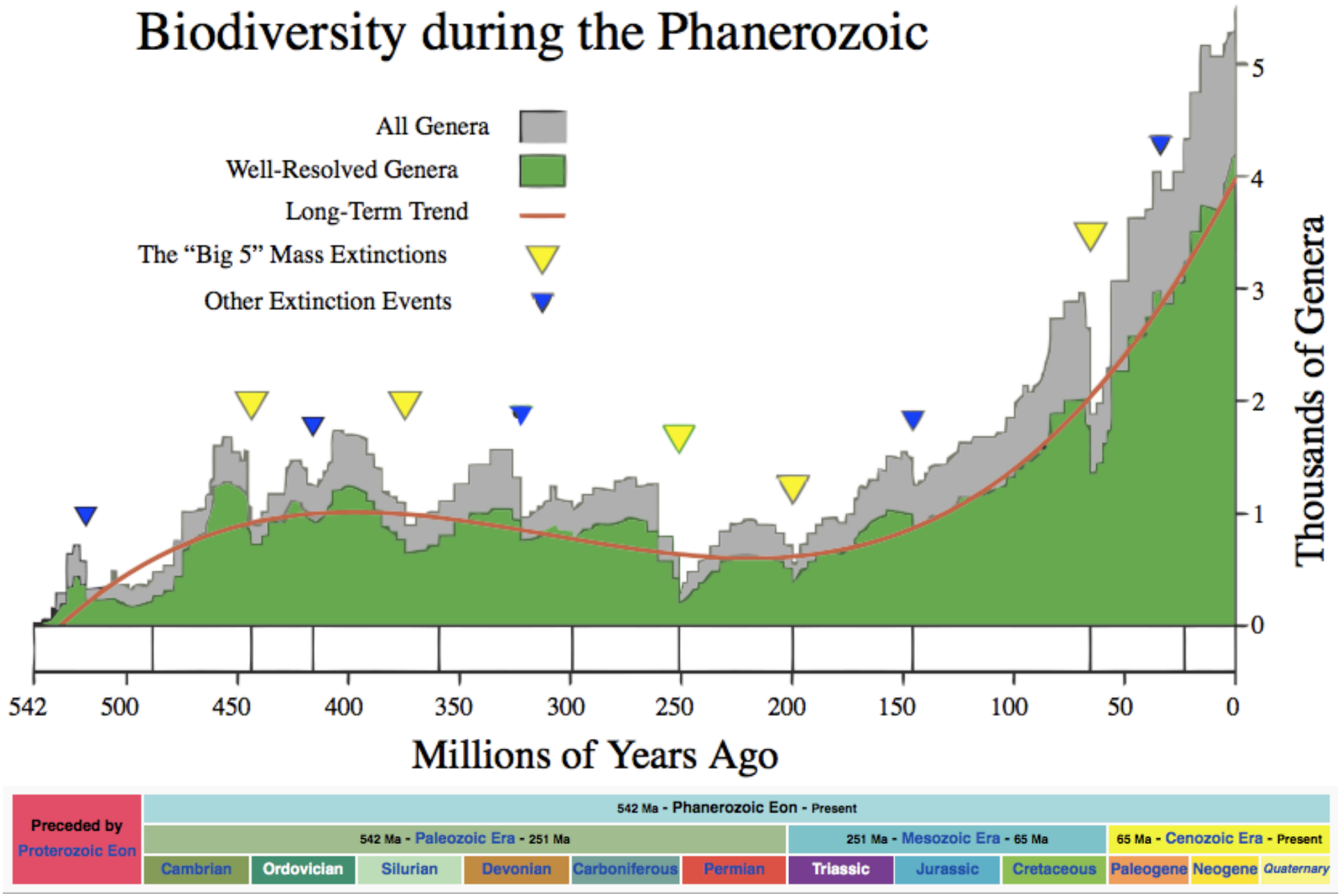


Did an impact kill the dinosaurs?



Mass Extinctions

- Fossil record shows occasional large dips in the diversity of species: *mass extinctions*.


Biodiversity during the Phanerozoic
All Genera
Well-Resolved Genera
Long-Term Trend
The "Big 5" Mass Extinctions
Other Extinction Events
Thousands of Genera
0
1
2
3
4
5
542
500
450
400
350
300
250
200
150
100
50
0
Millions of Years Ago
Preceded by Proterozoic Eon
542 Ma - Phanerozoic Eon - Present
542 Ma - Paleozoic Era - 251 Ma
251 Ma - Mesozoic Era - 65 Ma
65 Ma - Cenozoic Era - Present
Cambrian
Ordovician
Silurian
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
Paleogene
Neogene
Quaternary

Mass Extinctions

- Fossil record shows occasional large dips in the diversity of species: *mass extinctions*.
- The most recent was 65 million years ago, ending the reign of the dinosaurs.

Iridium—evidence of an impact.

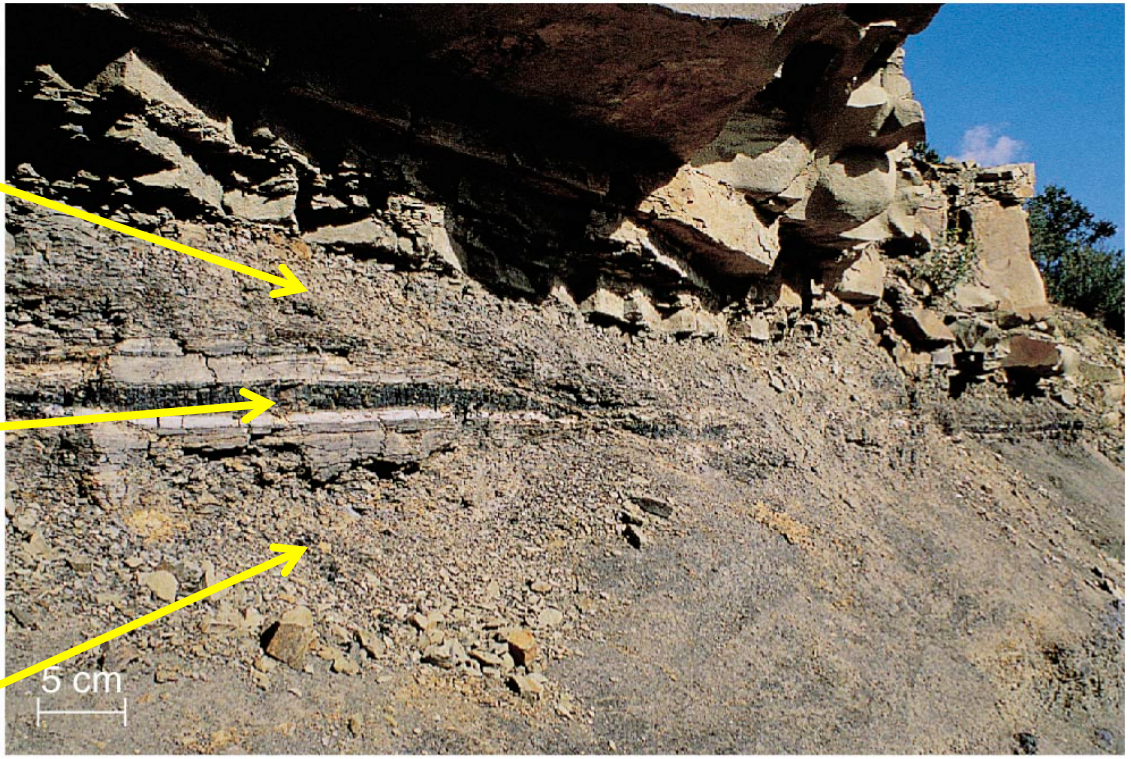
- Iridium is very rare in Earth surface rocks but often found in meteorites. *Why?*
- Luis and Walter Alvarez found a worldwide layer containing iridium, laid down 65 million years ago, probably by a meteorite impact.
- Non-avian dinosaur fossils all lie below this layer.

Iridium Layer

No non-avian dinosaur fossils in upper rock layers.

Thin layer containing rare element iridium.

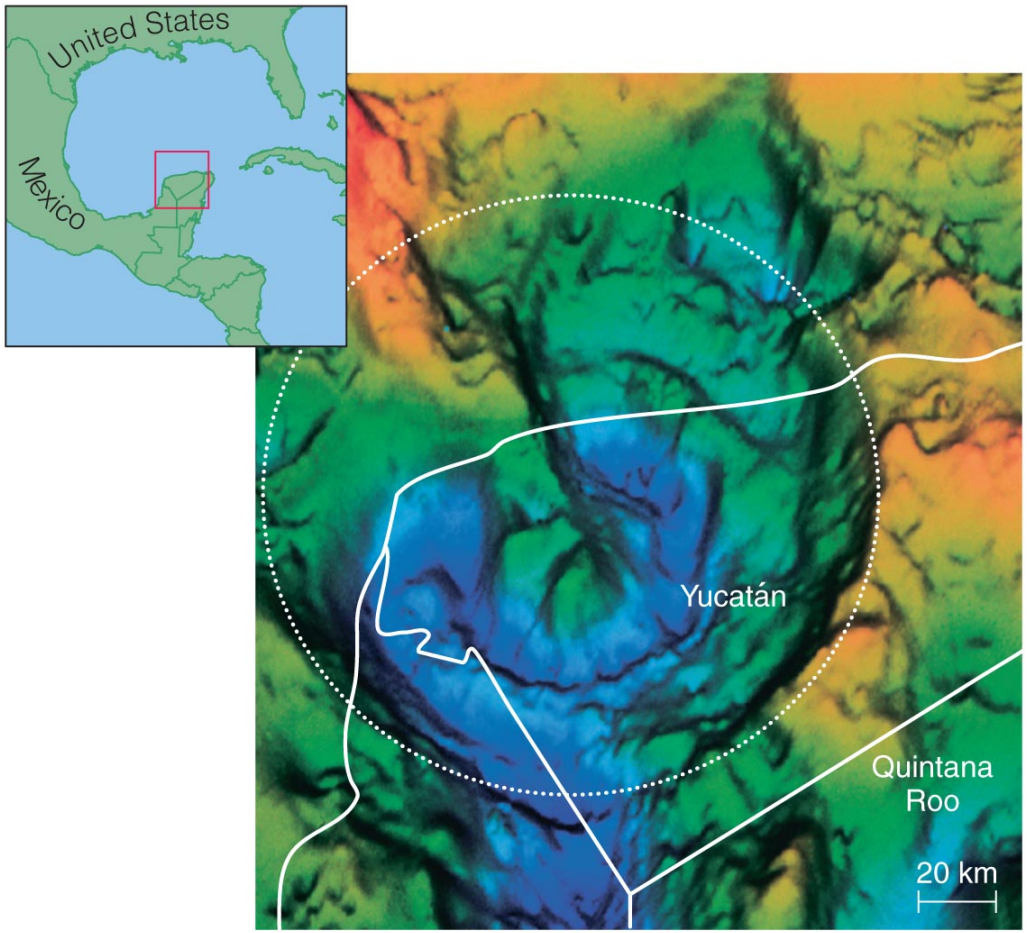
Dinosaur fossils in lower rock layers.



Consequences of an Impact

- A meteorite 10 km in diameter would send large amounts of debris into the atmosphere.
- Debris would reduce the amount of sunlight reaching Earth's surface.
- The resulting climate change may have caused mass extinction.

Likely Impact Site



- Scientists found a large subsurface crater about 65 million years old in Mexico.

The K-T Impact

- Initial impact of a 10 km asteroid or comet…
  - Atmosphere has almost no effect on incoming object: strikes surface at full speed.
  - Explosive yield of approximately 100 million megaton TNT equivalent (Hiroshima = 16 kilotons).
  - Impacting asteroid and approx. 100 km^3 of Earth rock are vaporized and thrown 100 km into atmosphere.
  - Intense fireball and blast wave flattens and ignites everything for few × 1,000 km across.
  - Molten debris rains down across planet, seeding massive wildfires —90% of all plant life burns.
  - Huge earthquakes cause massive tsunamis… devastate coastlines around the globe.

The K-T Impact

- Next 10–1,000 years…
  - Atmospheric debris and smoke completely block sunlight from reaching the surface.
  - Temperature plummets (like “nuclear winter”).
  - Photosynthesis stops and most plants die.
  - Food chain collapses.
  - Eventually, debris settles out of atmosphere and the Sun starts to shine again…
- But then there’s dramatic global warming…
  - Carbon dioxide from fires causes a greenhouse effect… temperature rises and planet becomes too hot!
  - This lasts for an unknown length of time…
- Only a fraction of species survive this ordeal…

Is the impact threat a real danger or just media hype?

Facts About Impacts

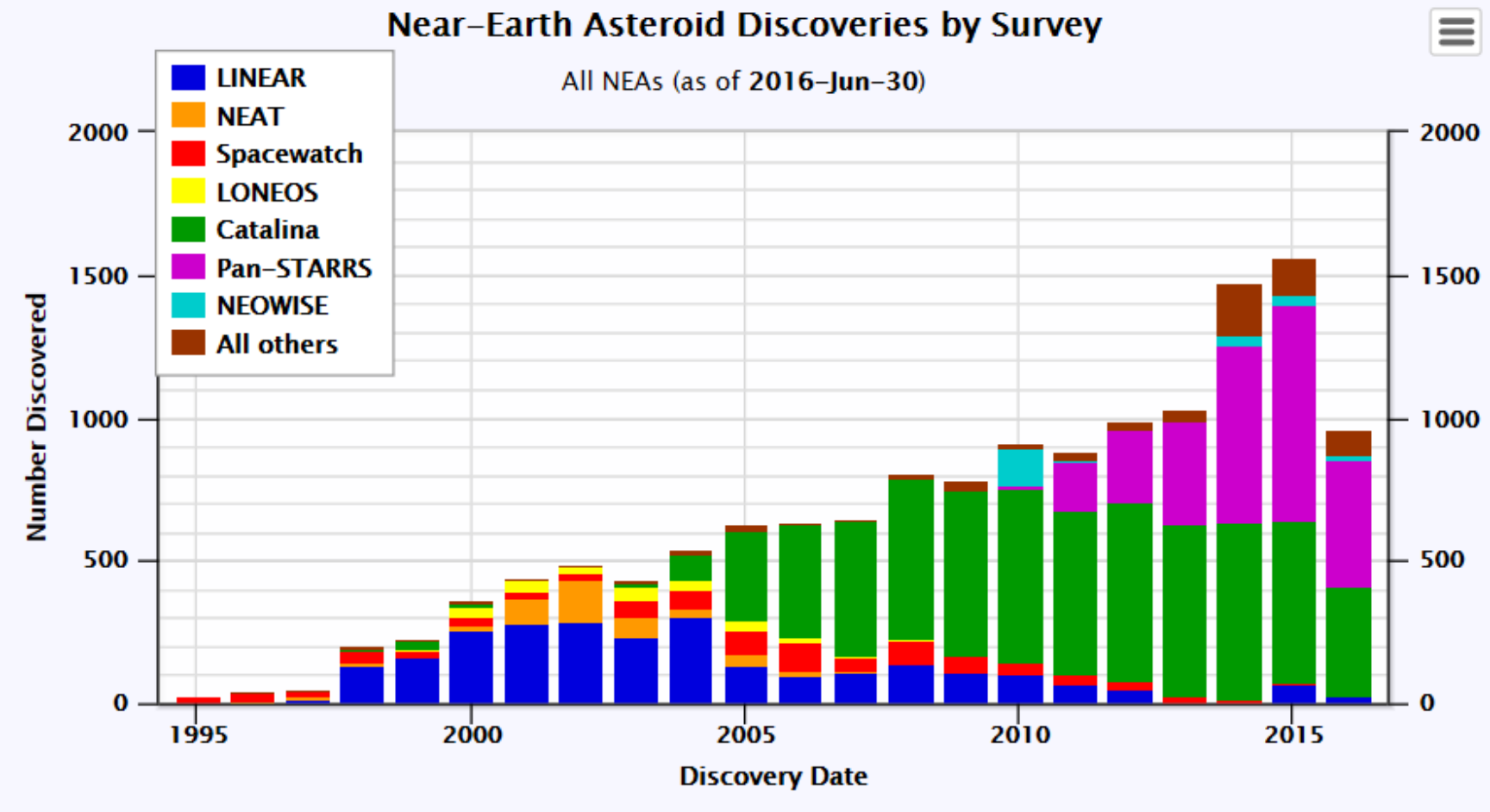
- Asteroids and comets have hit Earth.
- A major impact is only a matter of time: not IF but WHEN.
- Major impacts are very rare.
- Extinction-level events: ~ millions of years.
- Major damage: ~ hundreds–thousands of years.

Meteor Crater, Arizona: 50,000 years ago (50 meter object).

Tunguska, Siberia: June 30, 1908. A ~40 meter object disintegrated and exploded in the atmosphere.

Chelyabinsk, Russia (Feb. 15, 2013)

Detection of Near-Earth Asteroids



Asteroid 2004 MN_4 (99942 Apophis): A Really Near Miss!

- On Friday April 13, 2029, Apophis is predicted to pass within 5.7 ± 0.2 Earth radii of our planet.
  - Originally had 1-in-38 chance of hitting Earth, until new observations refined orbit!
  - Estimated size: about 270 m across.
- No predicted mass loss/shape change.
- However, spin may be affected, and internal stresses may be measurable.
  - Great opportunity for in-situ experiments!
- No chance of impact, but a small chance still exists during its return in 2036.
  - Upcoming radar observations will tell us more.