Astronomy 150:

Killer Skies

This Class (Lecture 7):
Dino-Killers

Next Class:
Jupiter in Peril

HW3 due Monday

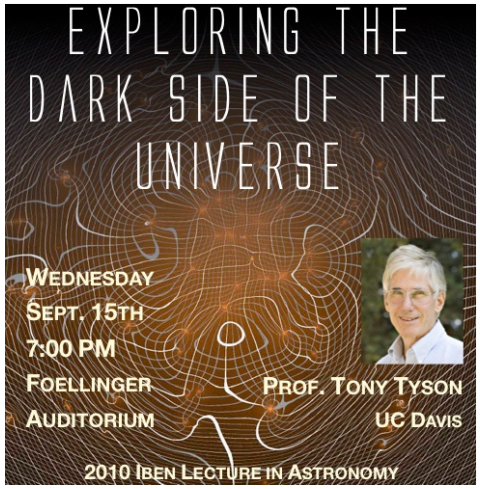
Music: ***It's the End of the World As We Know It*– REM**

Next Week is Computer Labs!

- No lectures on Monday (Sept 13th) and Wednesday (Sept 15th), so see you in a week.
- Time to work on your asteroid computer lab (due Nov 12th).
- Download instructions and worksheet from website (under assignments)
- ASTROMETRY OF ASTEROIDS can be downloaded to your computer (http://www3.gettysburg.edu/~marschal/clea/astlab.html and install the AstrmLab.EXE program), or you can go to any of the computer labs (running Windows) and look in the Programs for ASTRO 121 menu (for ICS labs) for the Asteroid Program or the ASTRO 150 menu (for ATLAS labs).

General Public Astro Talk

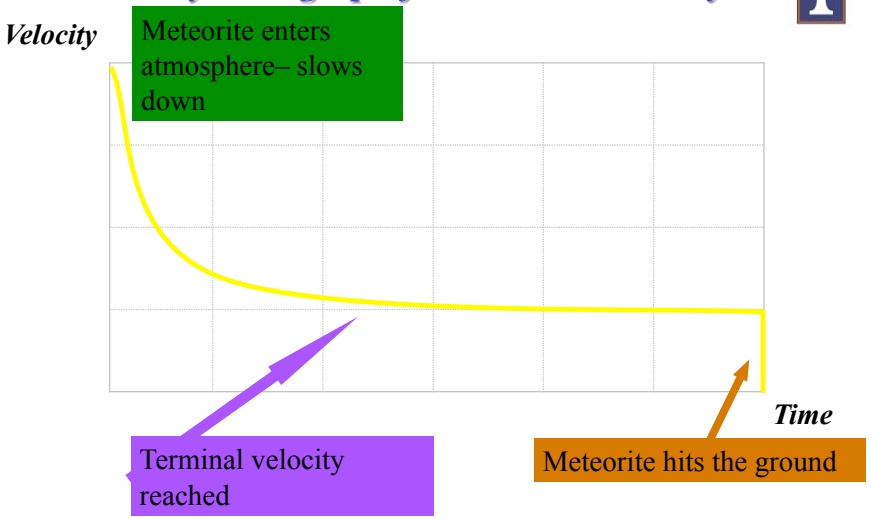
- Wednesday night is the yearly Iben lecture in astronomy.
- This year it is about Dark Energy!
- Exciting topic.
- Go and write 1-2 page summary about the talk (i.e. what you learned, liked, etc.), and you get 2% extra credit!!!!
- Due Sept 22nd in class. Must be typed!



Outline

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

Velocity-time graph for terminal velocity…



Up on Speed

- Terminal velocity depends on both the shape of the object and the mass.
- Initial velocities of meteorites range from 11-72 km/s.
- They impact the upper atmosphere– low-mass objects will be more affected than high mass objects.

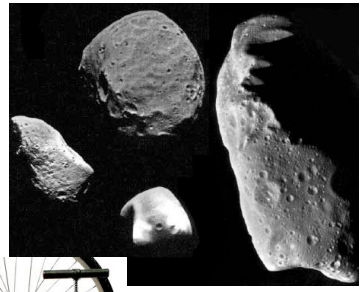
Interesting Question

Which of the following will have the lowest terminal velocity?

a) Jet airplane
b) Rocket
c) Sheet of paper
d) Bowling ball
e) Human

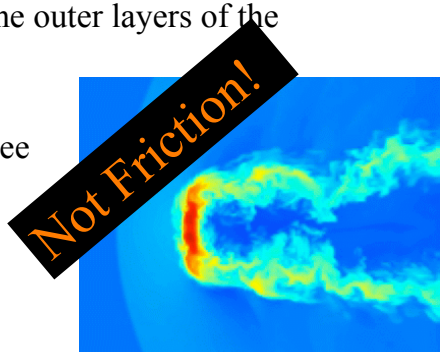
Why does a meteor shine?

- The meteroid compresses the air in front of it, so-called ram pressure.
- Just like quickly pumping up a bicycle tire, this heats up the air.
- This heats up the meteroid.



Why does a meteor shine?

- Due to ram pressure, the outer layers of the object can melt or boil away, called ablation.
- The meteor light you see is a combination of ablation and ionizing of the atmosphere by the extreme heat.

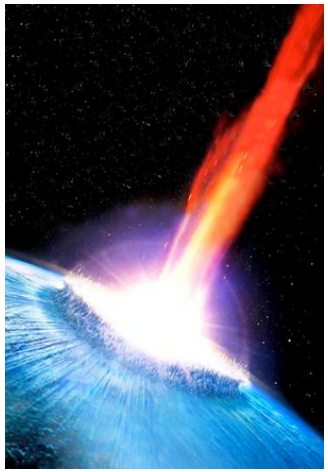


Ramming Speed!

- Objects less than a few kilograms will burn up completely in the atmosphere.
- Objects a few kilograms to 7000 kg will slow down due to the atmospheric drag.
- These reach their terminal velocity– about 90-180 m/s (200-400 mph).

The Big One

- Objects around 9,000 kg will keep some of their initial velocity– about 2-4 km/s (1.5 mps).
- Really big objects (9 x 10^5 kg) will hardly notice the atmosphere, impacting at near their initial velocities (>11 km/s!).
- http://www.youtube.com/watch?v=vZiZU42sn6w



It's a Drag

- Atmospheric flight puts a lot of stresses on the object.
- Larger objects, particularly stone varieties, may break apart into many objects at 11-27 km (7-17 miles) up.
- This causes an ellipse of smaller meteorites on the ground.

Cool Touch

- After the meteor reaches terminal velocity, the ram pressure is gone, and the lights go out.
- At this time, the meteorite cools off quickly.
- The inside of the meteorite has been in space for 4.5 billion years, so it is cold and the upper atmosphere is cold.

Cool Touch

- Sometimes newly fallen meteorites are actually covered in frost.
- But they are never above ambient temperature.
- You will not get burned.
- Big ones, it is a different story.

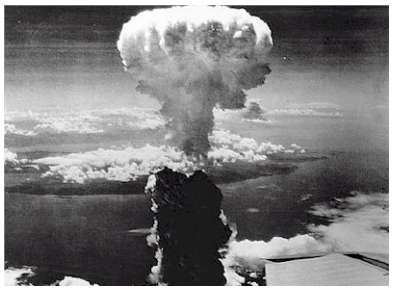
It's a myth that they can start fires!

What do they Look like?

- New rocky meteorites will still have their fusion crust– dark color.
- Iron meteorites, a welded metal look.
- But not always. It can wear away quickly, or the meteorite could have broken up after terminal velocity.
- http://www.aerolite.org/museum-quality-meteorites.htm

Why Does it Hurt So?

- Space Junk is moving at high speeds; small objects can cause significant damage.
- It's really about the energy released.
- Gravitational energy is converted into kinetic energy $\Rightarrow KE = \frac{1}{2} M V^2$
- That means that a 0.25 km radius rock (10 km/s) releases as much energy as 7200 megatons of TNT, as much as an all-out nuclear war!



http://knowledgenews.net/moxie/science/nuclear-weapons-2.shtml

Interesting Question

Which meteorite imparts the most energy?

a) 1 kg moving at 100 km/hr
b) 1 kg moving at 200 km/hr
c) 2 kg moving at 100 km/hr
d) 100 kg moving at 10 km/hr
e) 100 kg moving at 1 km/hr

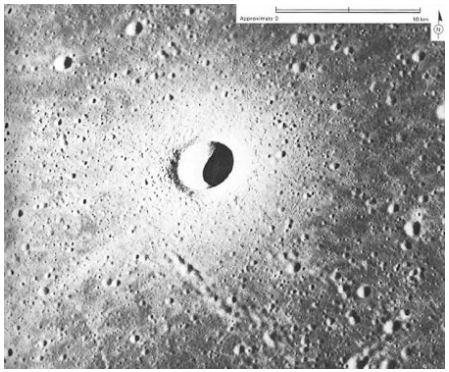
Hints: $1^2 = 1$: $2^2 = 4$: $10^2 = 100$: $100^2 = 10{,}000$: $200^2 = 40{,}000$

Impact events

- The cratering process is very rapid
- Since the objects travel so fast, a huge amount of energy is transferred upon impact

Cratering

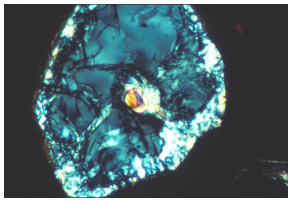
- A blanket of ejecta is dispersed around the crater
- Rock is fractured, crushed, and broken
- In large impact events, the rock can even be vaporized (depending on the type of rock)



http://www.daviddarling.info/images/ejecta_blanket.jpg

Cratering

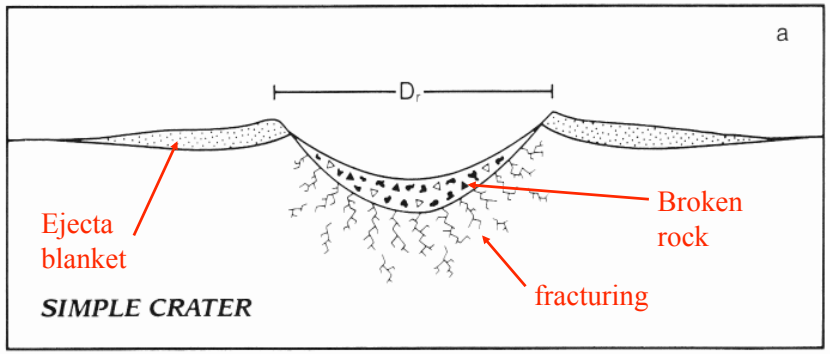
- Very high pressures are reached, resulting in shock metamorphism (pressure-temperature increases)
- After the initial compression comes decompression, which may cause the rock to melt



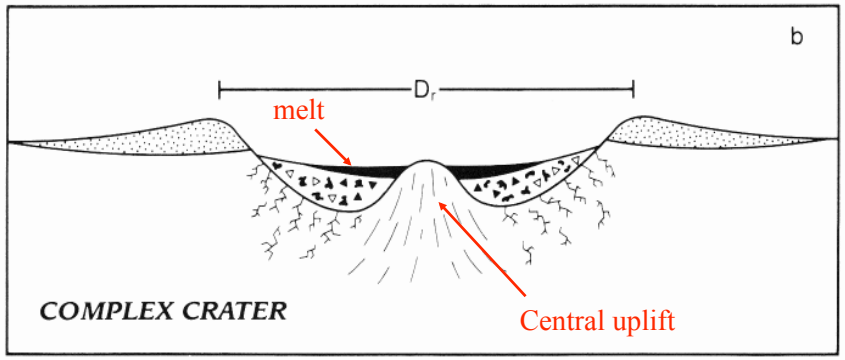
Carbon metamorphed into diamond near a crater site!

Granite metamorphed straight into glass without melting!

http://rst.gsfc.nasa.gov/Sect18/Sect18_3.html

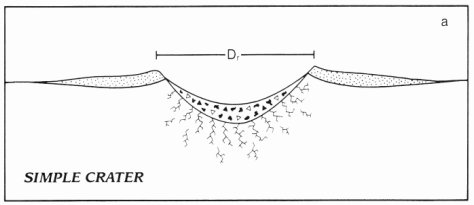


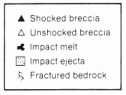
- Simple craters are basically simple bowls
- With time, the ejecta blanket outside the crater is eroded

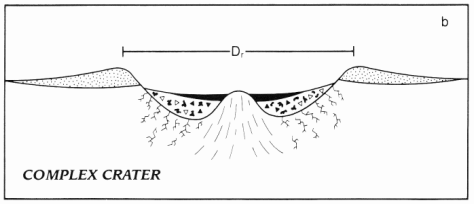


- Complex craters are generated by rebound of the central core
- This core, as it decompresses, may melt

Simple vs. Complex Craters



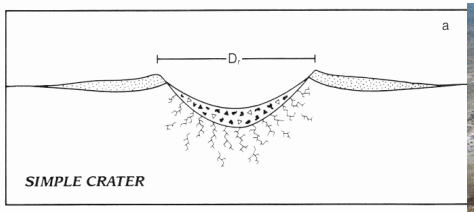


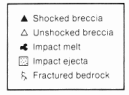


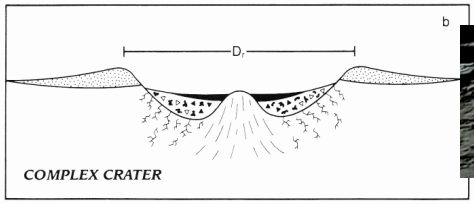
- Simple bowl structure
- Diameter is 15-20 times diameter of impacting object
- All less than 1-2 miles across on Earth

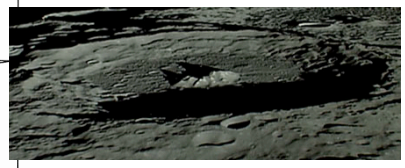
- Complex structure with central peak, peak ring, or multiple rings
- Melt sheet generated
- Terraced, collapsed walls; about 10x impactor diameter

Simple vs. Complex Craters

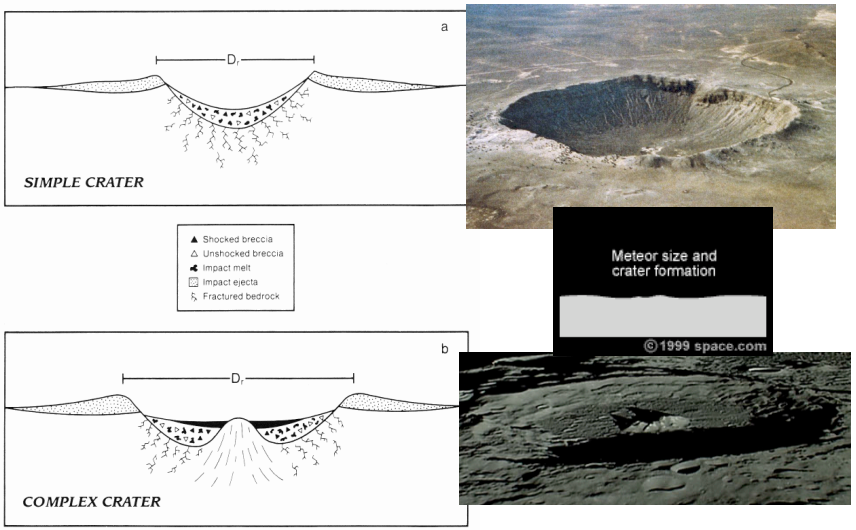








Simple vs. Complex Craters

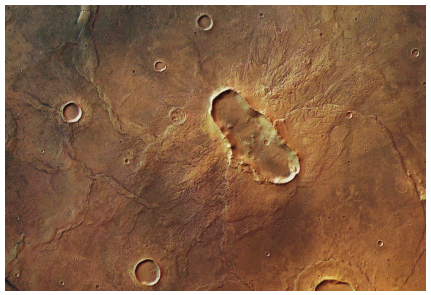


Why are Craters Round?

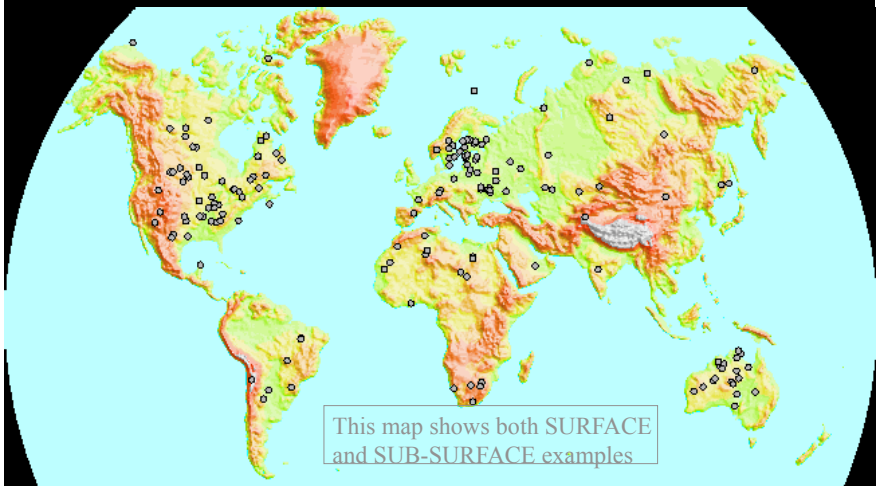
- Impacts should be happening at all impact angles.
- In fact, most impact are not straight down.
- So, why are most craters round?
- In the simple flour-rock experiment, you can get odd shaped craters.
- What's up?

Why are Craters Round?

- Impact vaporizes the impactor.
- Explosion!
- It's like dropping a bomb.
- This causes round craters.
- In rare cases, objects will hit with shallow, grazing impacts, creating oblong craters.

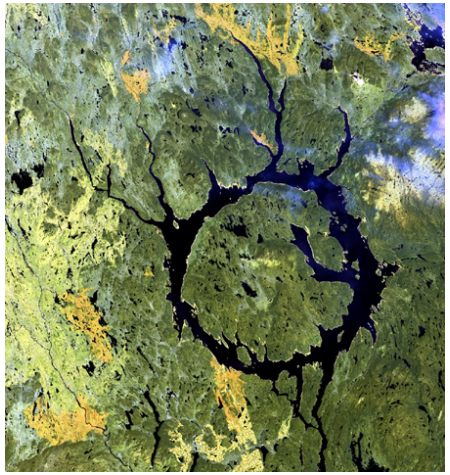


There are about 200 large, well-preserved impact craters worldwide…BUT…>>200 impact events during Earth's history



More of Earth's Craters

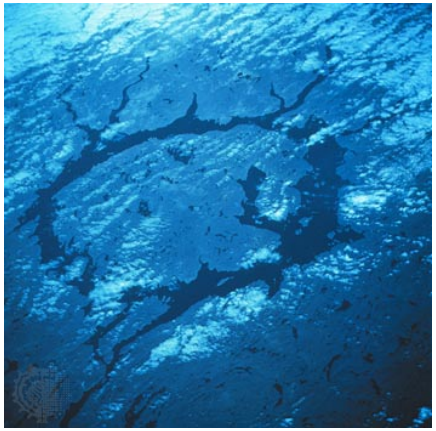
Manicouagan Crater in Quebec, Canada – 100 km wide



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

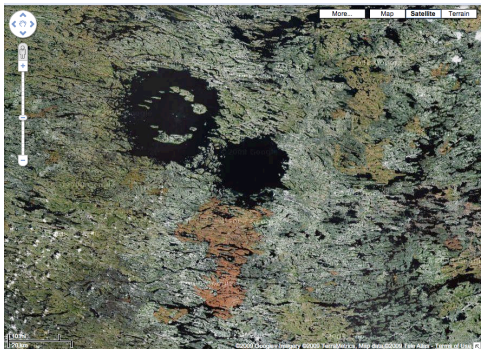
Manicouagan Crater

- 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

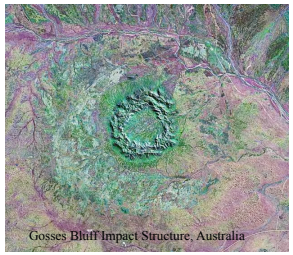


Earth's Craters

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

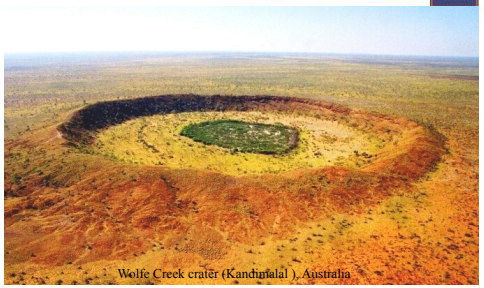


And more…



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
(Sylacauga, Alabama)

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

- Last 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?

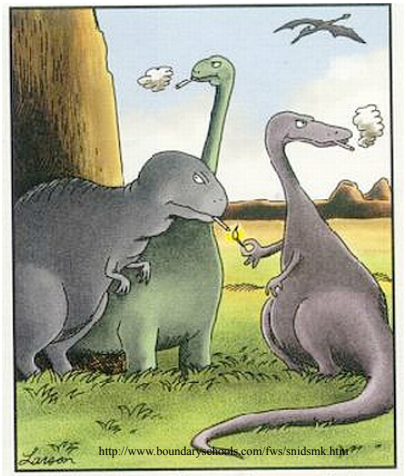
a) Reality TV didn't become popular until recently.
b) Hard to establish facts of death in historic cases, so not reliable.
c) When they're dead, they don't respond too well to detailed questions.
d) It is very unlikely to ever happen.
e) Bring out your dead cart is very hush-hush.

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?

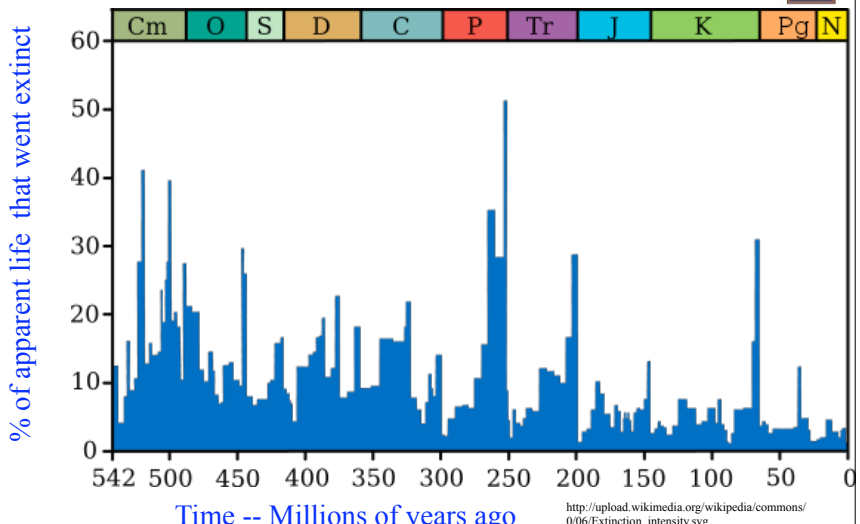
- 65 million years ago, 75-95% of all the species on Earth disappeared
- 2nd largest known mass extinction in geological history
- Was an asteroid collision to blame?



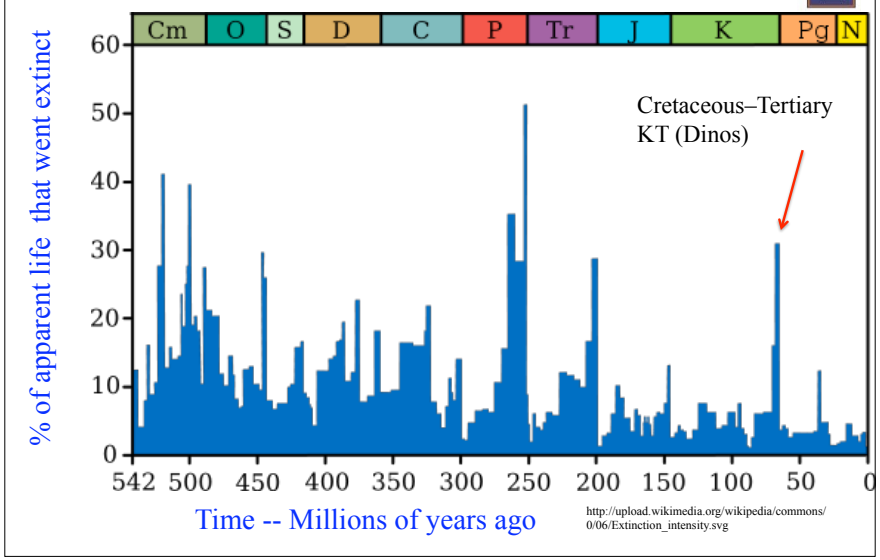
The real reason dinosaurs became extinct

Did an impact kill the dinosaurs?

Extinction Events -- how many are due to impacts?



Extinction Events – The Big Five



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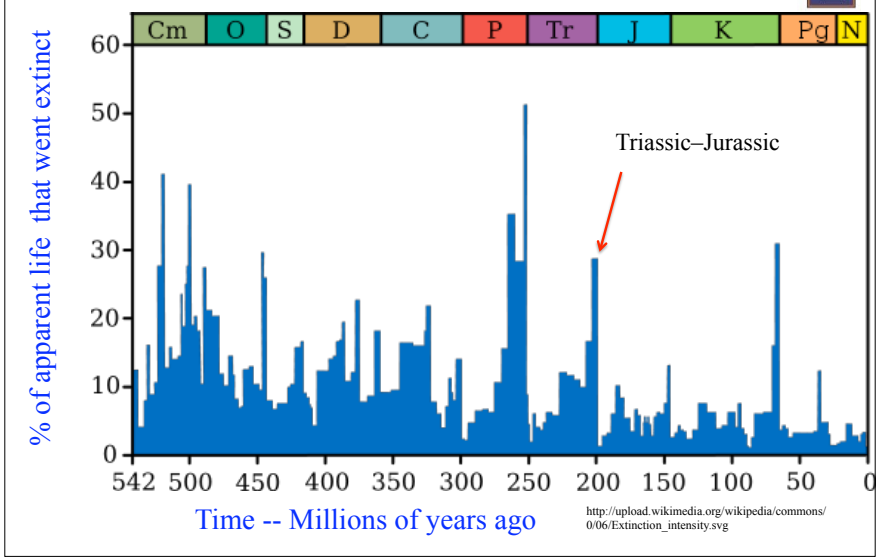

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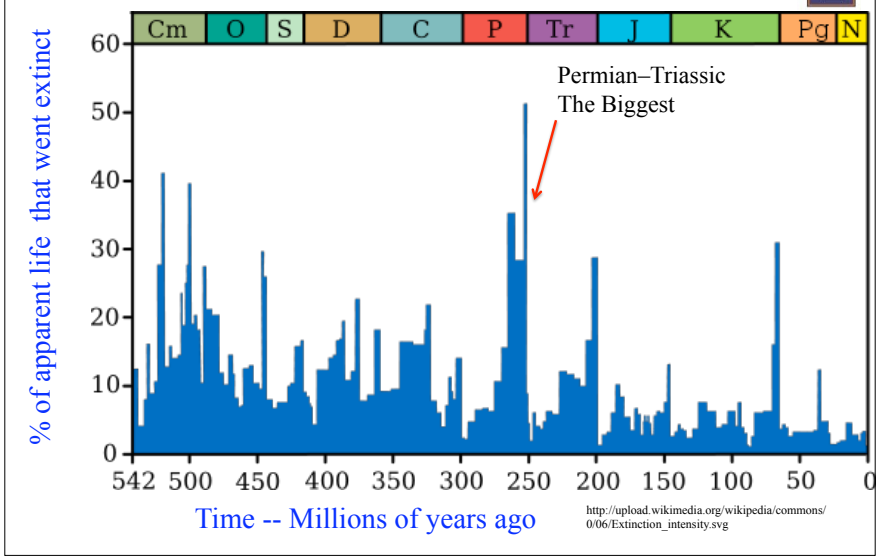

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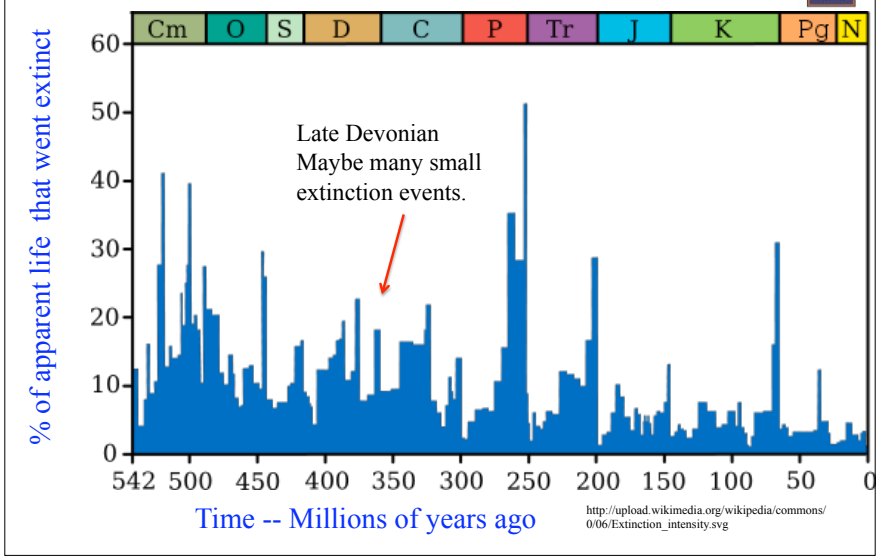
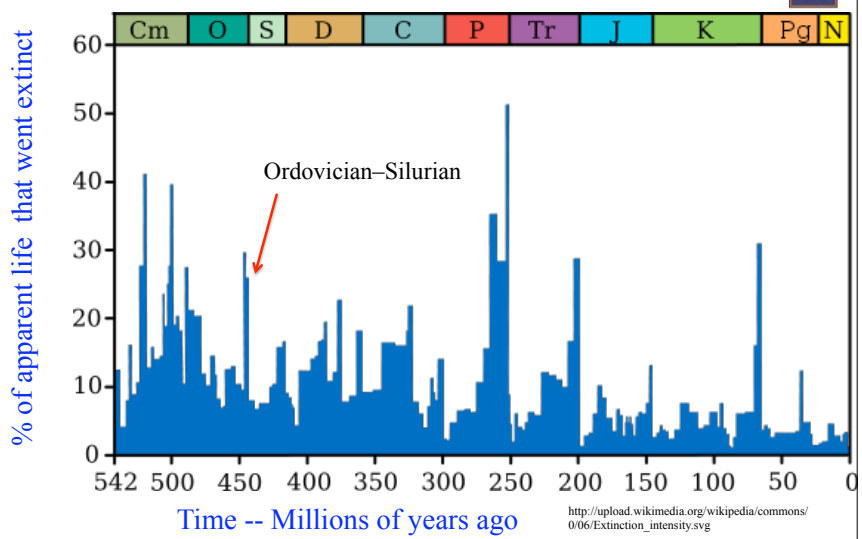


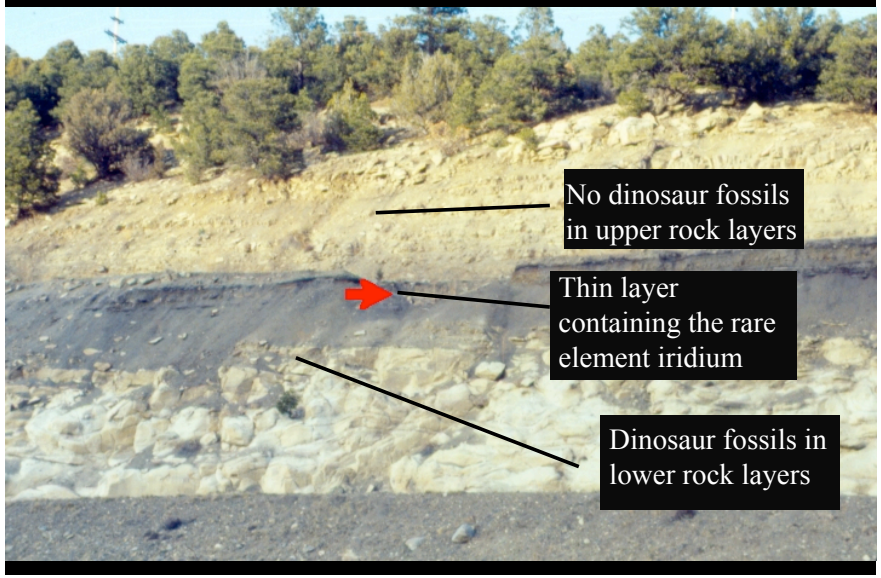
Extinction Events – The Big Five



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.

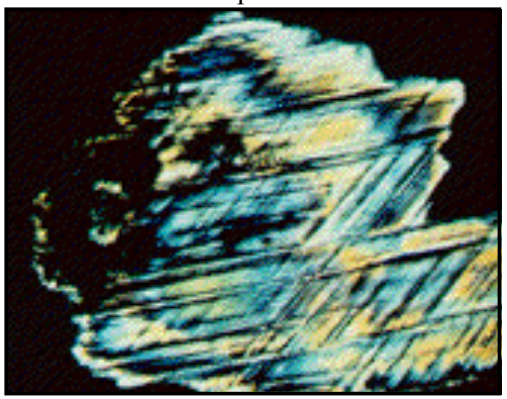
Cretaceous-Tertiary (KT) Boundary



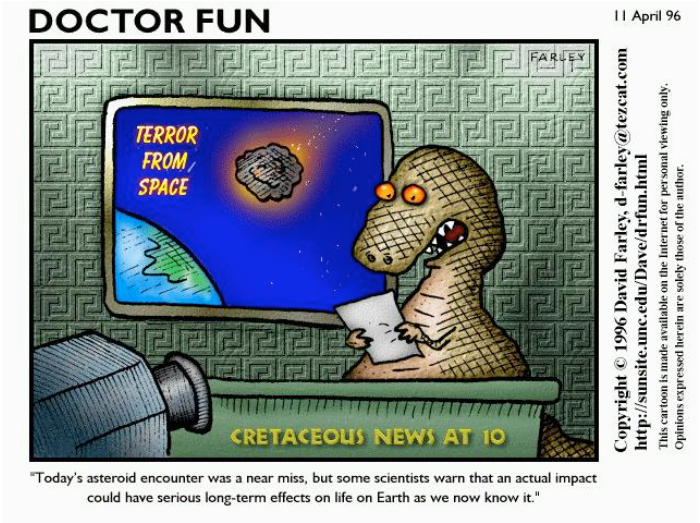
Other meteorite evidence

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

Shocked quartz under the microscope



Be Aware

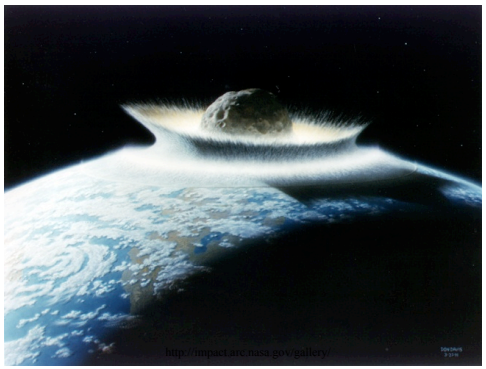


Consequences of an Impact

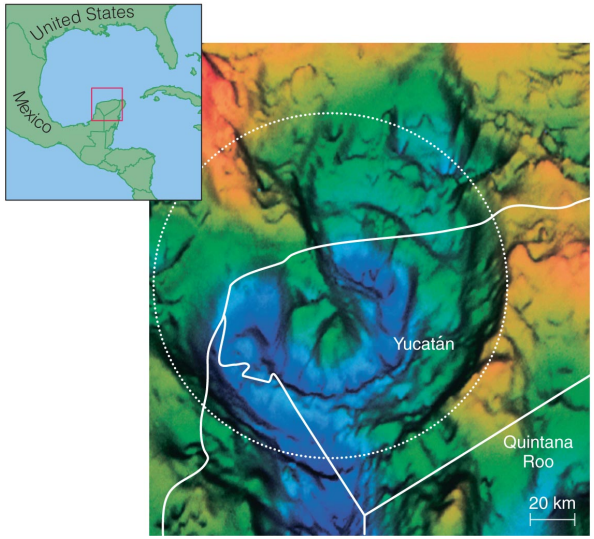
- A 10-km meteorite hitting Earth would send large amounts of debris into the atmosphere.
- Debris would reduce the amount of sunlight reaching Earth's surface.
- The resulting climate change may have caused mass extinction.
- Affected bigger creatures more than smaller ones.

Hmm…

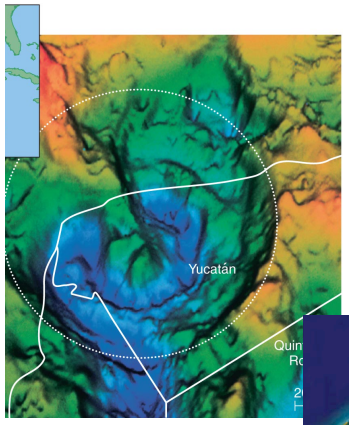
- Okay, so caused by the impact of a large object with the Earth 65 million years ago
- But where?



Likely Impact Site

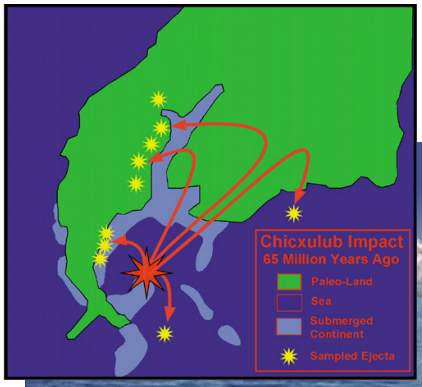


Geologists recently found the remains of a large crater in México. The crater is about 65 million years old!



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

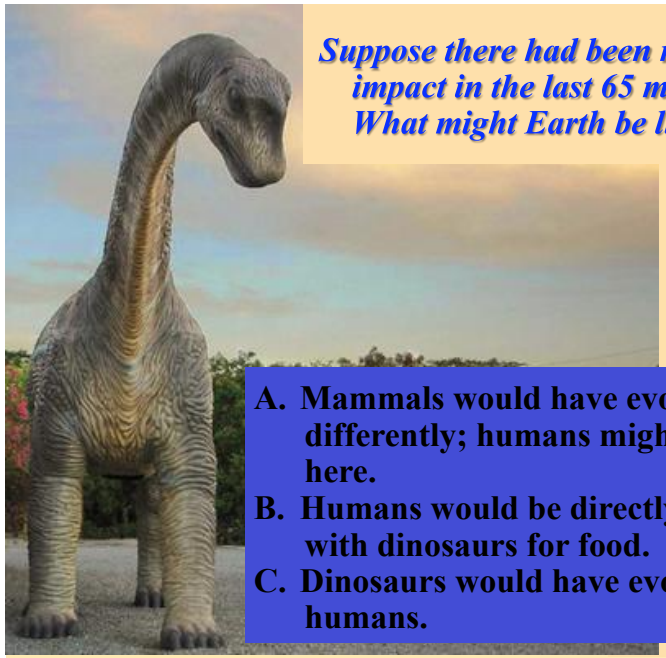
Bad Day!



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.

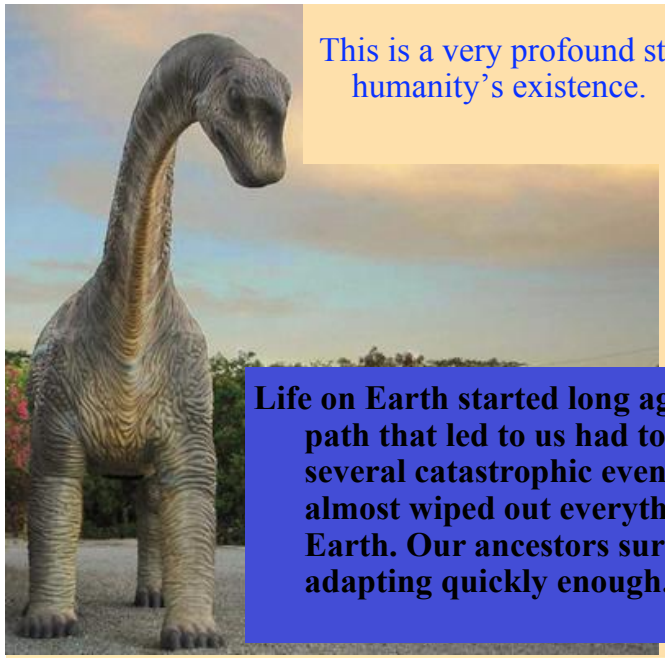
http://www.lpl.arizona.edu/SIC/impact_cratering/Chicxulub/Regional_Effects.html

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



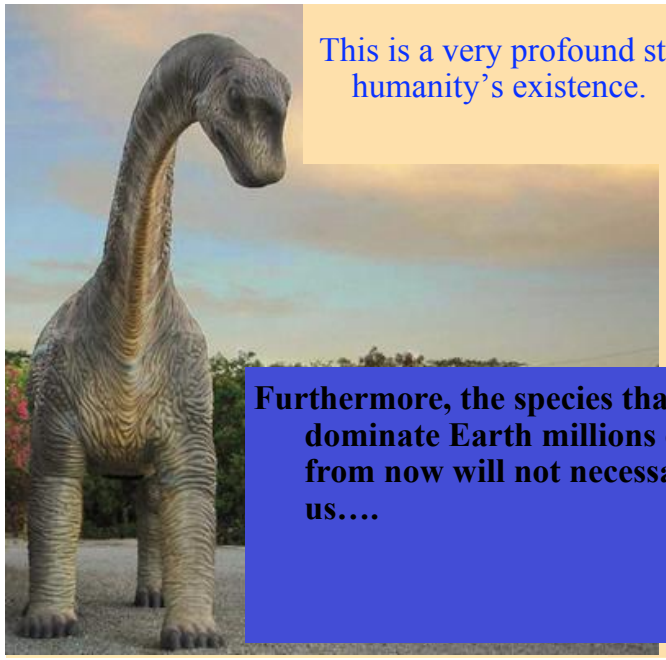
Suppose there had been no major impact in the last 65 million years. What might Earth be like today?

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….