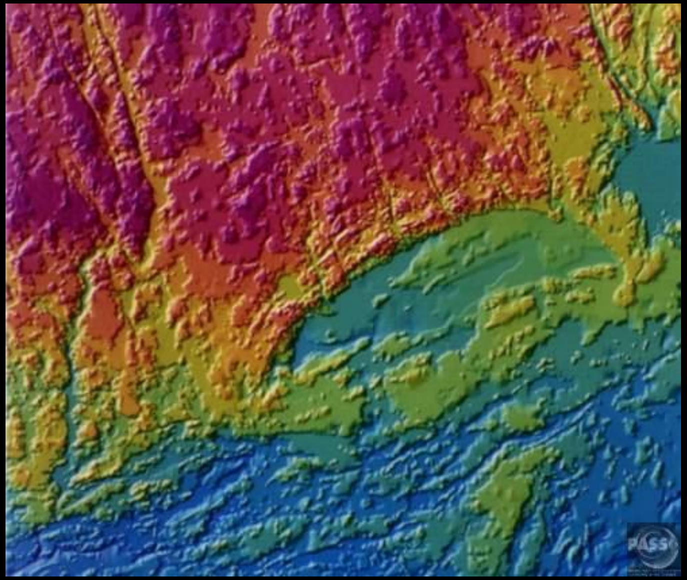
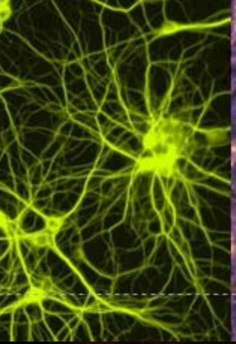
5. Space Debris Returns: Asteroid Impacts

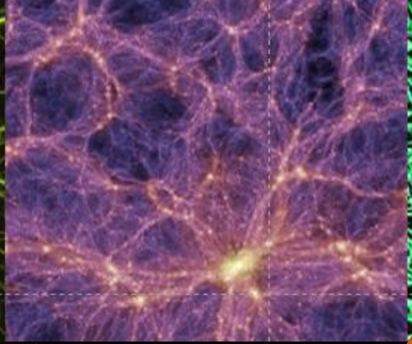
Arizona→

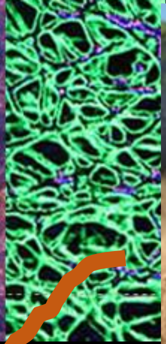
Sudbury and Chesapeake→

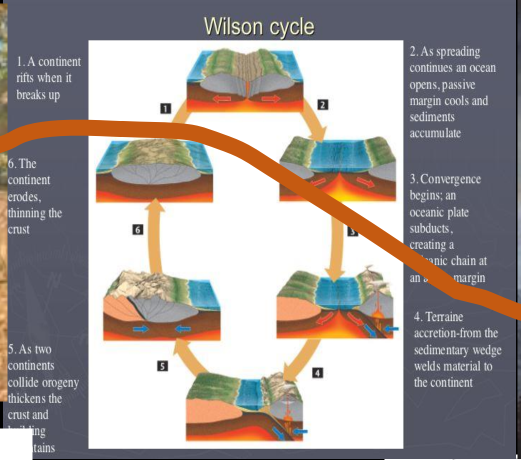


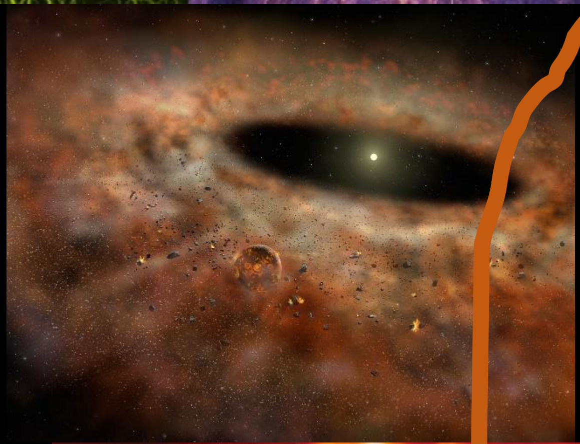
Chicxulub

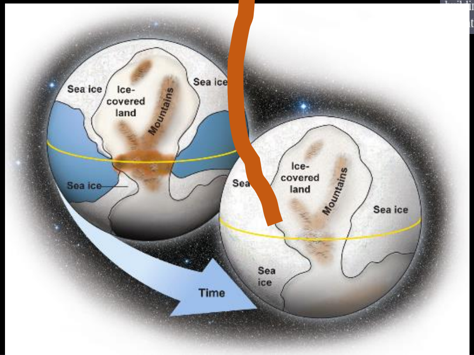


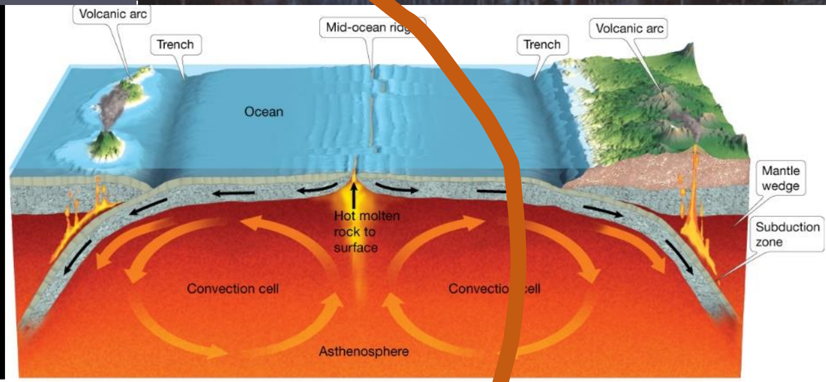


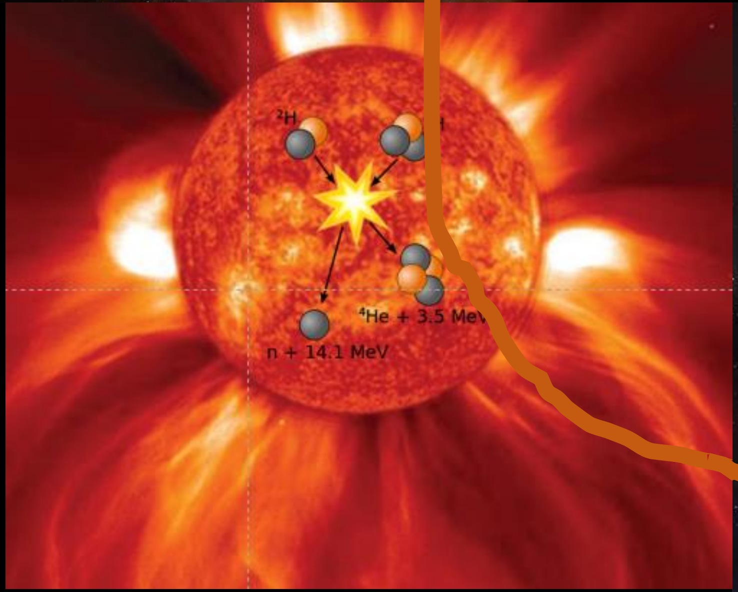


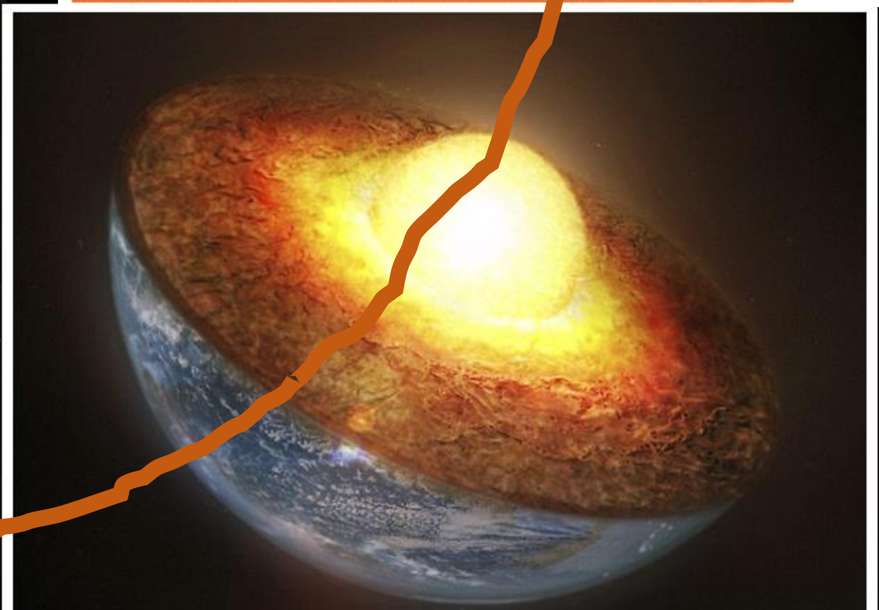

Wilson cycle
1. A continent rifts when it breaks up
2. As spreading continues an ocean opens, passive margin cools and sediments accumulate
3. Convergence begins; an oceanic plate subducts, creating a
4. Terraine accretion-from the sedimentary wedge welds material to the continent
5. As two continents collide orogeny thickens the crust and
6. The continent erodes, thinning the crust
1
2
3
4
5
6




Sea ice
Ice-covered land
Mountains
Sea ice
Sea ice
Time
Sea ice
Ice-covered land
Mountains
Sea ice
Sea ice


Volcanic arc
Trench
Trench
Volcanic arc
Ocean
Mantle wedge
Subduction zone
Hot molten rock to surface
Convection cell
Asthenosphere


^{2}H
^{4}He + 3.5 MeV
n + 14.1 MeV



Barringer Crater

~50,000 years old (Pleistocene)

~2.5 miles circumference

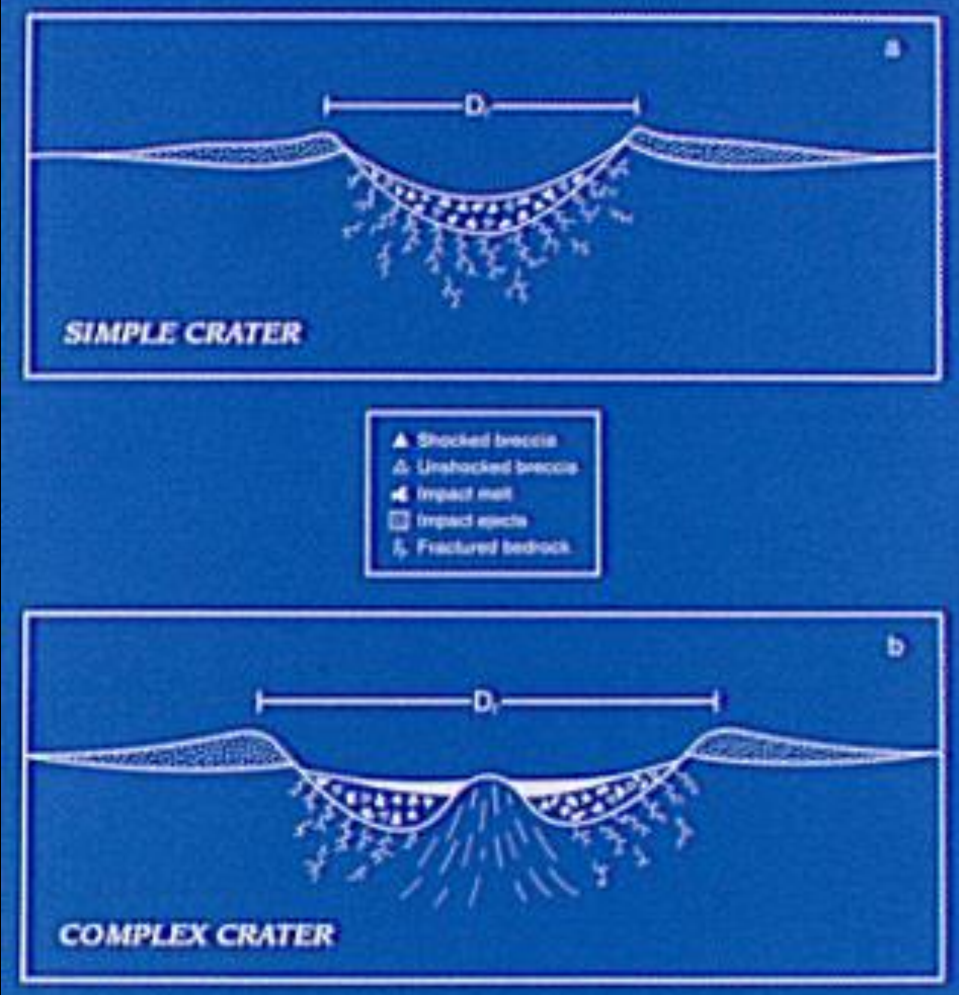
Nickel-iron meteorite ~50 meters in size

Moving @ 8 mps, produced 10 megaton

Geometry of Impact Craters

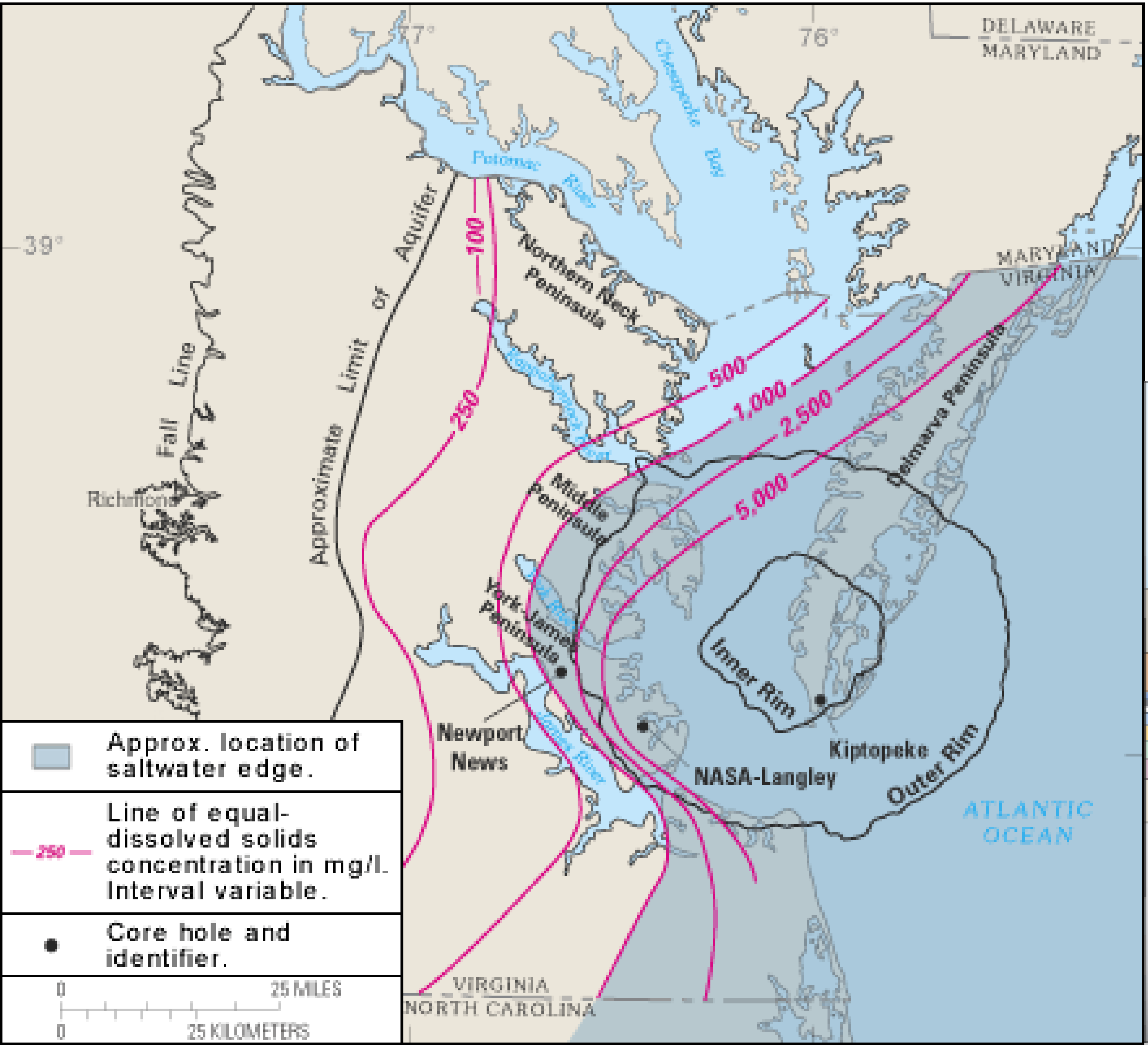
~small impacts make a ‘simple crater’, with concave-up geometry, an ejecta blanket, impact metamorphism of surrounding rock, and tektites (glass)

Impacts larger than 4 km (on Earth) Produce craters with a ‘central peak’ hydrodynamic flow of material lifted by inward-collapsing crater walls, while some impact-shattered debris is briefly turned to fluid by strong vibrations




©2014 Google – Imagery ©2014 NASA, TerraMetrics

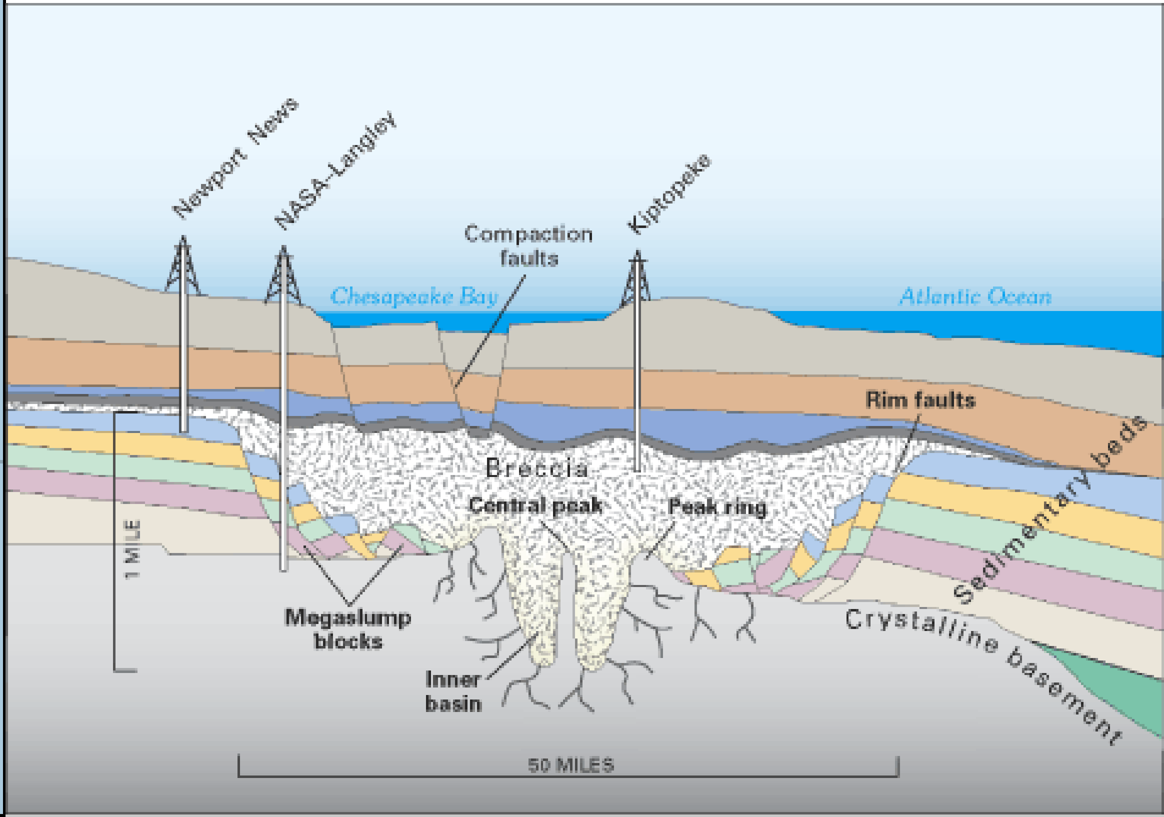
Chesapeake Bay Impact Crater



~35 Ma (Eocene)

~85 miles wide

Discovered while exploring For petroleum



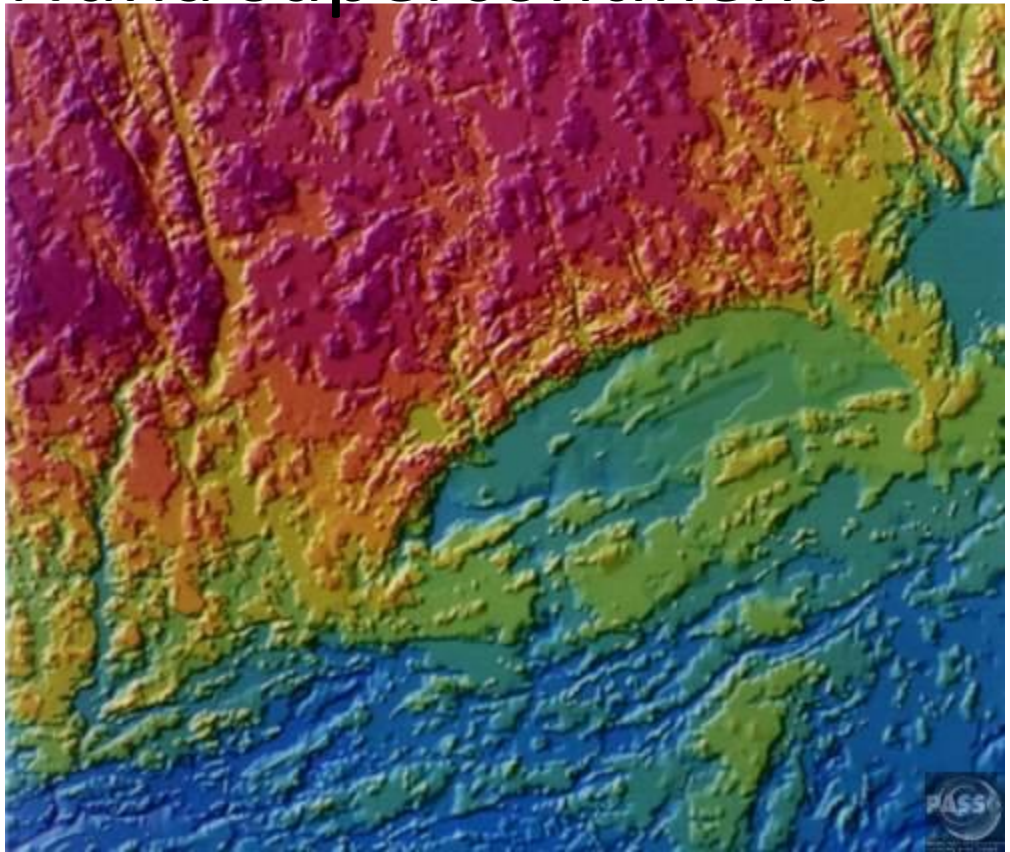
Sudbury Impact Crater

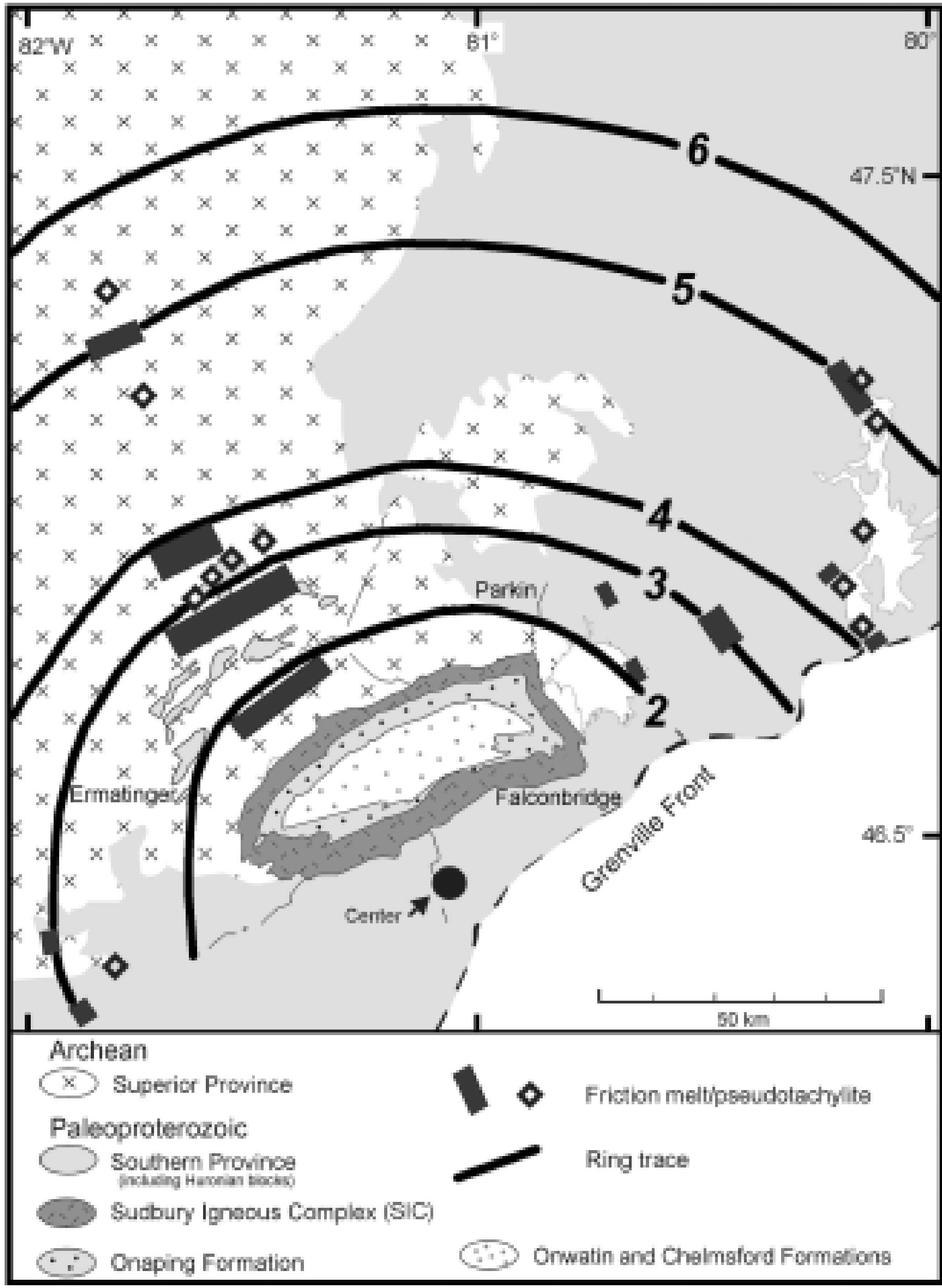
~1.8 Ga (Paleoproterozoic)

~10 miles wide

Flung material into MN & WI

Impacted Nuna supercontinent





Beaverhead Crater (in our backyard!)

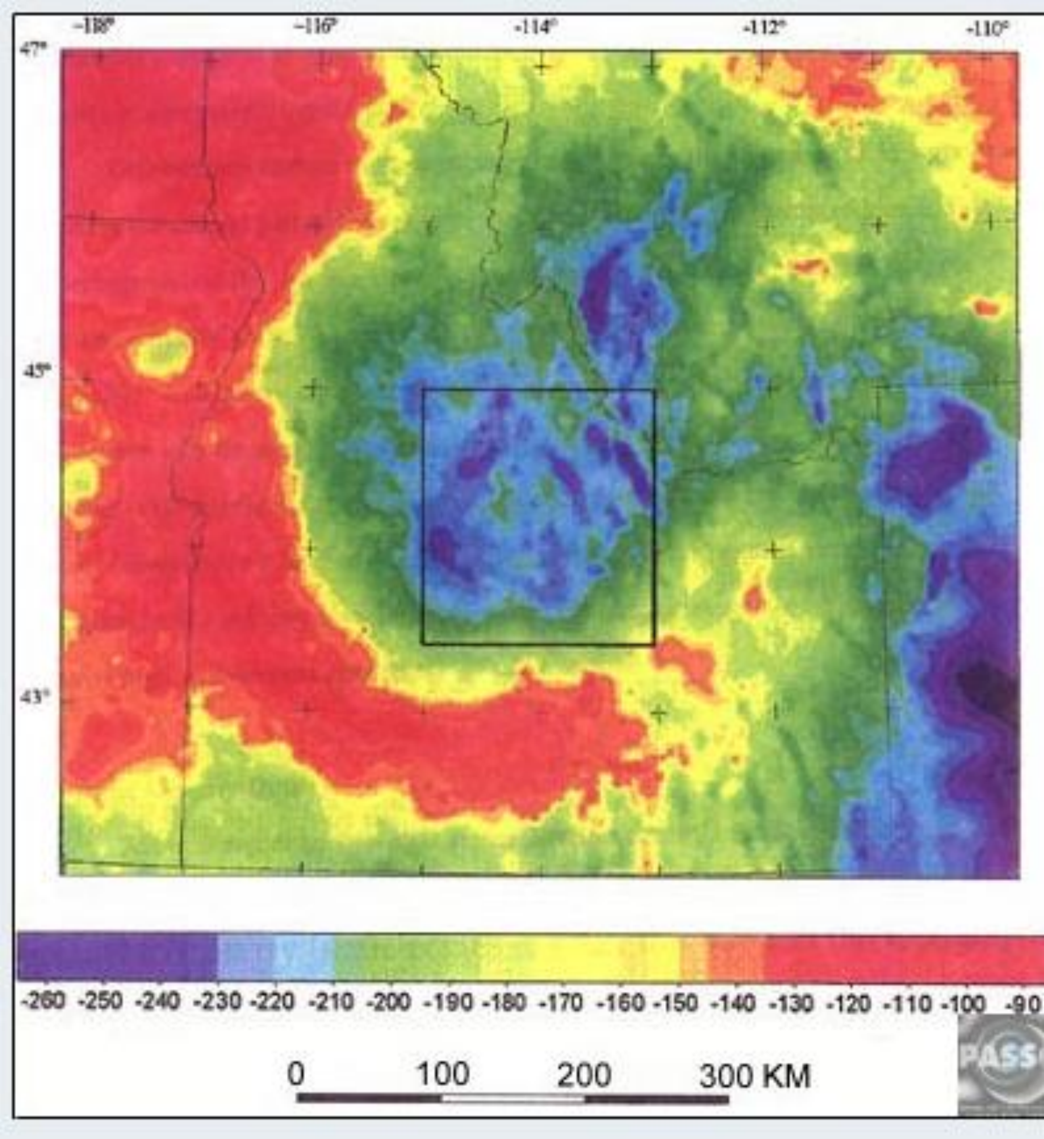
~1.2 Ga (Mesoproterozoic)

Impact thin crust and
triggered a delamination event
To allow mountains to uplift

The Mesoproterozoic Beaverhead Impact Structure and Its Tectonic Setting, Montana-Idaho: $^{40}Ar/^{39}Ar$ and U-Pb Isotopic Constraints

Karl S. Kellogg, Lawrence W. Snee, and Daniel M. Unruh

U.S. Geological Survey, Denver Federal Center, Denver, Colorado 80225, U.S.A.
(e-mail: kkellogg@usgs.gov)



<u>Tunguska Event</u>

1908 (like, ~100 years ago!)

Meteor broke up in ATM and

Did not leave a crater

But a large ‘strewn field’

Leveled forests….

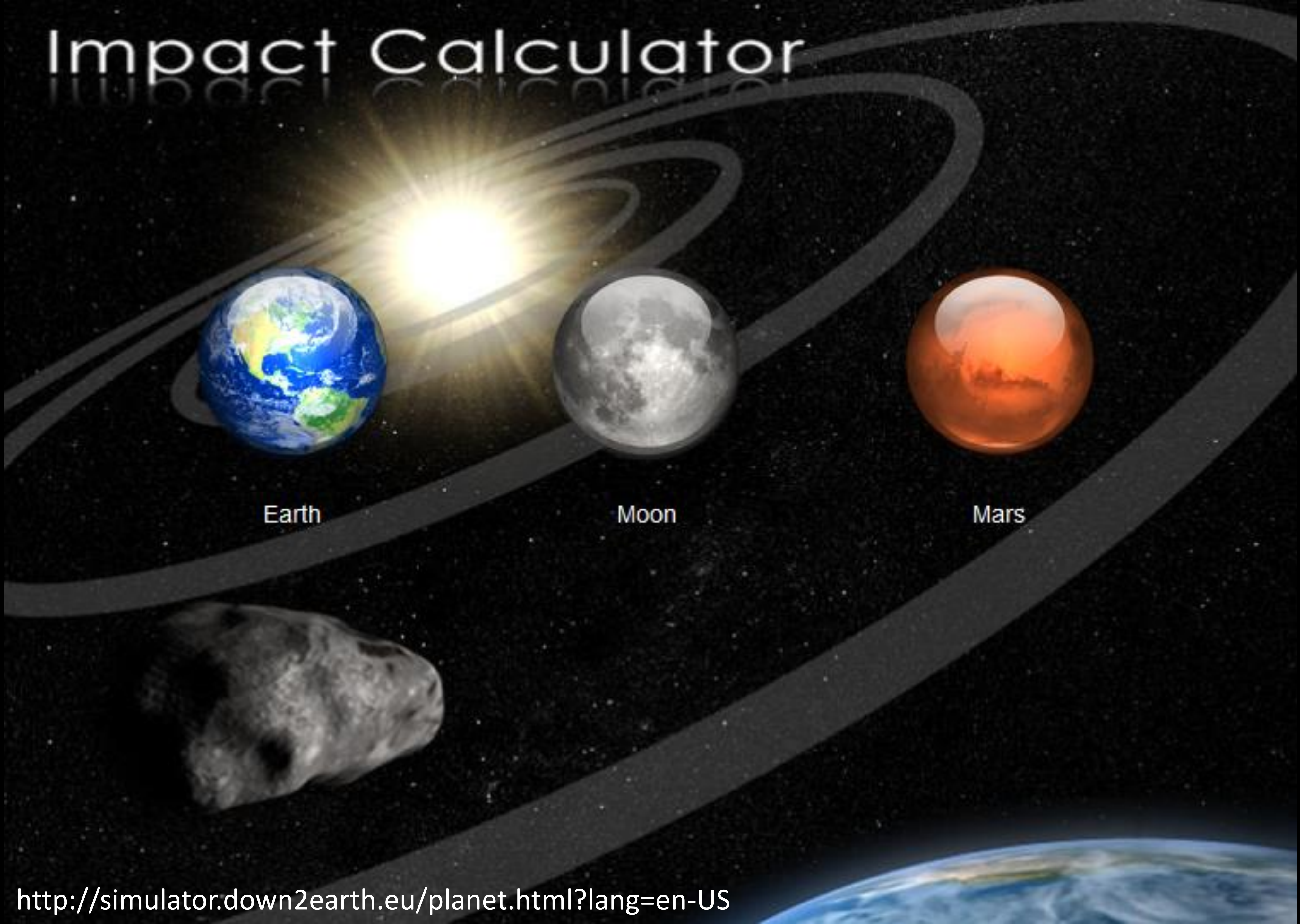
Heard up to a thousand miles away!

Earth Impact Effects Program

Robert Marcus, H. Jay Melosh, and Gareth Collins

http://impact.ese.ic.ac.uk/ImpactEffects/

https://www.purdue.edu/impactearth/



http://simulator.down2earth.eu/planet.html?lang=en-US

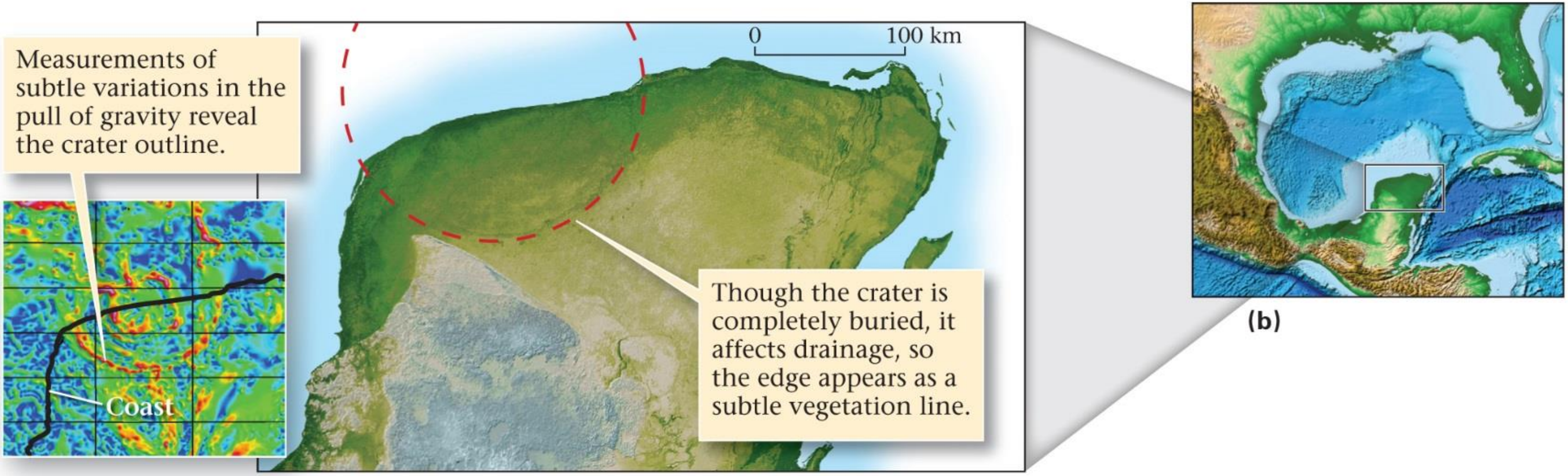
Todays dose of violence brought to you by…

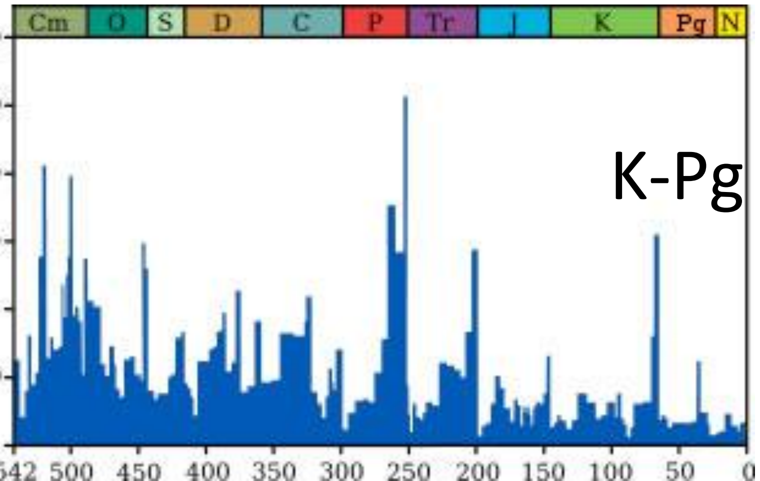
Lecture 2:

Now we get the main attraction, one of the most famous impacts of all time… one that caused a chan reaction on earth ending in what we today call a MASS EXTINCTION!!

Yes, the Dino Killing asteroid… the Chixilub Impact Crater as evidence…

5. Space Debris Returns: Asteroid Impacts



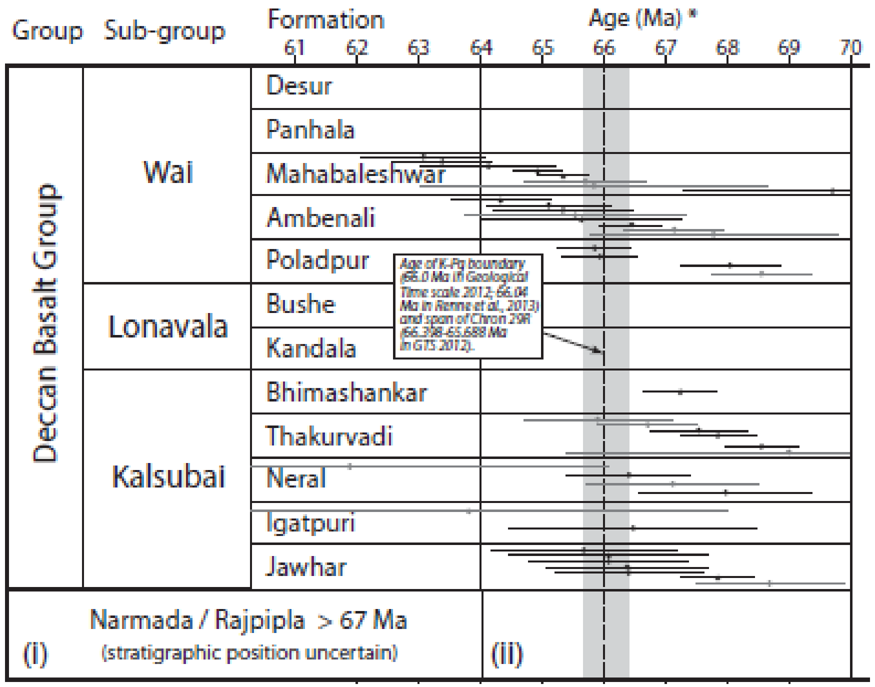


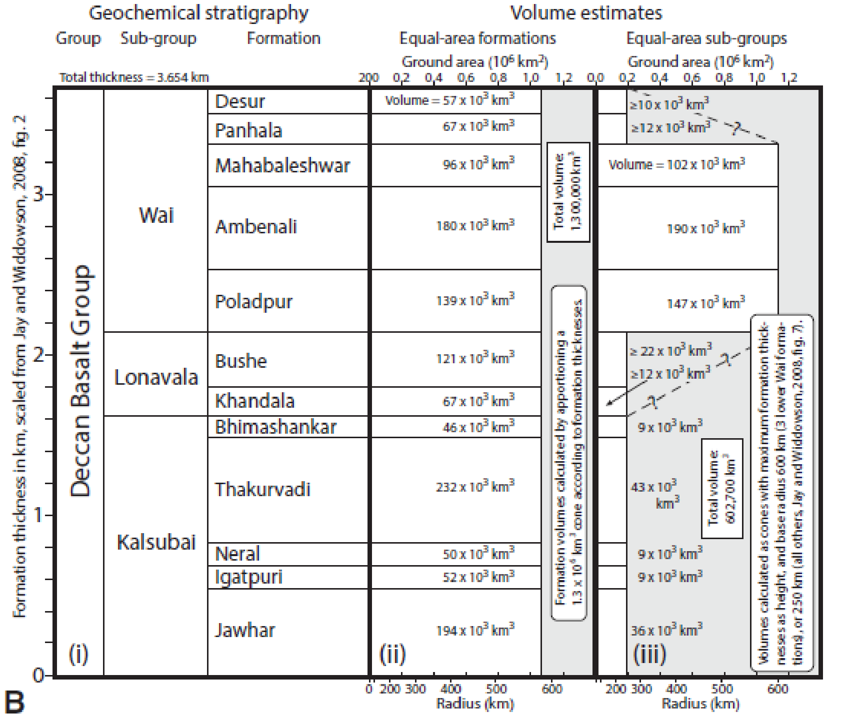
K-Pg

K-Pg Mass Extinction
“End of Dinosaurs”

Triggering of the largest Deccan eruptions by the Chicxulub impact

Mark A. Richards[1,†], Walter Alvarez[1,2], Stephen Self[1], Leif Karlstrom[3], Paul R. Renne[1,4], Michael Manga[1], Courtney J. Sprain,[1,4] Jan Smit,[2,5] Loÿc Vanderkluysen[6], and Sally A. Gibson[7]
[1]Department of Earth and Planetary Science, University of California, Berkeley, California 94720, USA
[2]Osservatorio Geologico di Coldigioco, Contrada Coldigioco 4, 62021 Apiro (MC), Italy
[3]Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403, USA
[4]Berkeley Geochronology Center, Berkeley, California 94709, USA
[5]Department of Sedimentary Geology, Vrije Universeit, De Boelelaan 1085, 1081 HV Amsterdam, Netherlands
[6]Department of Biodiversity, Earth and Environmental Science, Drexel University, Philadelphia, Pennsylvania 19104, USA
[7]Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, UK





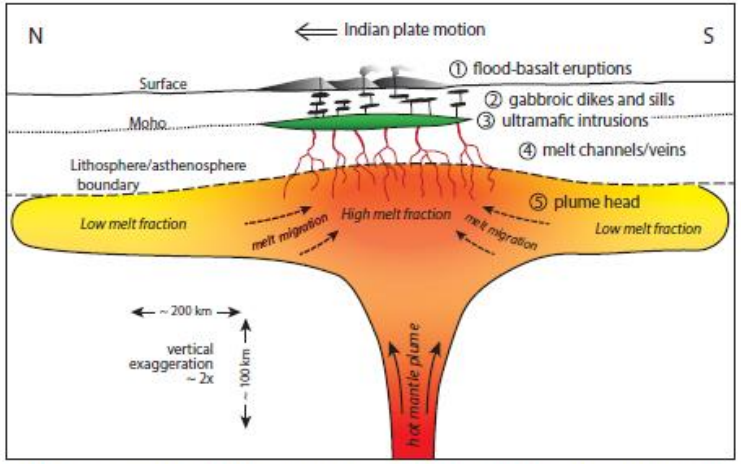
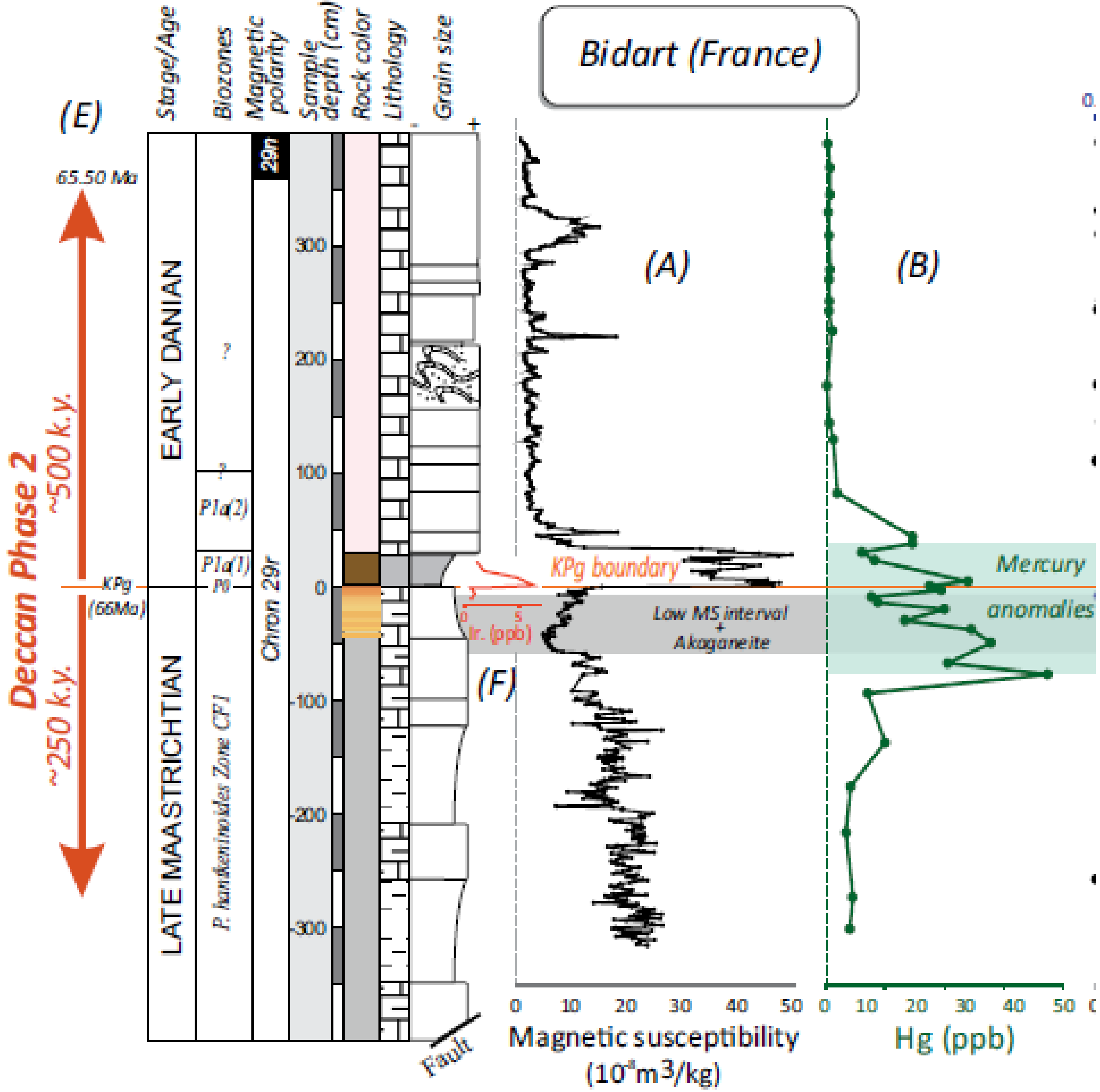


Figure 5. Cross-sectional diagram of the Deccan plume head melting beneath the Indian subcontinent. Magma transport regimes 1–5 described in text.



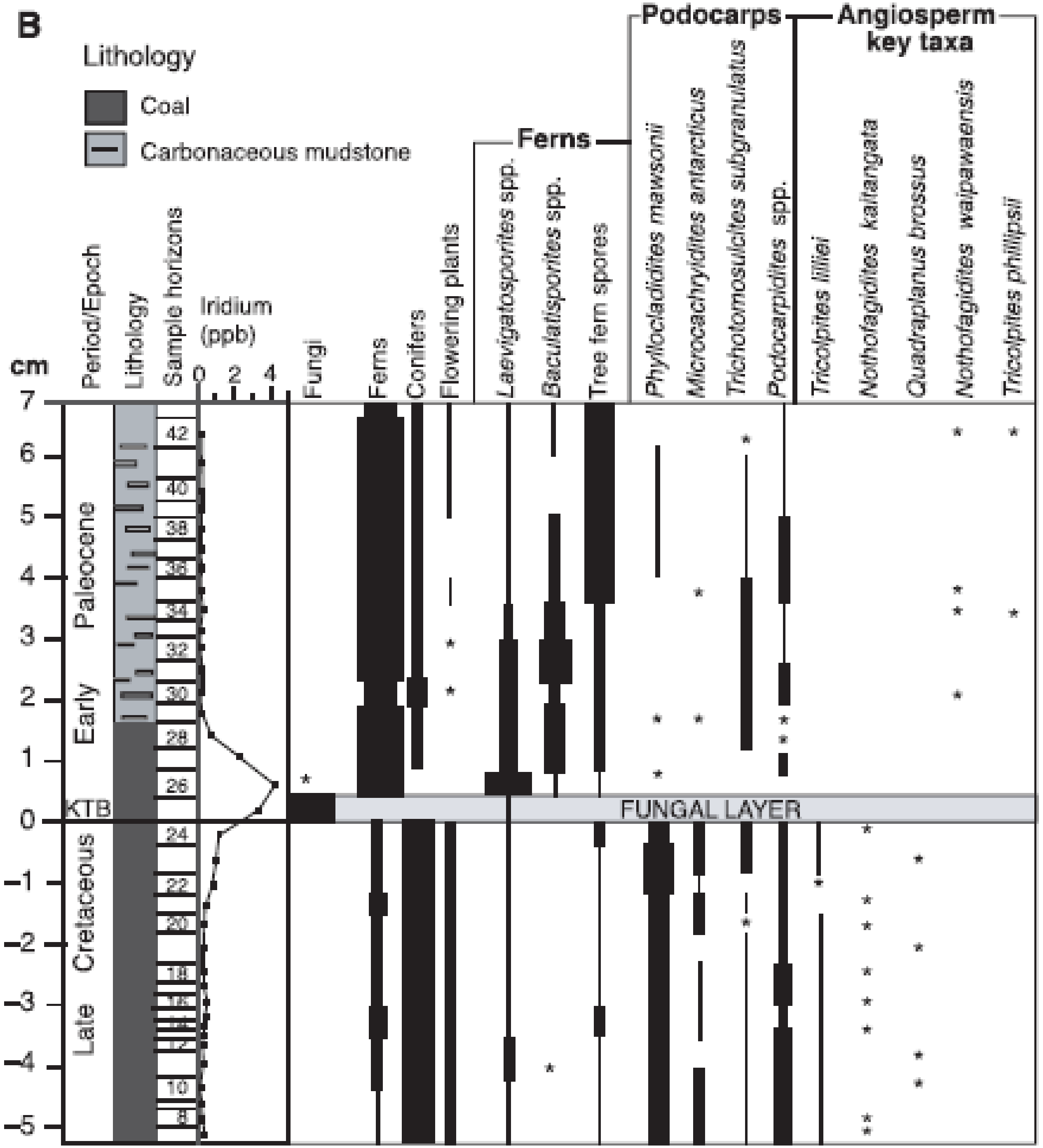
Bidart (France)
(E)
Stage/Age
Biozones
Magnetic polarity
Sample depth (cm)
Rock color
Lithology
Grain size
65.50 Ma
Deccan Phase 2
~500 k.y.
~250 k.y.
EARLY DANIAN
LATE MAASTRICHTIAN
KPg
(66Ma)
P1a(2)
P1a(1)
P0
P. hantkeninoides Zone CF1
29n
Chron 29r
300
200
100
0
-100
-200
-300
Fault
(A)
(B)
(F)
KPg boundary
Ir. (ppb)
Low MS interval + Akaganeite
Mercury anomalies
0 10 20 30 40 50
Magnetic susceptibility
(10⁻⁸m3/kg)
0 10 20 30 40 50
Hg (ppb)

Deccan Traps
India
Arabian Sea
Bay of Bengal

After?

Fungal Proliferation at the Cretaceous-Tertiary Boundary

Vivi Vajda[1] and Stephen McLoughlin[2]



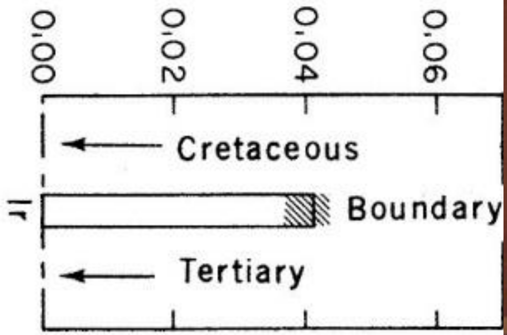
Science, 1980

Extraterrestrial Cause for the Cretaceous-Tertiary Extinction

Experimental results and theoretical interpretation

Luis W. Alvarez, Walter Alvarez, Frank Asaro, Helen V. Michel

Iridium is a naturally occurring element of the platinum group, but is extremely rare in the crust. High concentrations are found in meteors, which led to the ET hypothesis.

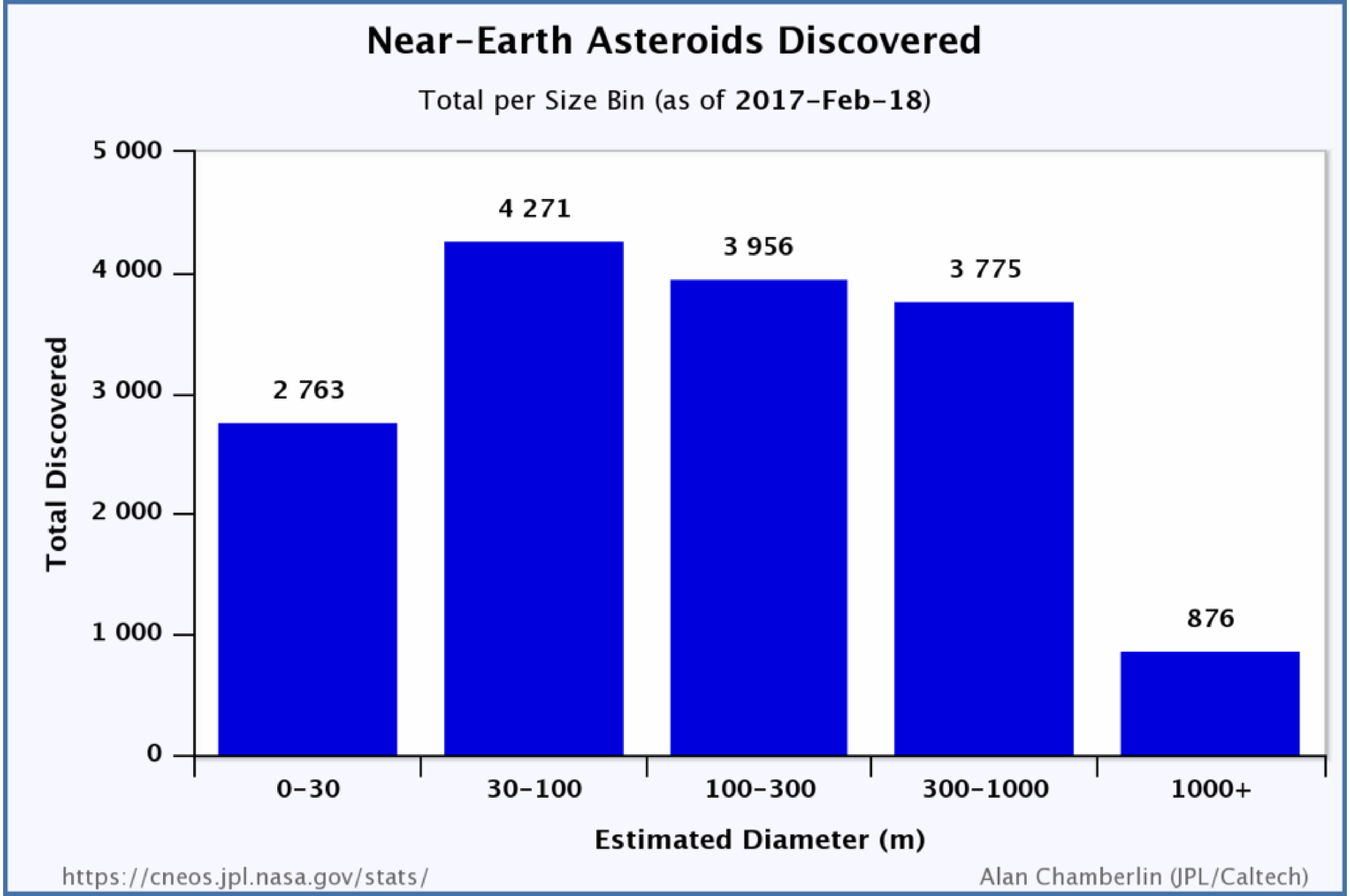


Contains ~1000 times
More iridium that
Surrounding layers

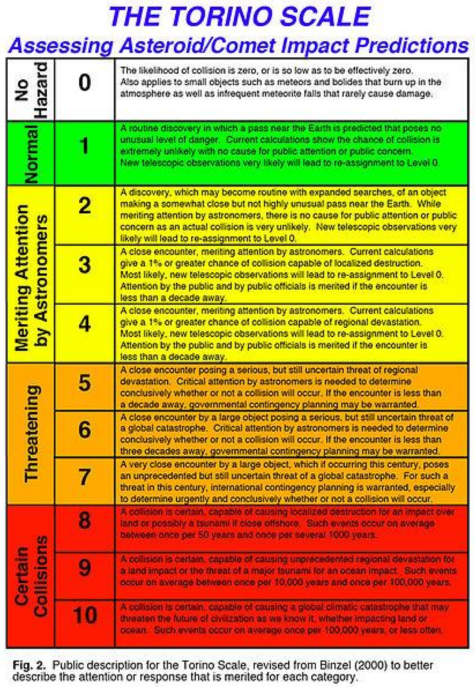
https://www.youtube.com/watch?v=YRDpPeKc-ZE

DOOM Video

https://www.youtube.com/watch?v=5qJPTjMnwNk


Near-Earth Asteroids Discovered
Total per Size Bin (as of 2017-Feb-18)
Total Discovered
5 000
4 000
3 000
2 000
1 000
0
2 763
4 271
3 956
3 775
876
0-30
30-100
100-300
300-1000
1000+
Estimated Diameter (m)
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)

Torino Scale-

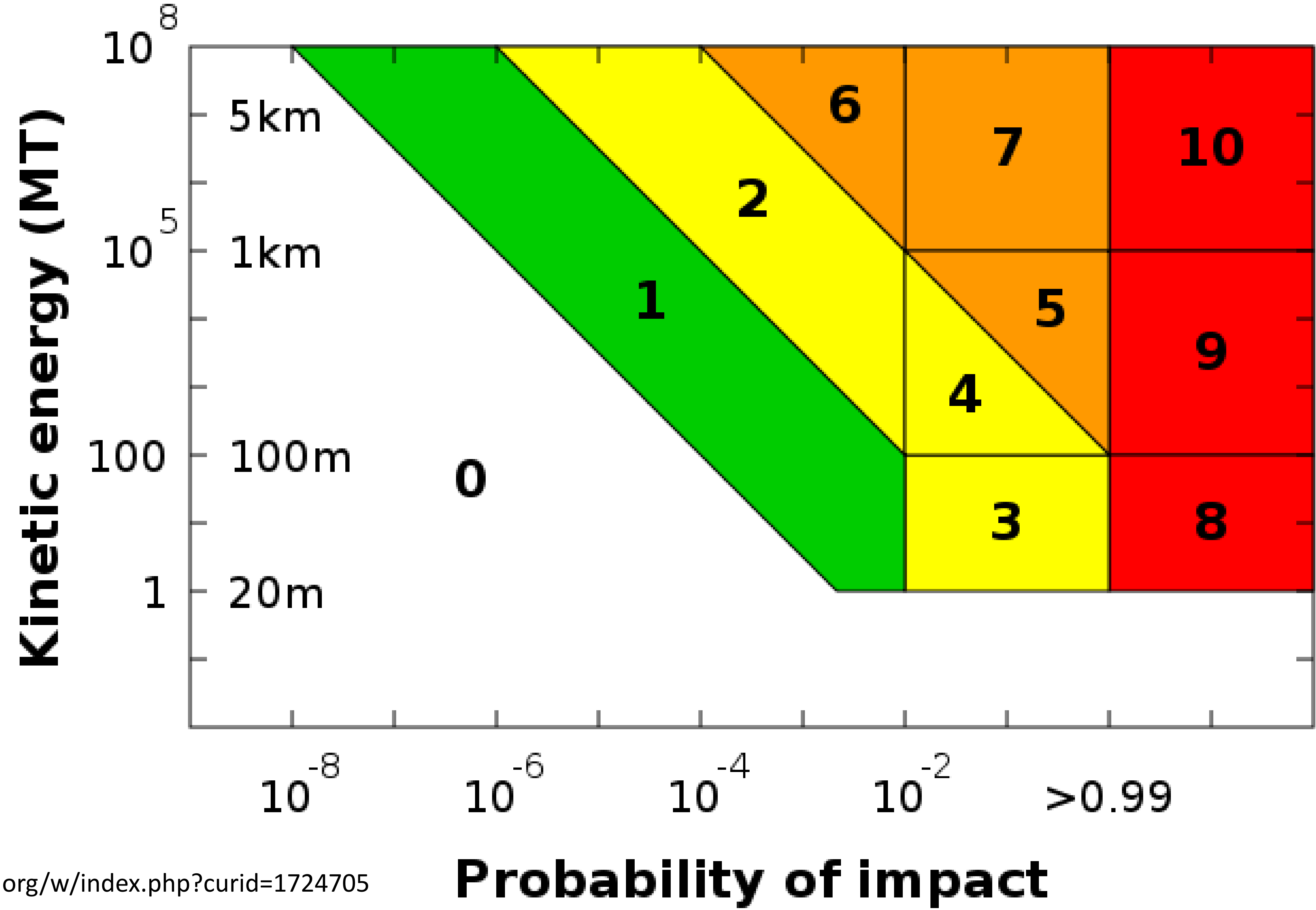


THE TORINO SCALE

Assessing Asteroid/Comet Impact Predictions

No Hazard	0	The likelihood of collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bolides that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal	1	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers	2	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.
	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
Threatening	5	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious, but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
	10	A collision is certain, capable of causing a global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Fig. 2. Public description for the Torino Scale, revised from Binzel (2000) to better describe the attention or response that is merited for each category.



Meriting Attention by Astronomers		less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
Threatening	5	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious, but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
	10	A collision is certain, capable of causing a global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Fig. 2. Public description for the Torino Scale, revised from Binzel (2000) to better describe the attention or response that is merited for each category.

THE TORINO SCALE

Assessing Asteroid/Comet Impact Predictions

No Hazard	0	The likelihood of collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bolides that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal	1	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers	2	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.
	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
Threatening	5	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious, but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
	10	A collision is certain, capable of causing a global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Fig. 2. Public description for the Torino Scale, revised from Binzel (2000) to better describe the attention or response that is merited for each category.

Todays dose of violence brought to you by…

This photo shows from left Helen Michel, Frank Asaro, Walter Alvarez and Luis Alvarez, co-authors of a seminal paper in 1980 on what killed the dinosaurs.