Astronomy 150:
Killer Skies

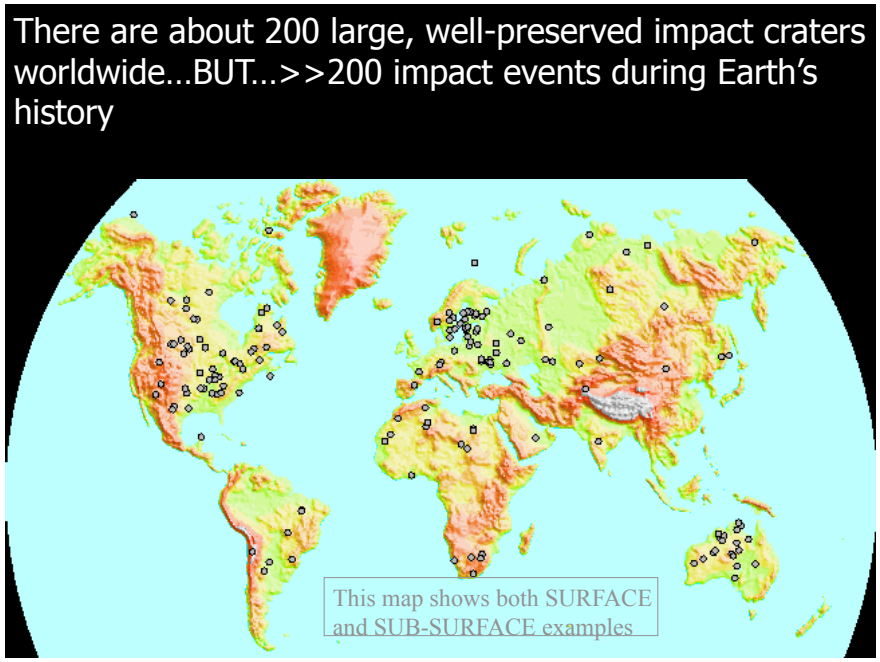
This Class (Lecture 7):
Dino-Killers

Next Class:
Jupiter in Peril

Music: ***It's the End of the World As We Know It*– REM**

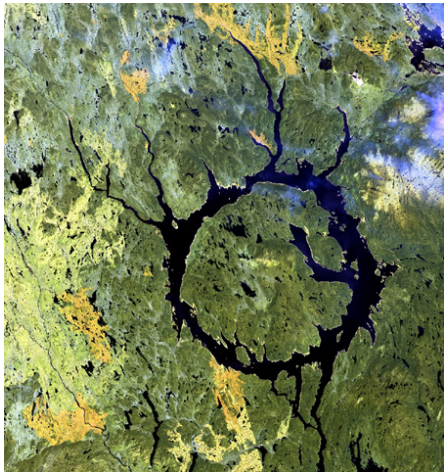
Outline

- Meteorites and the Earth
- Meteorites and you.
- 65 million years ago came death from above!



More of Earth's Craters

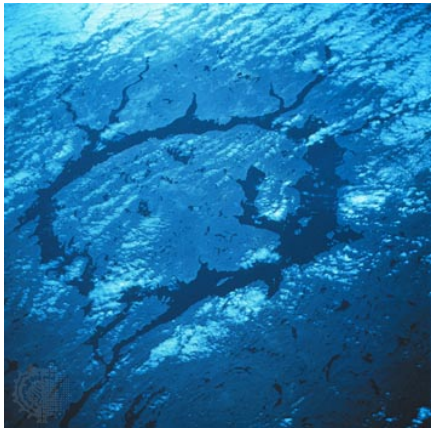
Manicouagan Crater in Quebec, Canada – 100 km wide



http://www.unb.ca/passc/ImpactDatabase/images/manicouagan.htm

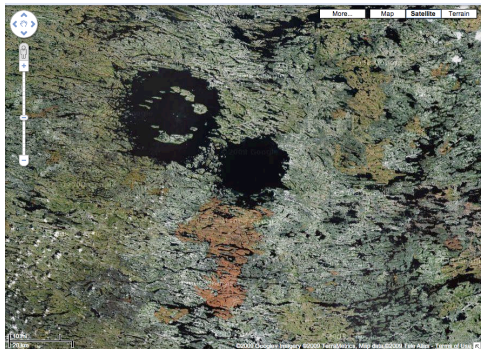
Manicouagan Crater

- A spectacular example of a complex crater
- Original rim removed by erosion…current diameter is **100 km**
- Has an uplifted central core and outer rings, which are filled by a lake
- Its age - 210 Ma - coincides approximately with a large extinction at the end of the Triassic period

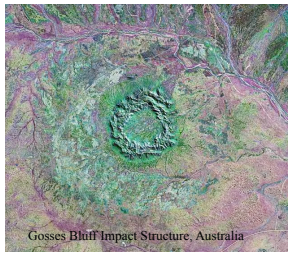


Earth's Craters

- Clearwater Lakes in Quebec, Canada – 26 km wide (290 million years ago) from a double impact!
- Submerged central peal in smaller lake.

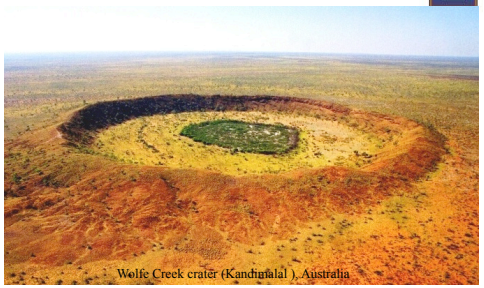


And more…



Gosses Bluff Impact Structure, Australia

Lake Bosumtwi, Ghana



Wolfe Creek crater (Kandimalal), Australia

Aorounga, Chad, Africa

Earth's Craters

- In general, the reasons there are so few craters on Earth's surface are:
  - The heat of atmospheric friction, often vaporizes the smallest meteoroids
  - Many meteorites land in water
  - Water erosion wears away craters
  - Plate tectonics/volcanism erase some
- But meteorite impacts **do** play a role in the history of Earth

Interesting Questions

Why are we not avoiding craters all the time?

a) Meteorites are just very uncommon on Earth.
b) They are only caused by micrometeorites.
c) We are protected from all meteorites by the atmosphere.
d) Earth's weather removes craters quickly.

Impact Calculator

http://www.classzone.com/books/earth_science/terc/content/investigations/es2506/es2506page08.cfm

Death from Above?

There has not been any evidence of anyone being killed by a meteorite. (Although there are stories…)

But, there is evidence of people being hit!

Ann Elizabeth Hodges (1923-1972)

Nov 30th, 1954 2:46 pm, Ann was dozing on the couch, when a meteorite (8.5 lbs) crashed through the roof, bounced off a radio, and hit her on the side!

Mbale meteorite (Uganda, 1992)

Meteorite broke into many pieces, a small one of which (3 g) hit a tree, then a young boy in the head.

http://home.wxs.nl/~terkuile/meteorites/mbale/mbale.html

Lies and Damned Lies

- This June, young German boy claims to have been hit by meteorite.
- "At first I just saw a large ball of light, and then I suddenly felt a pain in my hand. Then a split second after that there was an enormous bang like a crash of thunder."
- Supposedly left a 30 cm crater in pavement!
- What do you think?

Interesting Question

Why is it difficult to establish any human deaths from meteorites?

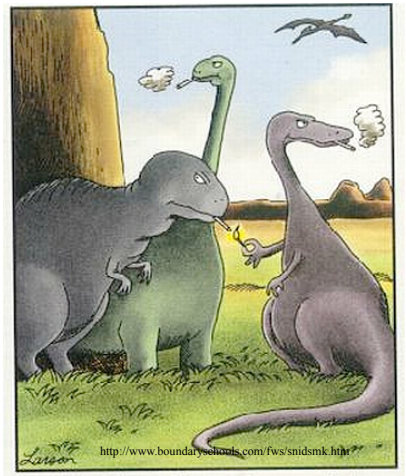
a) Reality TV didn't become popular until recently.
b) Hard to establish facts of death in historic cases, so not reliable.
c) When they're dead, they don't respond to well to worded questions.
d) It is very unlikely to ever happen.
e) Bring out your dead cart is very hush-hush.

Death from Above?

- So far no verifiable human deaths from above..
  (two animal cases: a dog in 1911 and a horse in 1896)
- So Death from above is rare….
- Or is it?
- We do have evidence of significant life being killed from above…

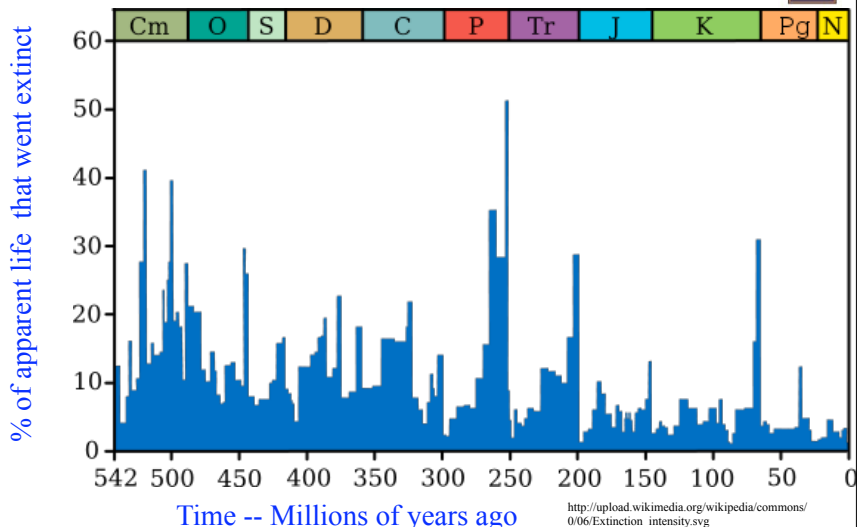
What Killed the Dinosaurs?

- 65 million years ago, 75-95% of all the species on Earth disappeared
- 2nd largest known mass extinction in geological history
- Was a meteoroid collision to blame?



Did an impact kill the dinosaurs?

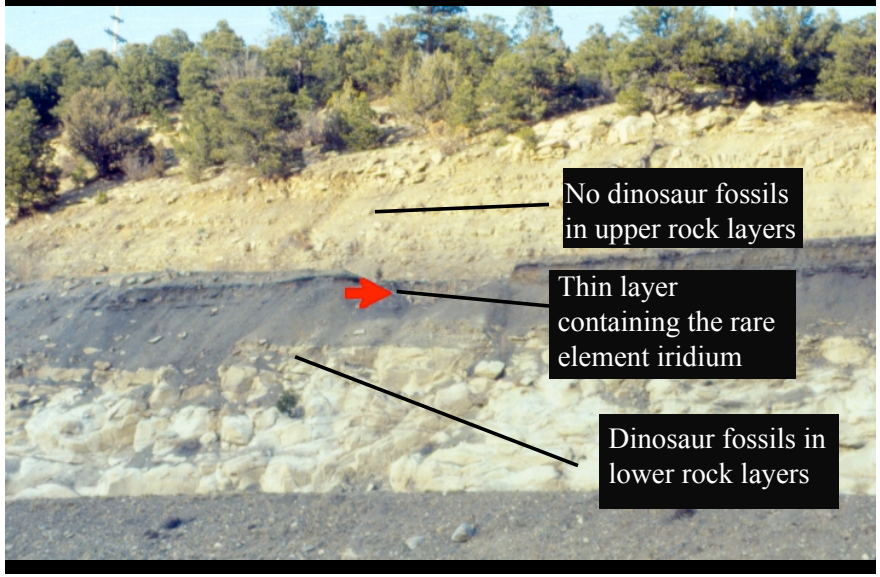
Extinction Events -- how many are due to impacts?



Iridium: Evidence of an Impact

- Iridium is an element that is very rare in Earth rocks, but is often found in meteorites!
- In 1980, Luis and Walter Alvarez found a worldwide layer of iridium, laid down 65 million years ago, presumably by a meteorite impact.
- Dinosaur fossils all lie below this layer. There are no such fossils above this layer.

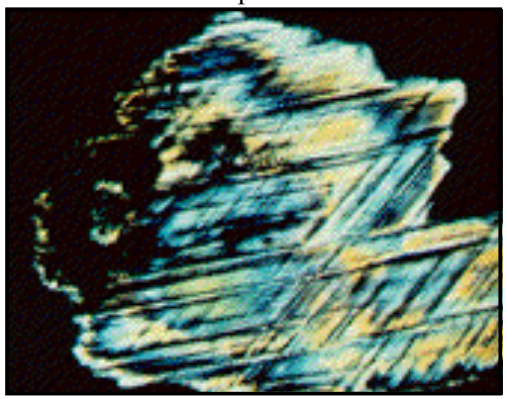
Cretaceous-Tertiary (KT) Boundary



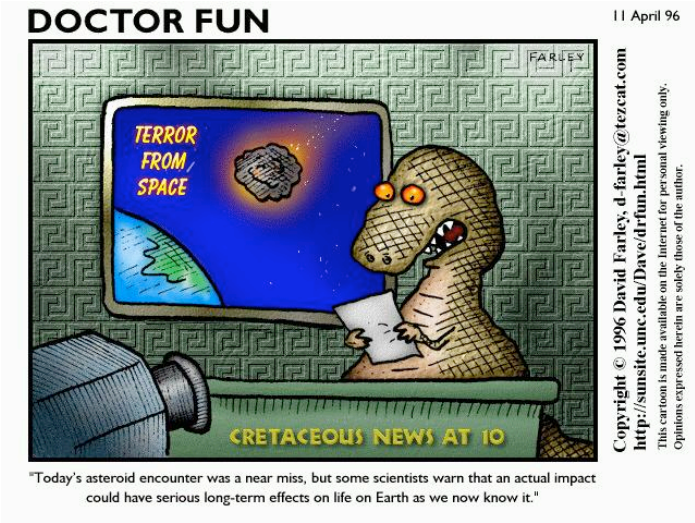
Other meteorite evidence

- Spherules…these represent melt droplets dispersed globally from the impact
- Shocked quartz…this requires high pressures

Shocked quartz under the microscope



Be Aware



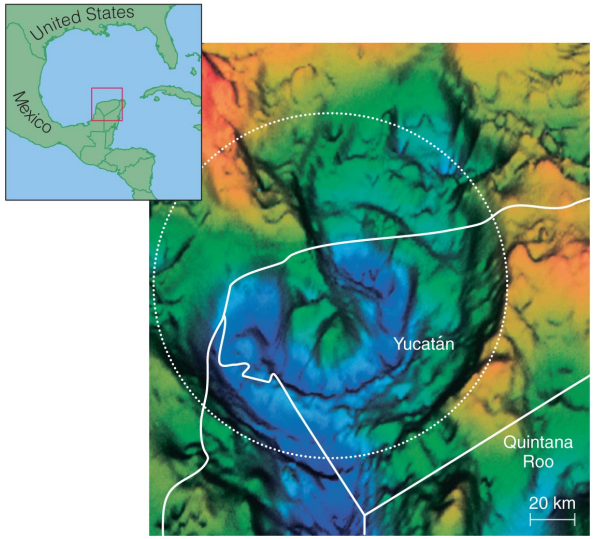
Consequences of an Impact

- A 10-km meteorite hitting Earth 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.
- Affected bigger creatures more than smaller ones.

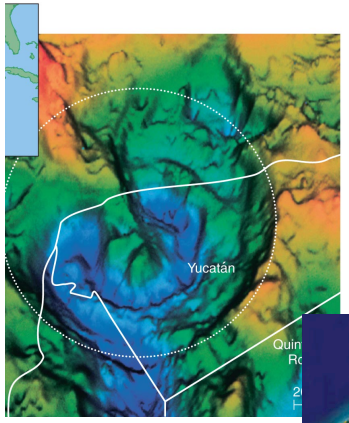
Hmm…

- Okay, so caused by the impact of a large object with the Earth 65 million years ago
- But where?

Likely Impact Site

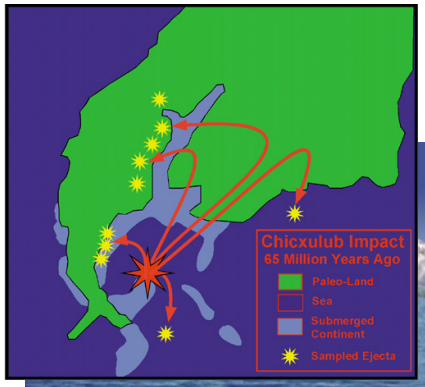


Geologists recently found the remains of a large crater in México. The crater is about 65 million years old!



But note that the crater itself has pretty much completely eroded away.

Bad Day!



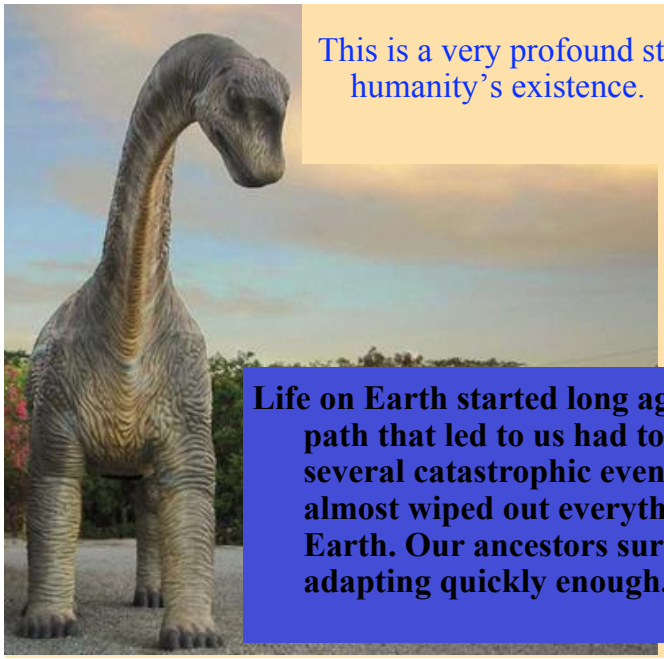
During the Cretaceous the northern part of the Yucatán was covered by a shallow sea. At the time of impact, tsunamis would have radiated across the Gulf of Mexico basin, reaching heights of 50 to 100 m as they approached the coast of what is today Chiapas, Tamaulipas, Nuevo Leon, Texas, Louisiana, and Alabama.

http://www.lpl.arizona.edu/SIC/impact_cratering/Chicxulub/Regional_Effects.html

http://impact.arc.nasa.gov/gallery/ac92-0249.jpg

Suppose there had been no major impact in the last 65 million years. What might Earth be like today?

A. Mammals would have evolved differently; humans might not be here.
B. Humans would be directly competing with dinosaurs for food.
C. Dinosaurs would have evolved into humans.



This is a very profound statement for humanity's existence.

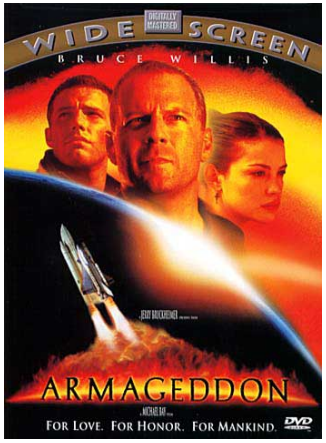
Life on Earth started long ago, but the path that led to us had to go through several catastrophic events that almost wiped out everything on Earth. Our ancestors survived by adapting quickly enough.

This is a very profound statement for humanity's existence.

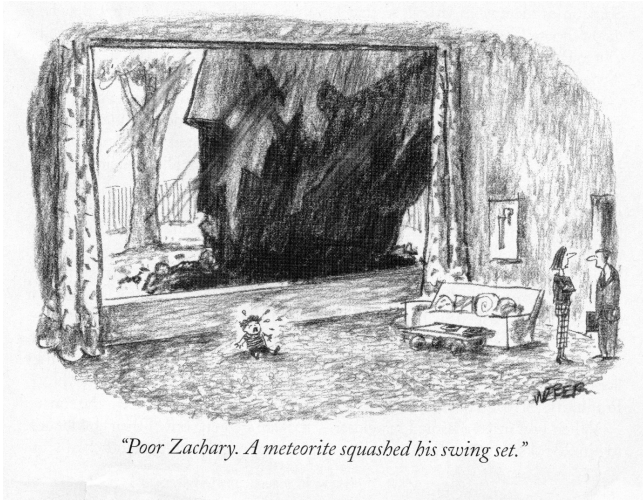
Furthermore, the species that's going to dominate Earth millions of years from now will not necessarily be us….

Massive Impacts = Extinctions?

- Asteroids and comets have hit the Earth.
- A major impact is only a matter of time: not IF but WHEN.
- Major impacts are very rare: For an extinction level event, you have to wait millions of years.
- But! For an event that causes major damage, you have to wait only roughly tens to hundreds of years.

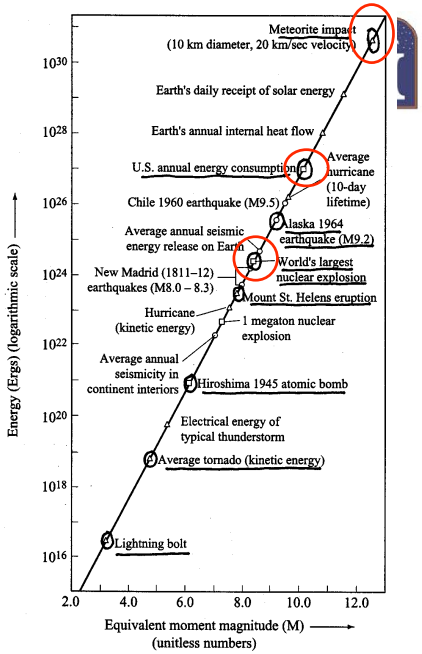


Effects upon children



"Poor Zachary. A meteorite squashed his swing set."

Comparative energies



Tunguska, Russia 30 June 1908

- Something big seems to have exploded in the atmosphere
- The exact cause is uncertain, but we suspect a comet or a meteor

Aerial view of Tunguska Natural Reserve

Eye Witness

I suddenly saw the sky split in two and fire appeared high and wide over the forest. The split in the sky grew larger, and the entire northern side was covered with fire. At that moment, I became so hot that I couldn't bear it, as if my shirt was on fire; from the northern side, where the fire was, came strong heat. I wanted to tear off my shirt and throw it down, but then the sky shut closed, and a strong thump sounded, and I was thrown a few yards. I lost my senses for a moment, but then my wife ran out and led me to the house. After that such noise came, as if rocks were falling or cannons were firing, the earth shook, and when I was on the ground, I pressed my head down, fearing rocks would smash it. When the sky opened up, hot wind raced between the houses, like from cannons, which left traces in the ground like pathways, and it damaged some crops. Later we saw that many windows were shattered, and in the barn a part of the iron lock snapped.

http://en.wikipedia.org/wiki/Tunguska_event

Theories?

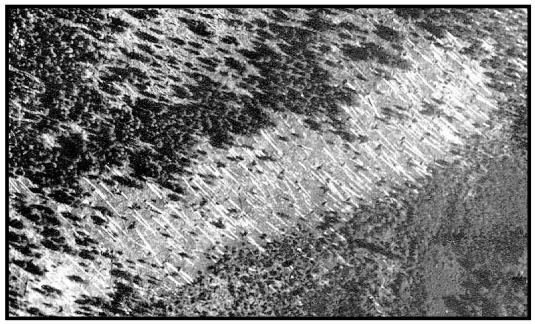
"Perhaps the earliest widely-held theory for the Tunguska explosion was that the world was about to end. As the minutes passed, this theory was dropped in favor of other, less final theories, until today one is hard-pressed to find anyone who truly believes the world ended on the morning of June 30, 1908.."

http://en.wikipedia.org/wiki/Tunguska_event

What happened?

- The object's entry appeared to be at an angle of 30-35°
- The object shattered in a series of explosions at about 8 km altitude

Tree blowdown from the explosions; Note parallel alignment of the trees



Big fires

- In the central region, forests flashed to fires that burned for weeks
- A herd of 600-700 reindeer was incinerated

Tunguska, Siberia, June 30, 1908

Black and white photos taken during field expedition in 1927; color photo taken in 1990

Aligned trees

- Trees were felled in a radial sense
- About 2,000 km^2 were flattened by the blasts

What happened?

- Our best scientific guess is that it was part of a comet 20-60 meters in diameter…
- …no crater was found…
- …and no meteoritic debris has been found

Felled trees aligned parallel to each other

Lake Cheko

- Recently, a team has suggested that a fragment from the event did impact 8 km away.
- They argue that it made Lake Cheko (elongated in correct direction).
- It has a strange conical shaped bottom with dense object at the bottom (investigated this year).

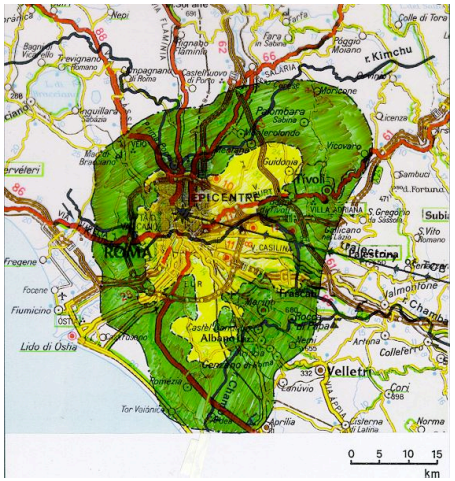
Tunguska, Siberia: June 30, 1908
A ~40 meter object disintegrated and exploded in the atmosphere

The energy of the explosion was equivalent to 1,000 Hiroshimas

Several hundred square miles of forest were destroyed.
What if this had happened over a city?

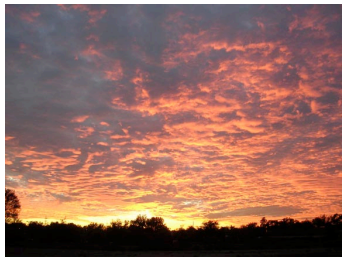
Area of devastation superimposed on a map of Rome.
Yellow=charred trees; Green=felled trees

- Devastation!
- Over a city, it could kill millions.



A Global View

- Soot from fires circled the globe, producing spectacular sunrises and sunsets for months afterward
- The Tunguska event was the largest known comet/asteroid event in the history of civilization
- http://www.youtube.com/watch?v=mQSwVMBIeKg
- We expect such events every 100 years or so!



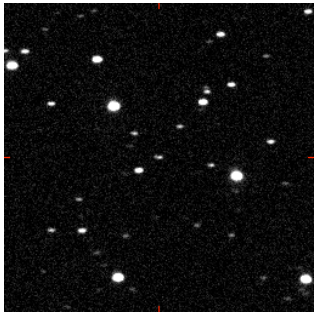
http://visionoftheworld.com/_wsn/page4.html

If something like Tunguska happens every ~100 years, how come we haven't heard about it? Why haven't more people been killed by asteroid impacts in the past?

- Before the 20th Century, human population was much lower, so likelihood of someone being affected is lower.
- If someone did see a Tunguska, less likelihood of word getting around -- news didn't disperse as easily back then.

Killer Asteroids

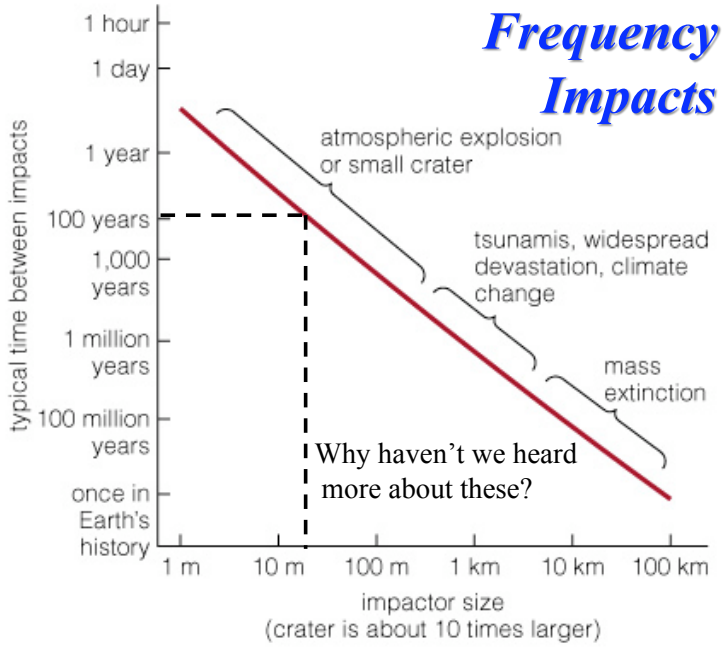
- Small asteroids are often hitting the Earth's atmosphere.
- Commonly giving off around 10 kilotons of energy.
- But how often are Killer Asteroids (~ 0.5 km in diameter) expected?



Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

http://antwrp.gsfc.nasa.gov/apod/ap040322.html

Frequency of Impacts



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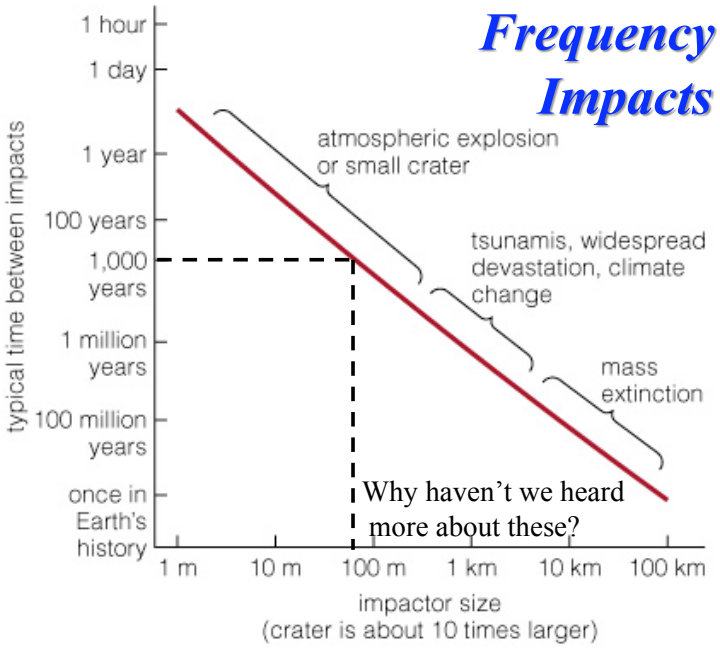
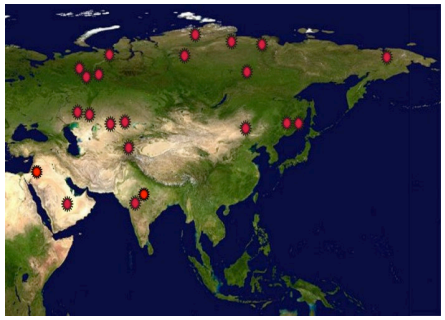


Well there are many known impact craters -- but the oceans would hide a lot more!



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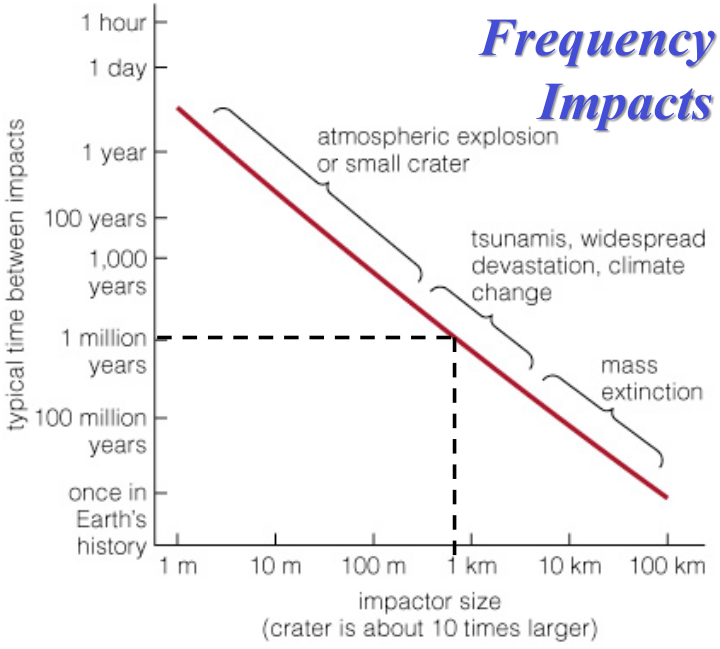

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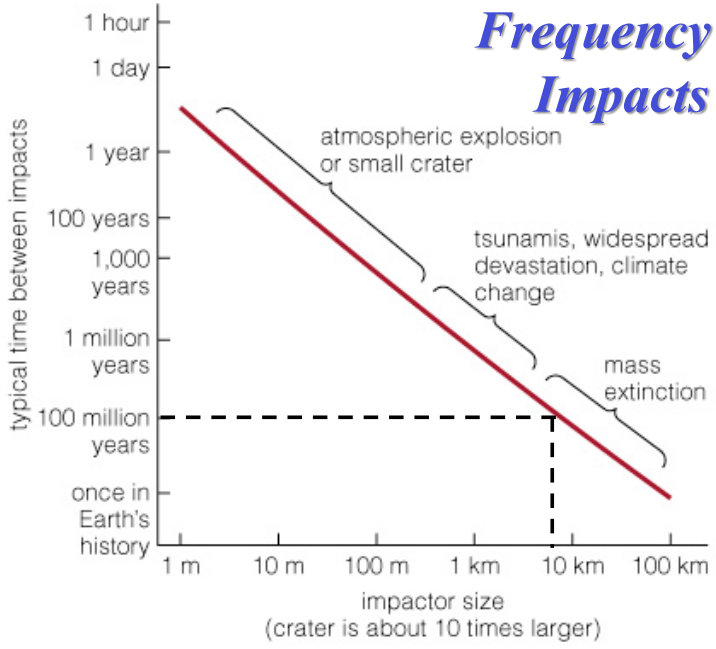
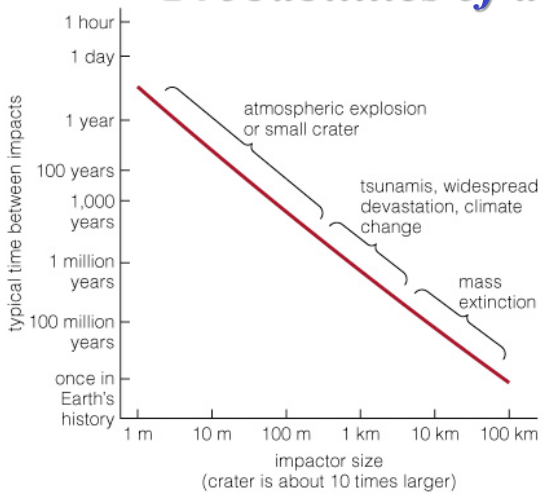


Probabilities of a collision



- Small impacts happen several times a year -- but our atmosphere protects us.
- Impacts large enough to cause mass extinctions are many millions of years apart.

Natural Catastrophes

- Common?
  - 5-10 m object hits Earth every ~1 years.
  - 50 m object hits Earth every ~1,000 years (Tunguska+).
  - 1km object hits Earth every ~500,000 years.
  - 5km object hits Earth every ~10 million years.
  - >10 km object hits Earth … last one was 65 million years ago
- Not a clock, just random events

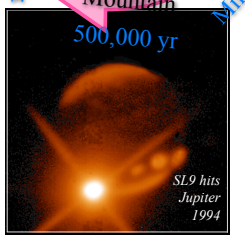
Sizes and Impact Frequencies

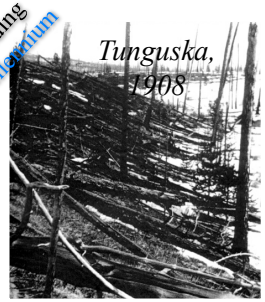
Smallest, most frequent

Second
Dust
Boulder
Week
Building
Millennium
15 km
100 Myr
Mountain
500,000 yr

Huge, extremely rare

K-T mass extinctor, 65 Myr ago

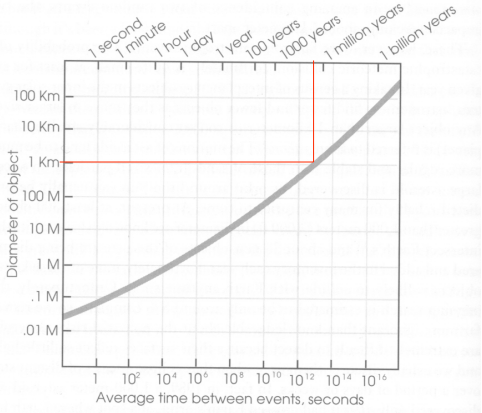




Tunguska, 1908

Other Probabilities - Zebrowski

Some scientists suggest that, on average, collisions of 1 km-diameter objects occur every 250,000 years



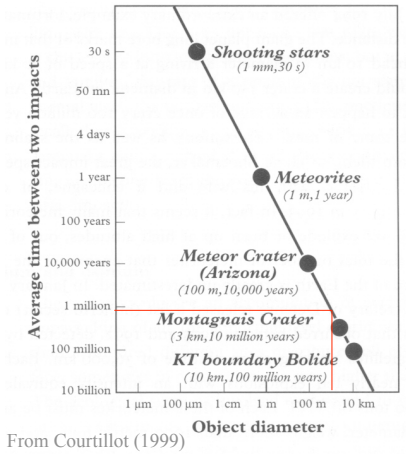
From Zebrowski (1997)

Probabilities - Courtillot

Is the previous estimate too high?

Other scientist suggests it is about 1 Ma between events.

Would that make you feel safer?



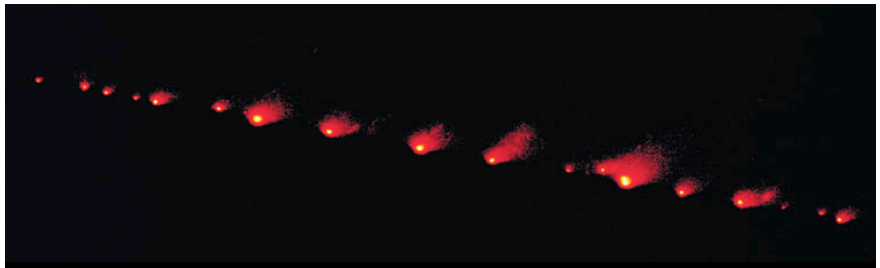
From Courtillot (1999)

Zebrowski vs. Courtillot

The differences we see on the two graphs give you some idea of the uncertainties involved

Nature of the event

- Impact cratering is an important process in the history of Earth and other planets
- Have we ever seen such a large impact?



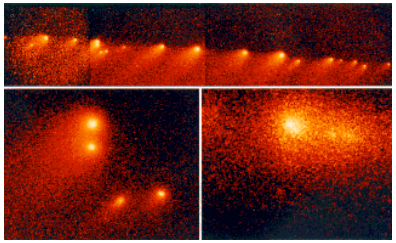
YES, we have seen a major impact….on Jupiter:

In 1994, Comet Shoemaker-Levy 9 (5km!) -- already broken up into fragments -- collided with Jupiter.

Each fragment impacted, reminding us that catastrophic collisions can and do happen.

The sequence of events

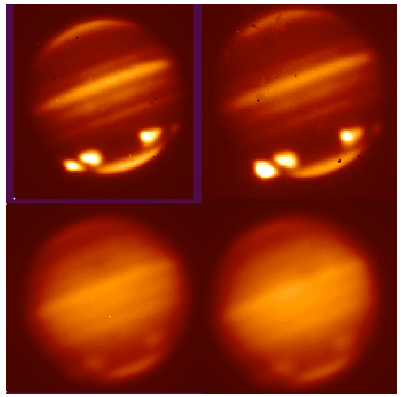
- The collision of the comet with Jupiter occurred over several days, 16-22 July 1994
- It was the first collision of two solar system bodies ever observed
- At least 20 fragments hit Jupiter at speeds of 60 km/ second



http://www2.jpl.nasa.gov/sl9/background.html

Sizes of fragments

- The largest fragments were about 2 km in diameter
- Huge plumes thousands of km high were generated
- Comparisons can be made with the Cretaceous-Tertiary (KT) extinction event– Dino Killer



http://www.as.utexas.edu/mcdonald/comet/jul21.gif

Stop Giggling?

http://www.youtube.com/watch?v=l6AIt36-whc