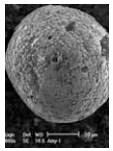
Astronomy 150:
Killer Skies

This Class (Lecture 7):
The Atmosphere and Meteors

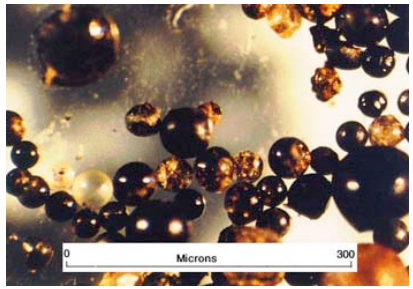
Next Class:
Dino Killer

HW2 due sometime…

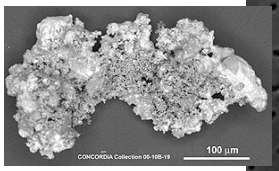
Music: *Shooting Star*– Bob Dylan

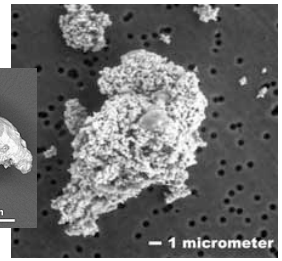


HW2: Micro-Meteorites



- Will probably be too small to see.
- Perhaps we should extend until after Oct 21st-- the next meteor shower (Orionids).
- Larger chance of big ones.





a) Yes
b) No

Night Obs

- Dates:
  - Monday, Sept. 21st
  - Tuesday, Sept. 22nd
  - Wednesday, Sept. 23rd
  - Thursday, Sept. 24th
  - Monday, Sept. 28th
  - Tuesday, Sept. 29th
  - Wednesday, Sept. 30th
  - Thursday, Oct. 1st

Go to assignment page on class website for more info.

You MUST download worksheet before you go.

Computer Labs

- Computer labs to look for real killer asteroids.
- Dates:
  - Monday Sept 28th
  - Monday, Oct 5th
  - Monday, Oct 12th
- Places:
  - Nevada Labs
  - Oregon Labs

- Limited space each day, so you ***MUST*** have a reservation for that day and that lab!
- See Assignments webpage for more info and to sign up!
- Lectures are cancelled for those dates.

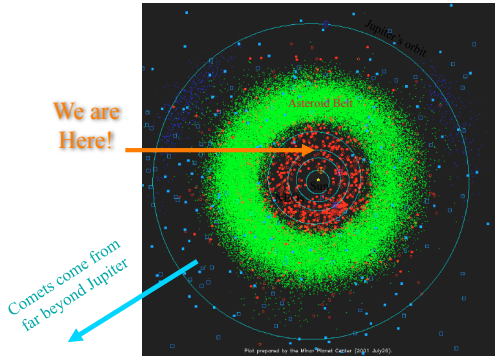
Outline

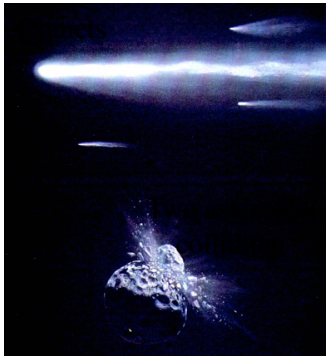
- Meteorites and the Earth
- Why do they hurt?
- Why do they slow down?

NEOs: Comets and Asteroids

"NEOs" = Near- Earth Objects.

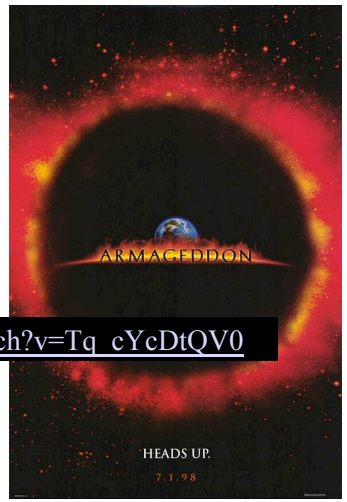
The processes that formed the planets 4.6 billion years ago left many small remnants: comets (beyond the outer planets) and asteroids (in a "belt" between the orbits of Mars and Jupiter). Some of them occasionally cross the Earth's orbit and can strike our planet...*if* it happens to be there at the same time.





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

http://www.youtube.com/watch?v=Tq_cYcDtQV0



Does Large Space Junk Ever Impact Objects in the Solar System?

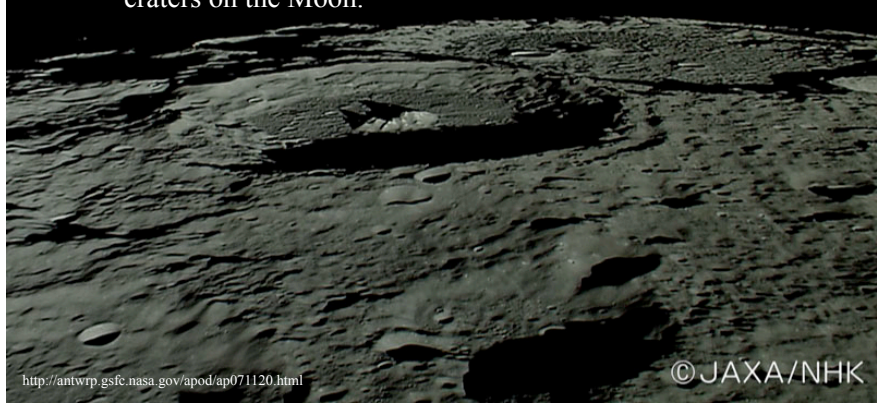
Image of the Moon with the Space Station in the foreground. Cool or what?

Proof in the Pudding: Moon Pie

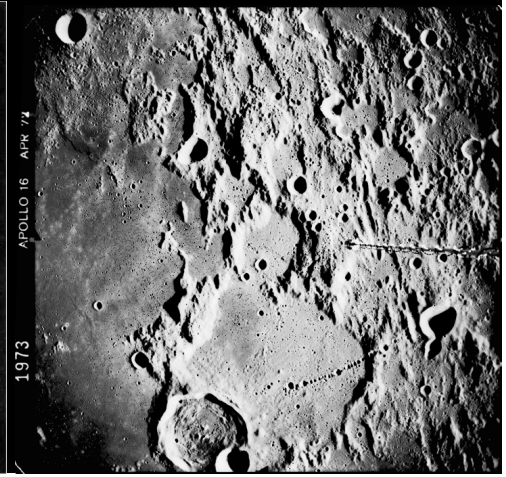
http://antwrp.gsfc.nasa.gov/apod/ap090206.html

Proof in the Pudding: Moon Pie

With even a small telescope, you can see >30,000 craters on the Moon.



- Full Moon (telescope view) with lighter highlands and darker basalt plains, filling multi-ringed basins
- Apollo 16 view of Descartes Highlands, with impact craters on all scales



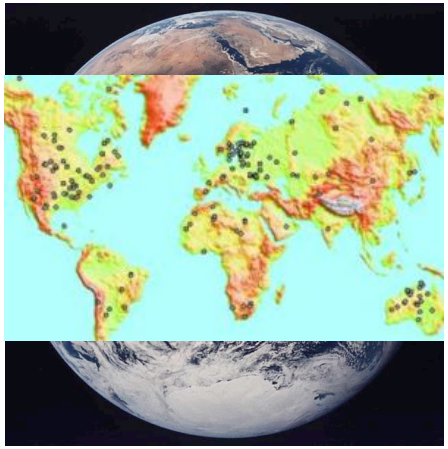
Group Discussion

The Moon clearly has had some LARGE impacts over its lifespan of ~4.5 billion years. Why didn't the Earth? I didn't fall into a crater on the way over here today.

a) When your group has a good answer click A on your Iclicker.

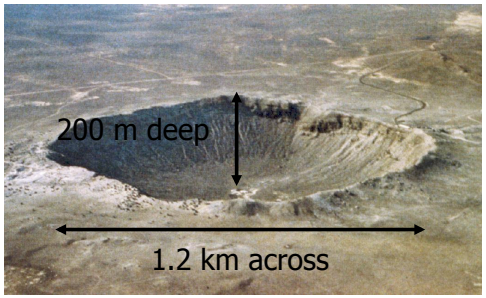
Meteorites and the Earth

- Many bodies in the solar system show massive amounts of cratering
- Earth is relatively crater free
- But we do know of many impact sites (~200)



Meteor Crater

- Near Winslow, Arizona
- Only realized to be a meteor crater by Shoemaker in the 1950's.
- Occurred 50,000 years ago



- A 50 meter meteoroid struck the ground at 40,000 km/hr
- The energy of a 20 megaton hydrogen bomb!

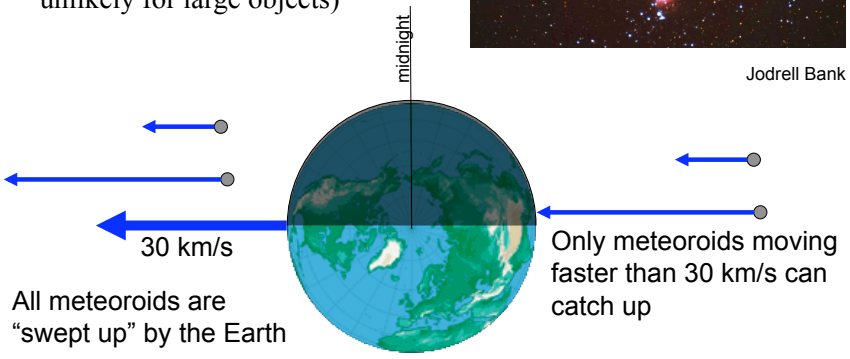
Why Does it Hurt So?

- But how can they impart so much energy?
- Space Junk is moving at high speeds.

Meteors

- The Earth's orbital velocity is 30 km/s (67,000 mph)
- Typical meteorite speed as it hits the atmosphere (50 km up) is around 11-70 km/s (high velocity unlikely for large objects)

Jodrell Bank



Nature of Gravity

- Gravity is a force, producing acceleration
- On the surface of the Earth, the acceleration due to gravity is 9.8 meters per second per second
- Drop two balls (one heavy, one light) off the leaning tower of Pisa:

They both fall at the same rate!

Time (seconds)	Velocity (m/s)	Accel. (m/s^2)
0	0	9.8
1	9.8	9.8
2	19.6	9.8
3	29.4	9.8

Nature of Gravity

- Even a non-moving meteor should speed up to 11 km/s.
- From Earth's gravity….

Time (seconds)	Velocity (m/s)	Accel. (m/s^2)
0	0	9.8
1	9.8	9.8
2	19.6	9.8
3	29.4	9.8

Question

A hammer and a feather are dropped on the Moon, which one hits the ground first?

a) Hammer
b) Feather
c) Hit at the same time
d) The feather floats up and never hits the ground. At least during our lifetime.

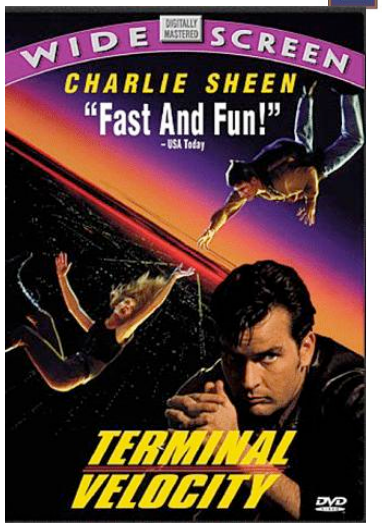
A Feather and a Hammer

http://www.hq.nasa.gov/office/pao/History/alsj/a15/a15v_1672206.mpg

Other Fun Experiments

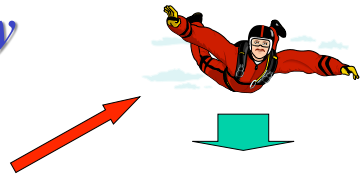
Terminal Velocity

- But… if we are not in a vacuum, the air causes resistance.
- A given object falling in the atmosphere will have gravity pulling downward, and air resistance pushing upward.
- When the two cancel, the object reaches its maximum velocity, or its terminal velocity.

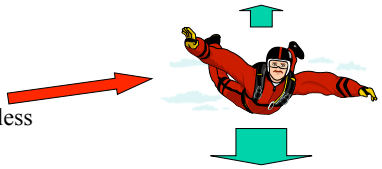


Terminal Velocity

Consider a skydiver:



1) At the start of the jump, there is no air resistance, so object accelerates downwards, speed increasing.

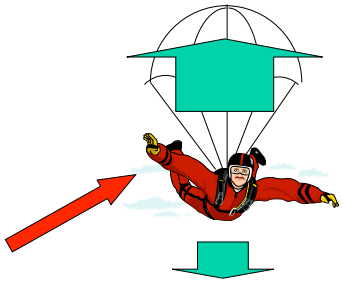


2) As the speed increases, air resistance increases. Object still accelerates, but less than before, speed still increasing.

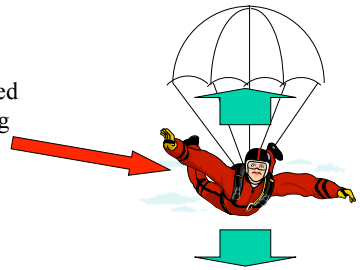
3) Eventually the air resistance equals the pull of gravity, and the object no longer accelerates. The speed is maxed out, or is at the Terminal Velocity-- depends on shape of object.

Terminal Velocity

Still considering a skydiver:

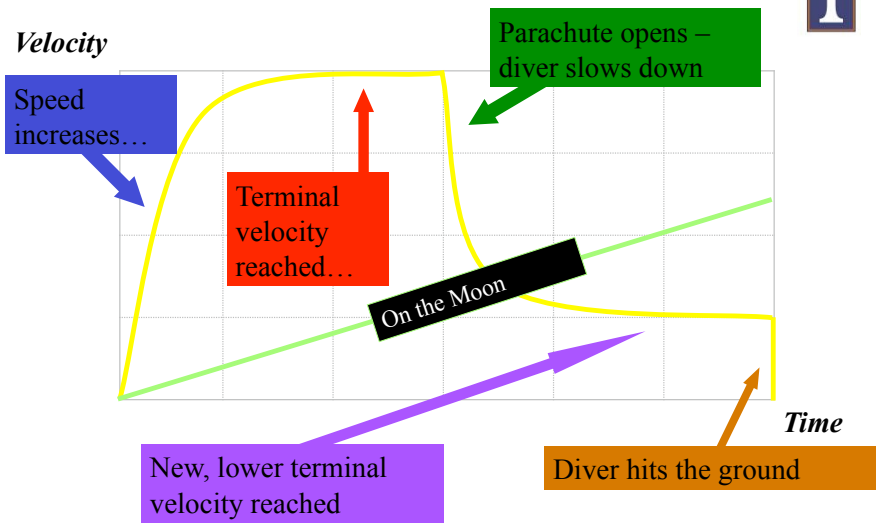


4) When opening the parachute, shape changes, and there is a lot more air resistance suddenly, so decelerate, speed decreases.



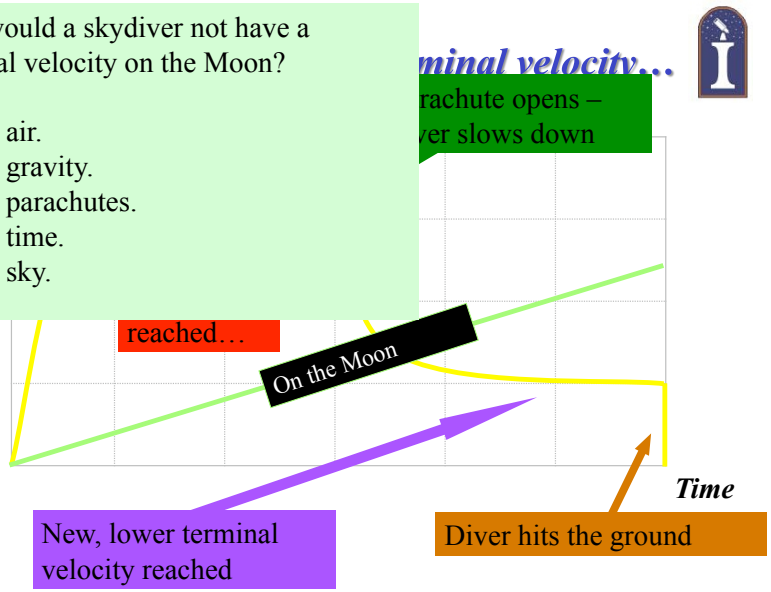
5) Because object is slowing down the air resistance decreases until it balances gravity. Then, skydiver has now reached a new, lower terminal velocity, allowing them to land safely.

Velocity-time graph for terminal velocity…



Why would a skydiver not have a terminal velocity on the Moon?

A. No air.
B. No gravity.
C. No parachutes.
D. No time.
E. No sky.



Question

A hammer and a feather are dropped in the lecture hall, which one hits the ground first?

a) Hammer
b) Feather
c) Hit at the same time
d) The feather floats up and never hits the ground. At least during our lifetime.

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.

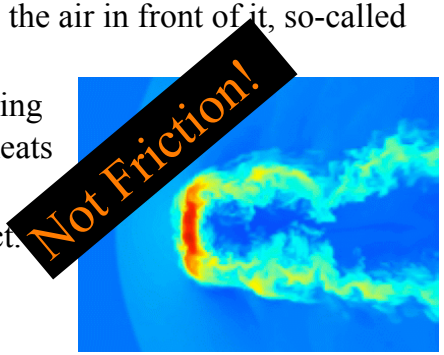
Interesting Question

Which of the following will have the lowest terminal velocity?

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

Ramming Speed!

- The object 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 object.
- 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.

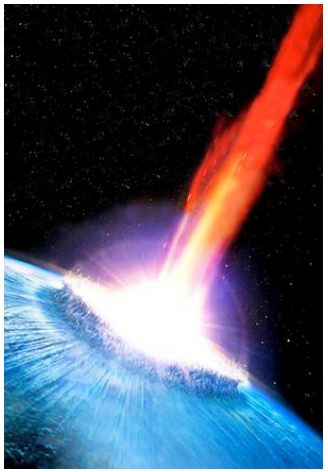


Ramming Speed!

- 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).
- 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.

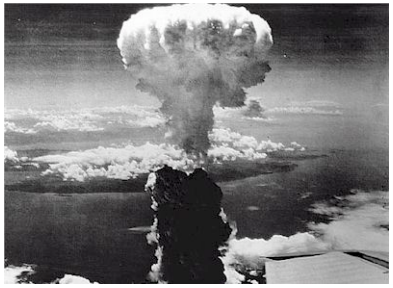
It's a myth that they can start fires!

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 a all-out nuclear war!



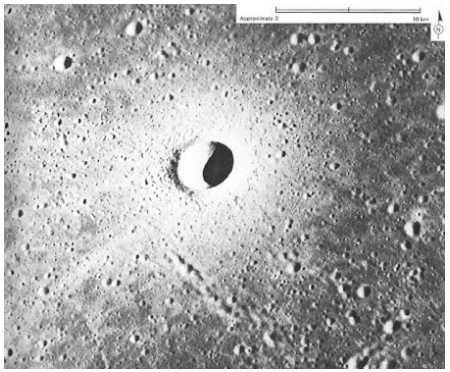
http://knowledgenews.net/moxie/science/nuclear-weapons-2.shtml

Impact events

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

Cratering

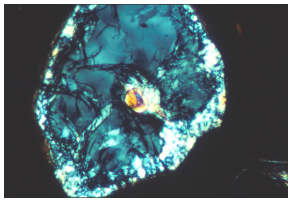
- A blanket of ejecta is dispersed around the crater
- Rock is fractured, crushed, and broken
- In large impact events, the rock can even be vaporized (depending on the type of rock)



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

Cratering

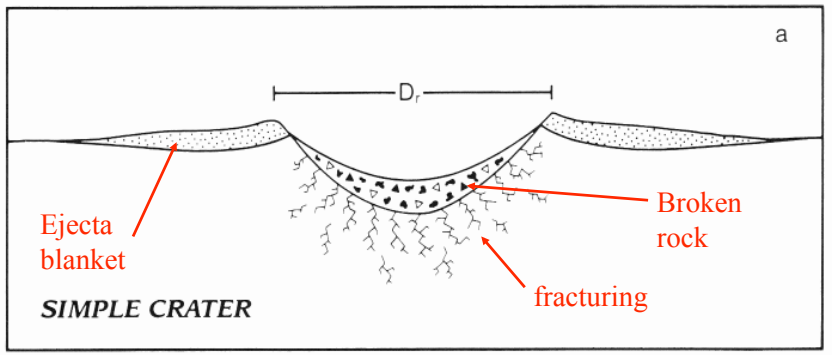
- Very high pressures are reached, resulting in shock metamorphism (pressure-temperature increases)
- After the initial compression comes decompression, which may cause the rock to melt



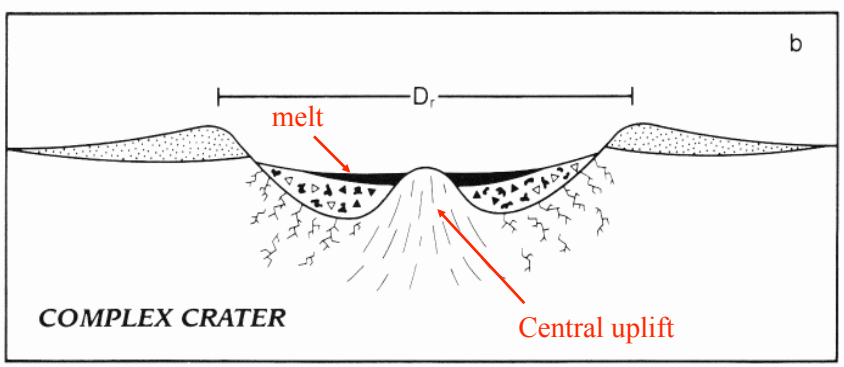
Carbon metamorphed into diamond near a crater site!

Granite metamorphed straight into glass without melting!

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

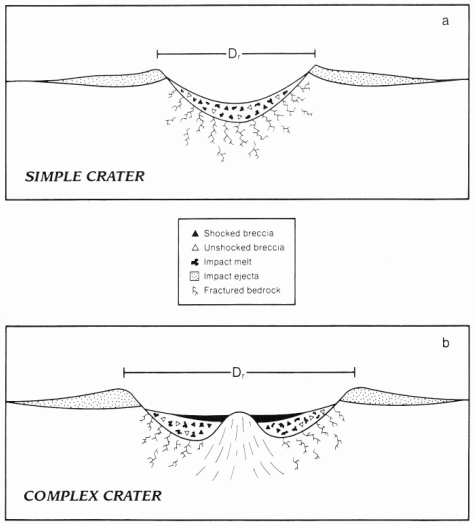


- Simple craters are basically simple bowls
- With time, the ejecta blanket outside the crater is eroded



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

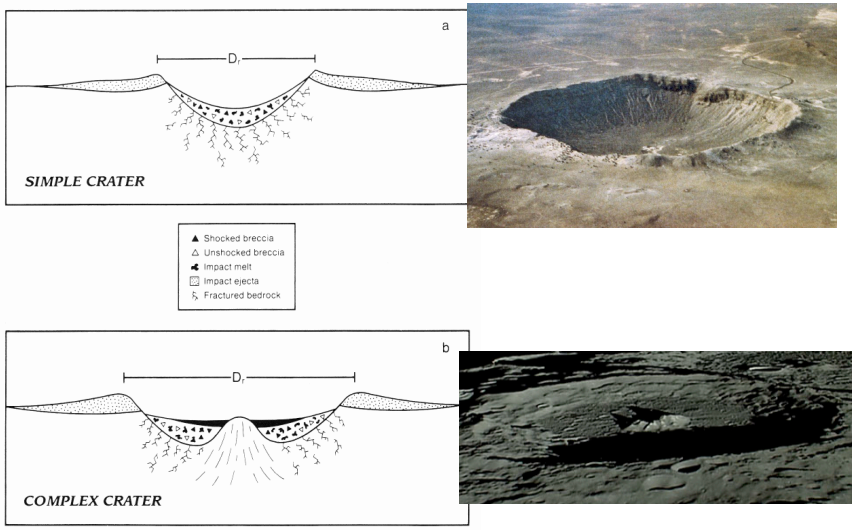
Simple vs. Complex Craters



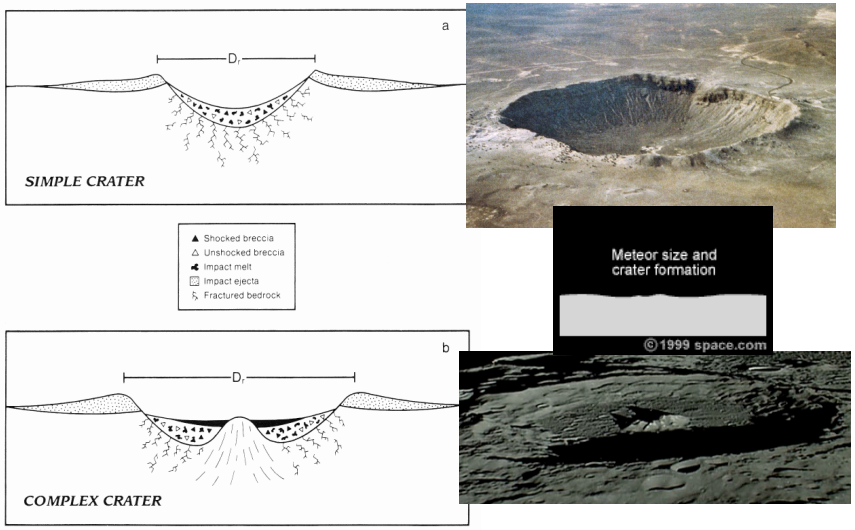
- Simple bowl structure
- Diameter is 15-20 times diameter of impacting object
- All less than 1-2 miles across on Earth

- 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.