

Title: Death of the Dinos: Giant Impacts and Biological Crises

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Abstract: Sixty-five million years ago dinosaurs ruled the warm Cretaceous Earth. Without warning, this world was swept away forever by the impact of an asteroid about 15 km in diameter, leaving a huge scar now called the Chicxulub crater in Yucatan, Mexico. This catastrophe set the stage for the ascendance of our own biological group, the mammals. Although the fact of this impact is now established beyond doubt, the precise means by which an impact could wipe out such a large fraction of the Earth's inhabitants is not fully understood. Recent study of the physical consequences of a large impact on the Earth have revealed a plethora of potentially disastrous effects, ranging from an immediate firestorm that ignited global wildfires to sulfuric acid aerosols, acid rain, and ozone depletion lasting decades. The extinctions caused by these physical traumas changed the way that the Earth's biosphere recycles carbon, leading to climatic changes lasting nearly a million years longer. Although no other major extinction in the past 500 million years can yet be tied unambiguously to an extraterrestrial impact, there is geological evidence of even larger impacts farther back in Earth's history, including the one that created the Sudbury ore body in Ontario more than a billion years ago. Concerns over the future possibility of such large impacts have led to a worldwide program to identify potentially threatening asteroids and has generated discussion of what humans might do to deflect such an asteroid if it is found. <kw>death of dinosaurs, mass extinction, extinction, dinosaurs, asteroid impact, asteroid impact effects, Jay Melosh, Cretaceous period, Chicxulub crater, 65 million years ago, large impacts, dinosaur, giant impacts, Walter Alvarez, thin layer of red clay, Jan Smit, KT boundary, iridium layer, spherules, microtektites, geology, Geologic history, distal ejecta, Apophis, large extraterrestrial bodies, plate tectonics, Cretaceous-Tertiary Boundary, twinning, Yucatan, Gulf of Mexico, fern, shocked quartz, soot, ozone depletion, acid rain, two-layer, thermal radiation, depletion of CO2</kw>

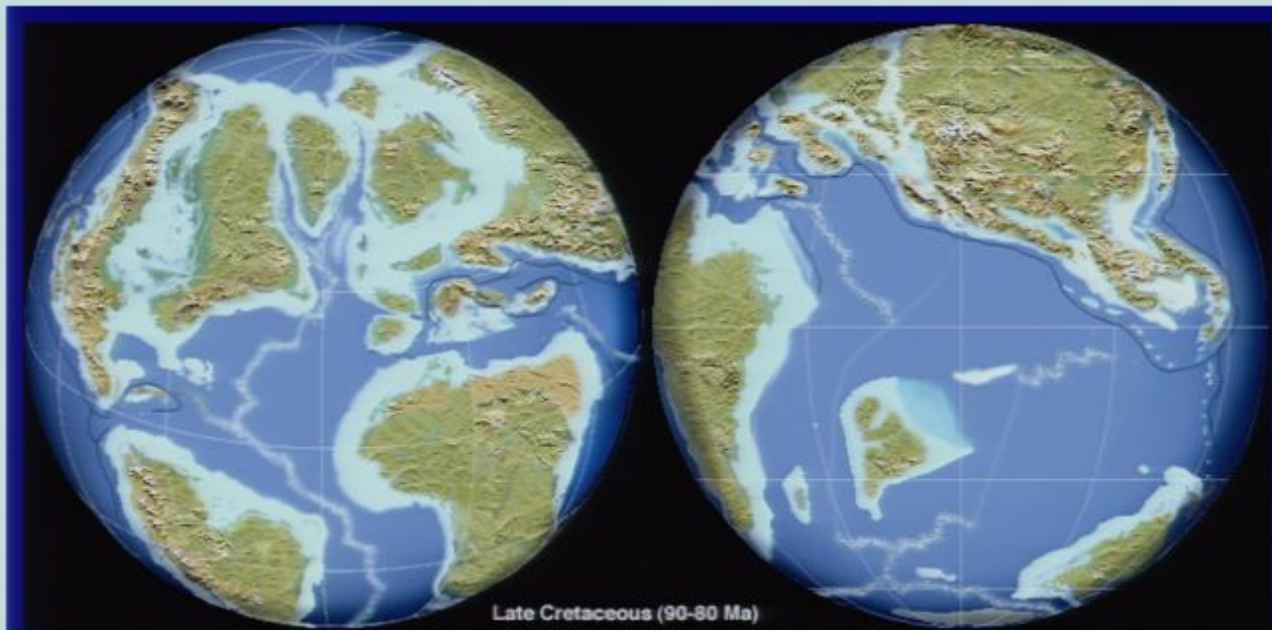
Death of the Dinosaurs: Giant Impacts and Biological Crises

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University of Arizona

Waterloo, 6 June 2007

65 Million years ago the world was a very different place...



The world was warm, there was no ice at the poles, and sea level was high. The seas were filled with strange creatures



The continents were covered with dense tropical forests and dinosaurs roamed the land



Flowering plants had just evolved, but grasses were still far in the future. A few birds took to the air, but the skies were dominated by flying reptiles



This world had evolved gradually over more than 100 Million years, but things were about to change suddenly...



The idea that an asteroid or comet impact wiped out the dinosaurs is relatively new.

Older ideas ran the gamut from climate change to inadequate pituitary glands.

The big breakthrough came in 1980 from a group led by Walter Alvarez at Berkeley, CA



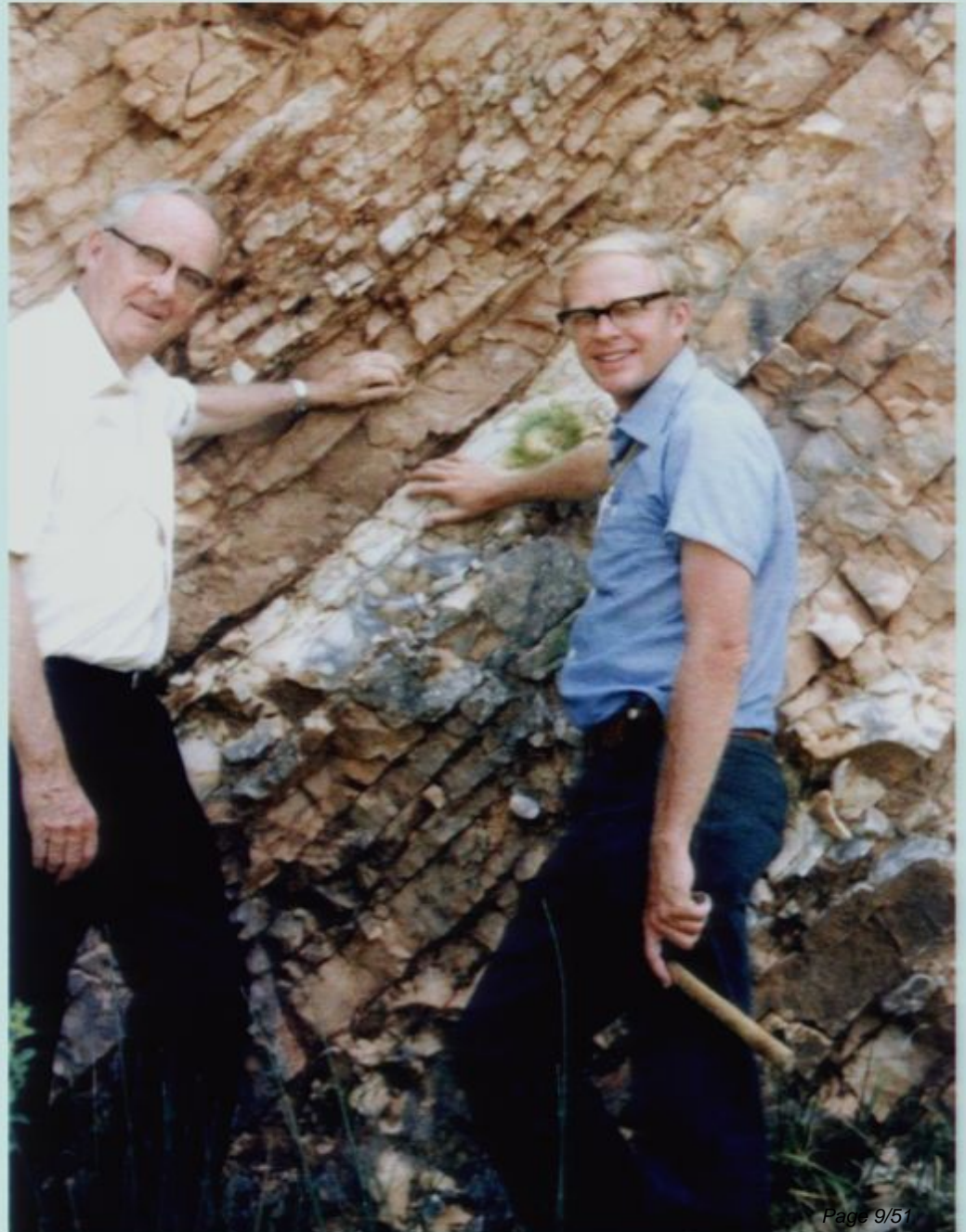
Helen Michel

Frank Asaro

Walter Alvarez

Luis Alvarez

Walter focused on a very thin layer of clay from rocks laid down in deep water in what is now central Italy.



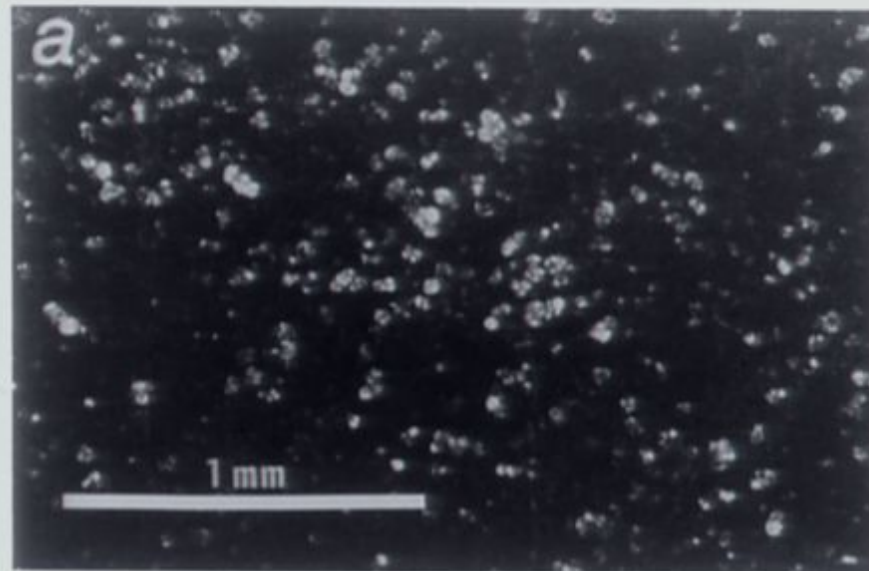
Thin as this
layer is, it
separates the
Cretaceous
world from our
modern,
mammal-
dominated
world



The Alvarez group was not alone. Jan Smit, working in Tunisia, made the same proposal at about the same time

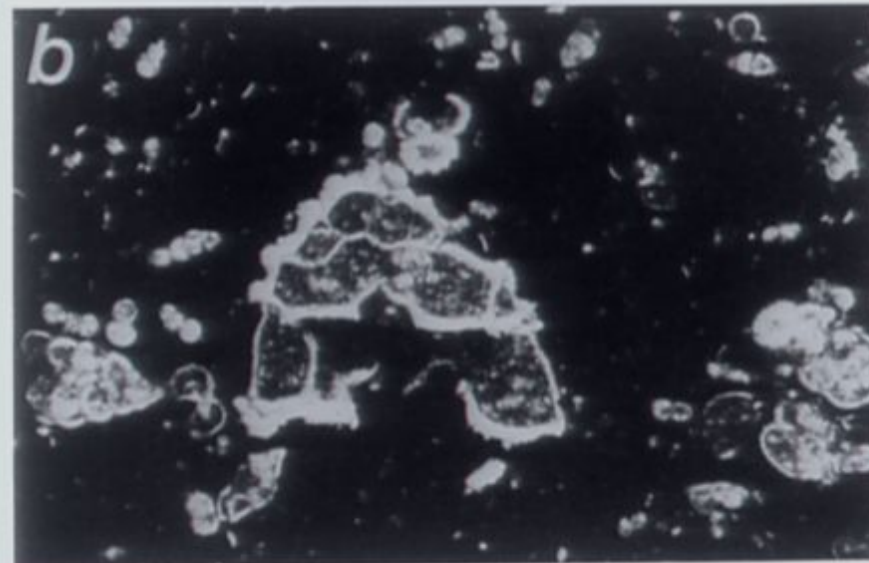


Both groups
found a
profound
change in the
small oceanic
organisms
across the K/T
boundary



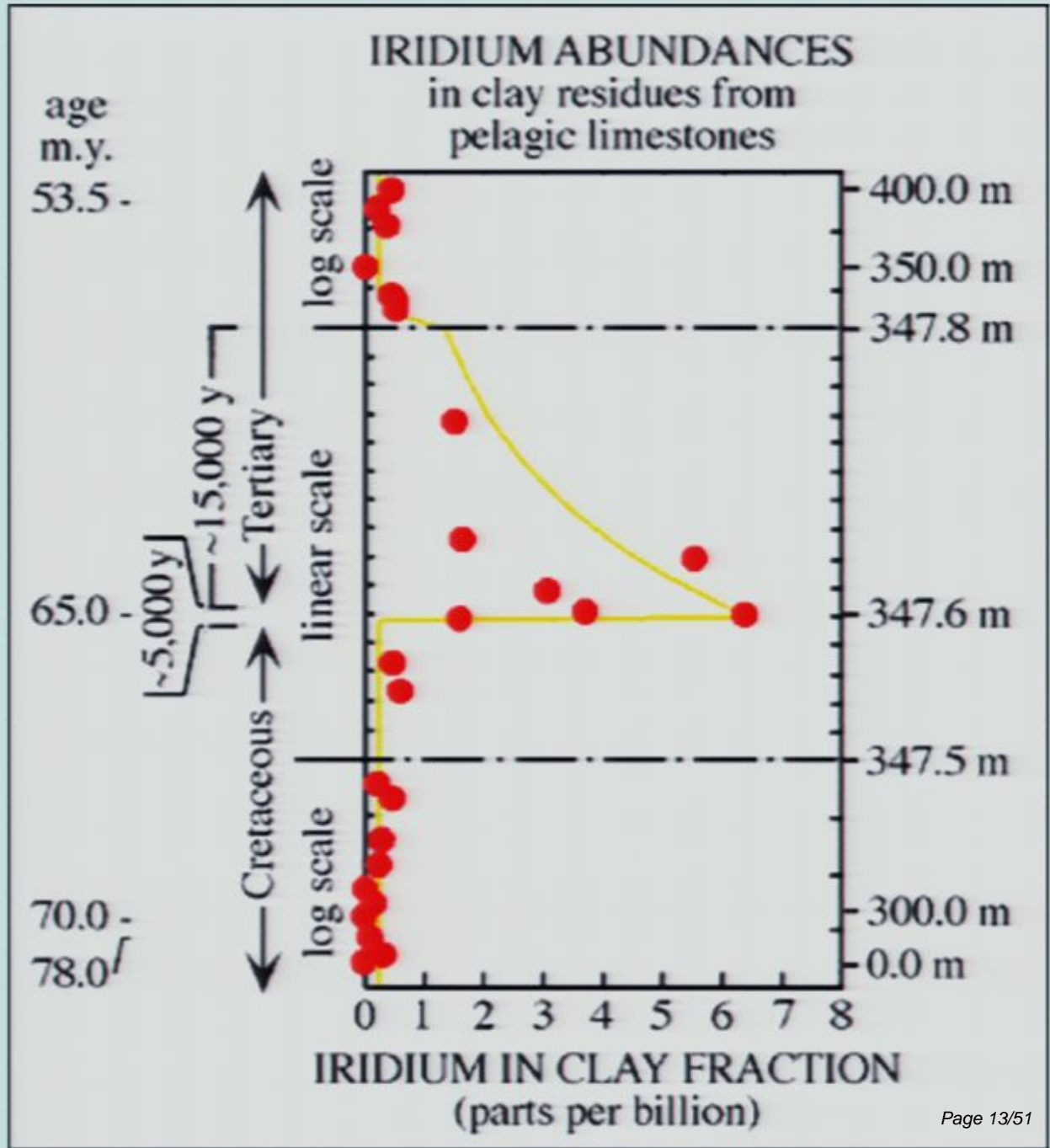
Tertiary

Photomicrographs from the Bottaccione Section at Gubbio of (a) the basal bed of the Tertiary, showing Globigerina eugubina, and (b) the top bed of the Cretaceous, in which the largest foraminifer is Globotruncana contusa.



Cretaceous

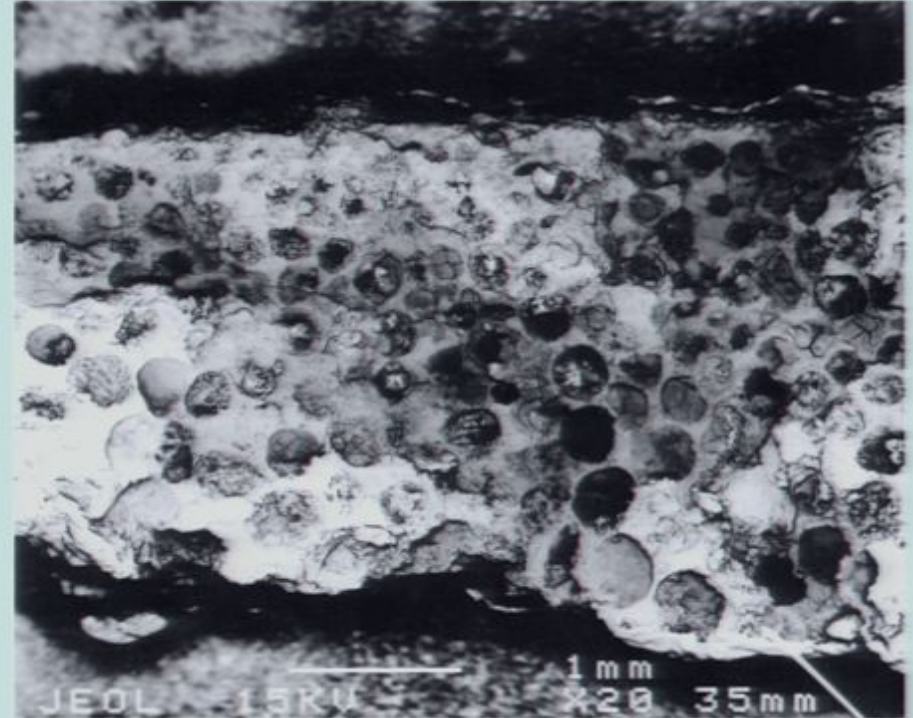
Right at the boundary, they found an enrichment in the rare element Iridium--a strong indication of asteroid impact



Soon, other sites were found from land locations and the boundary, where well preserved, was full of tiny spherules--microtektites

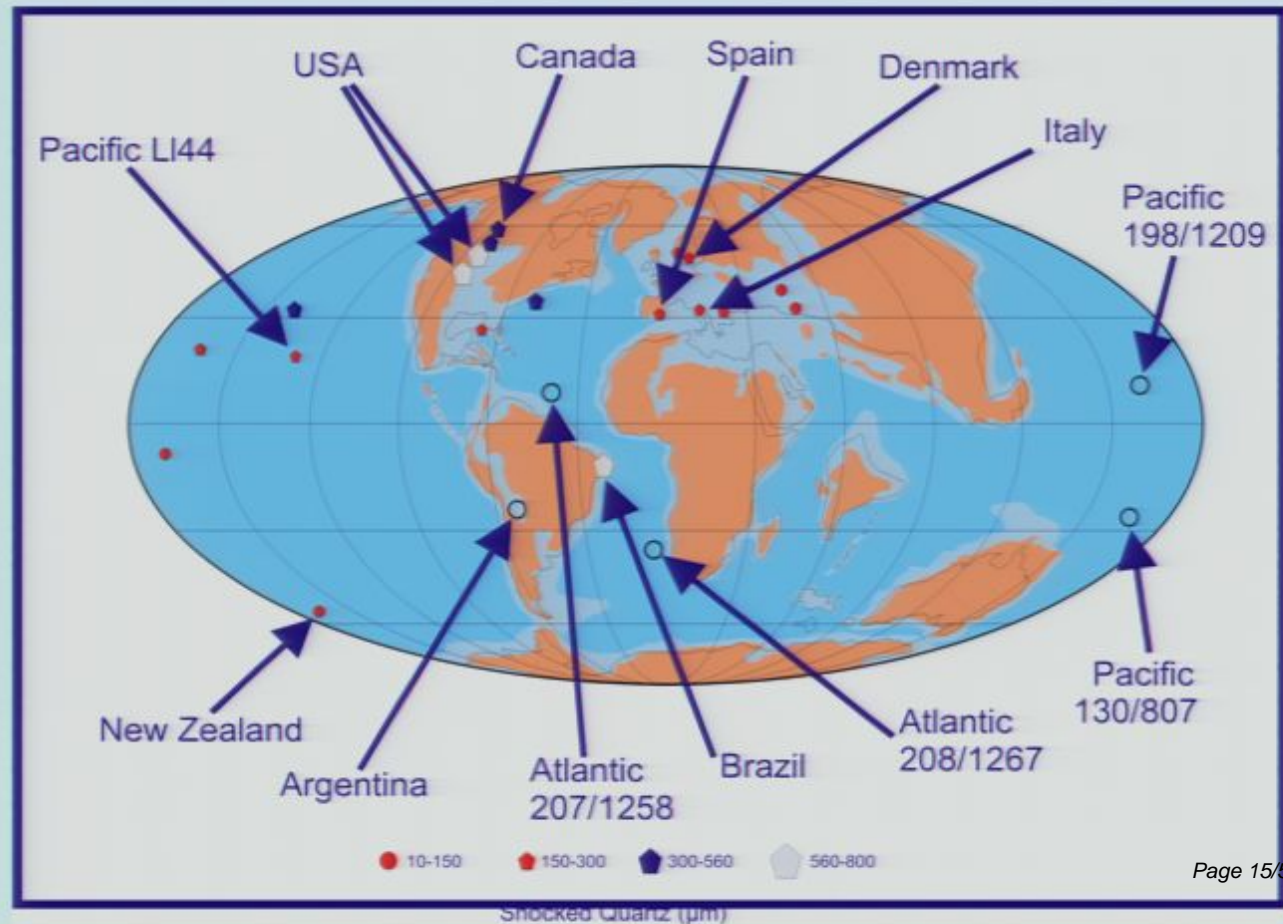
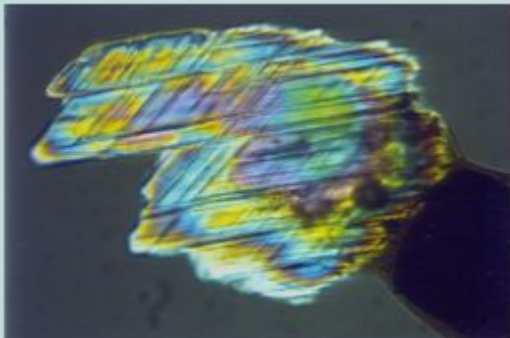
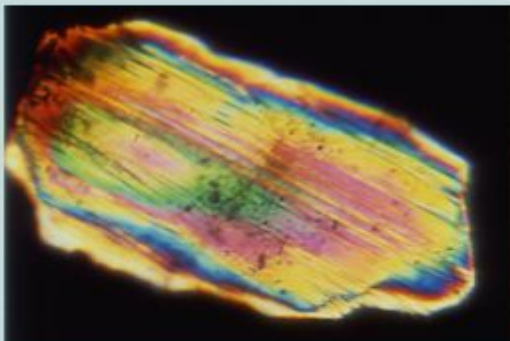


Raton, Colorado

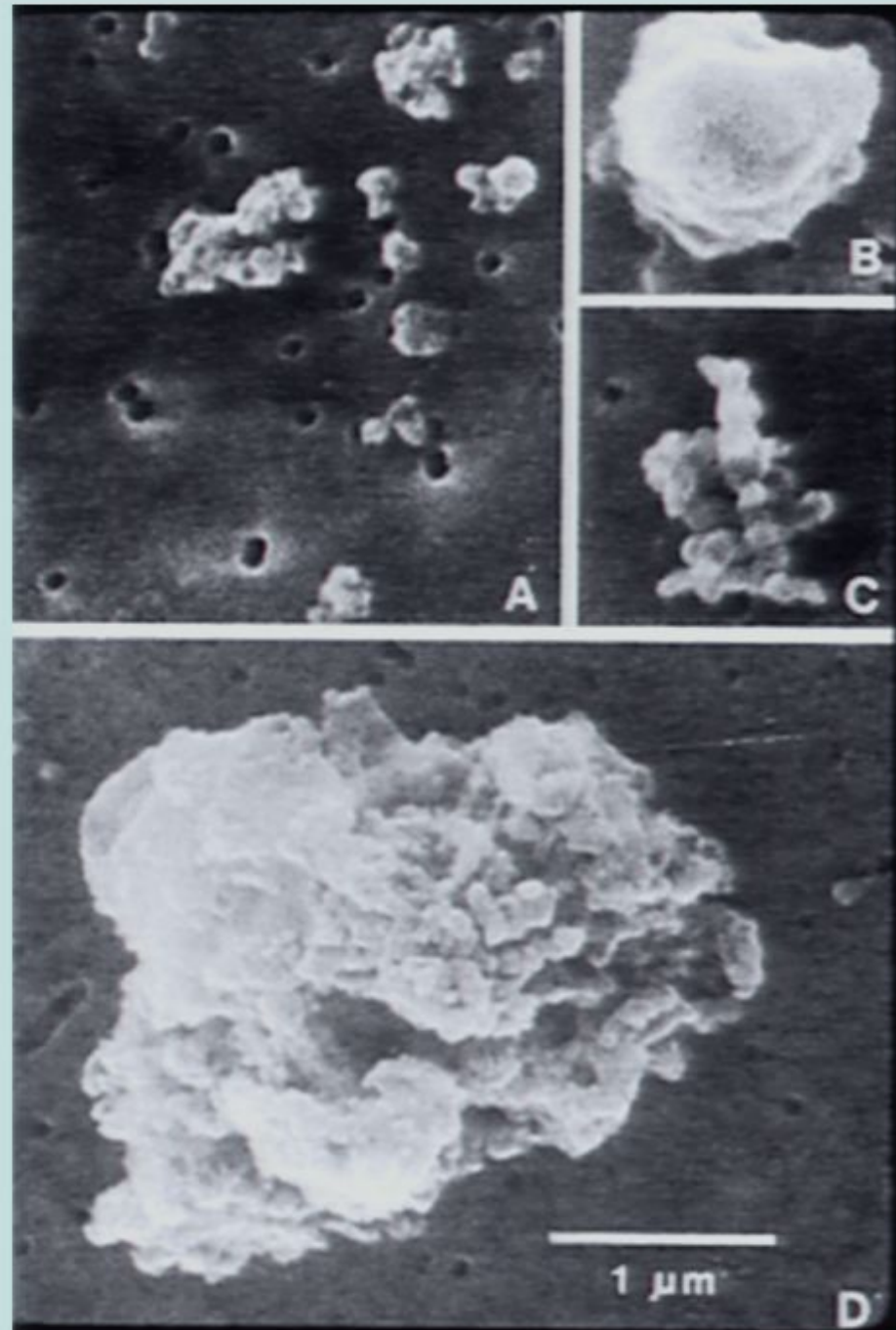


Caravaca, Spain

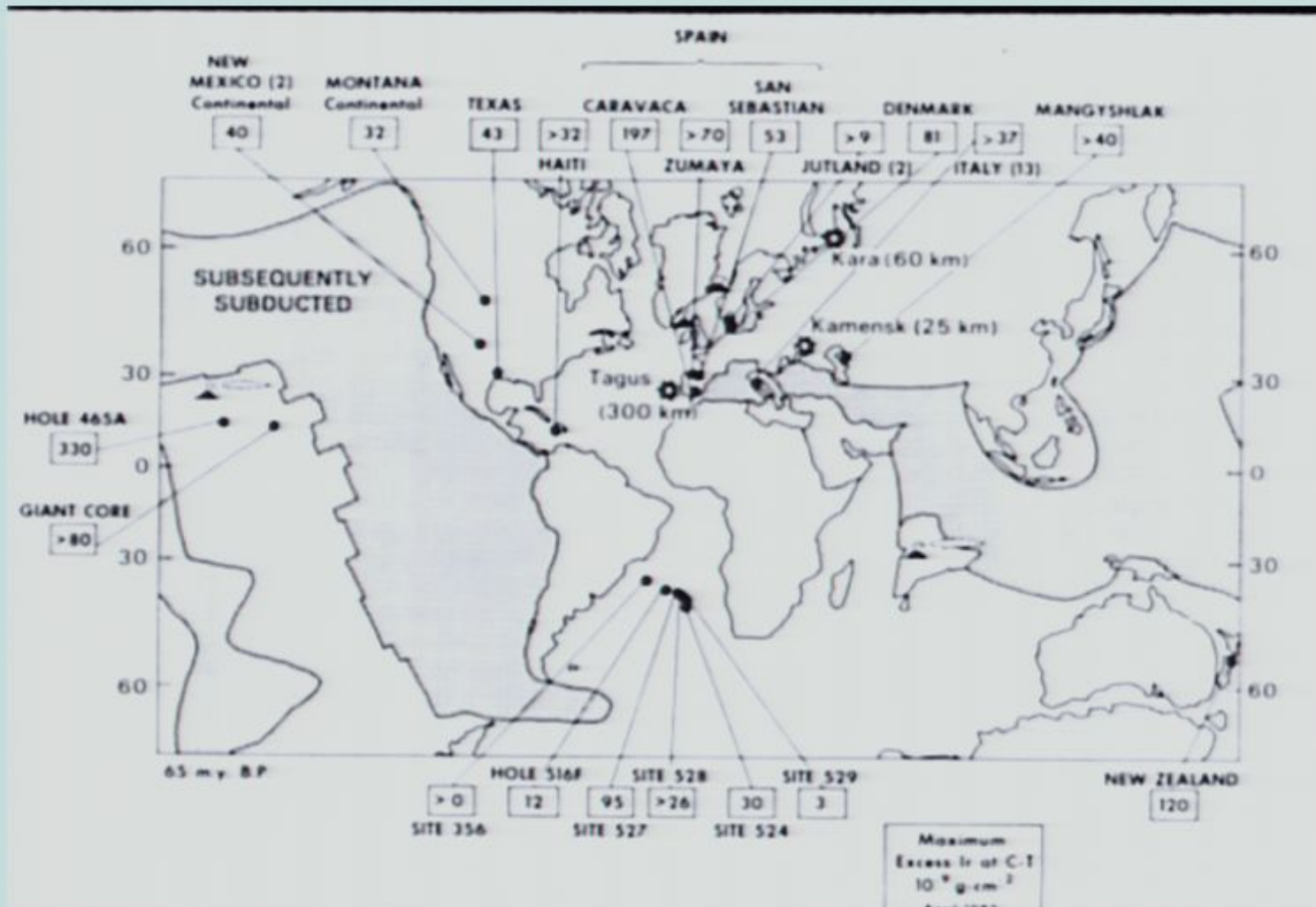
Both shocked quartz, another indicator of impact, and iridium are now found at hundreds of sites worldwide, all located exactly at the extinction horizon



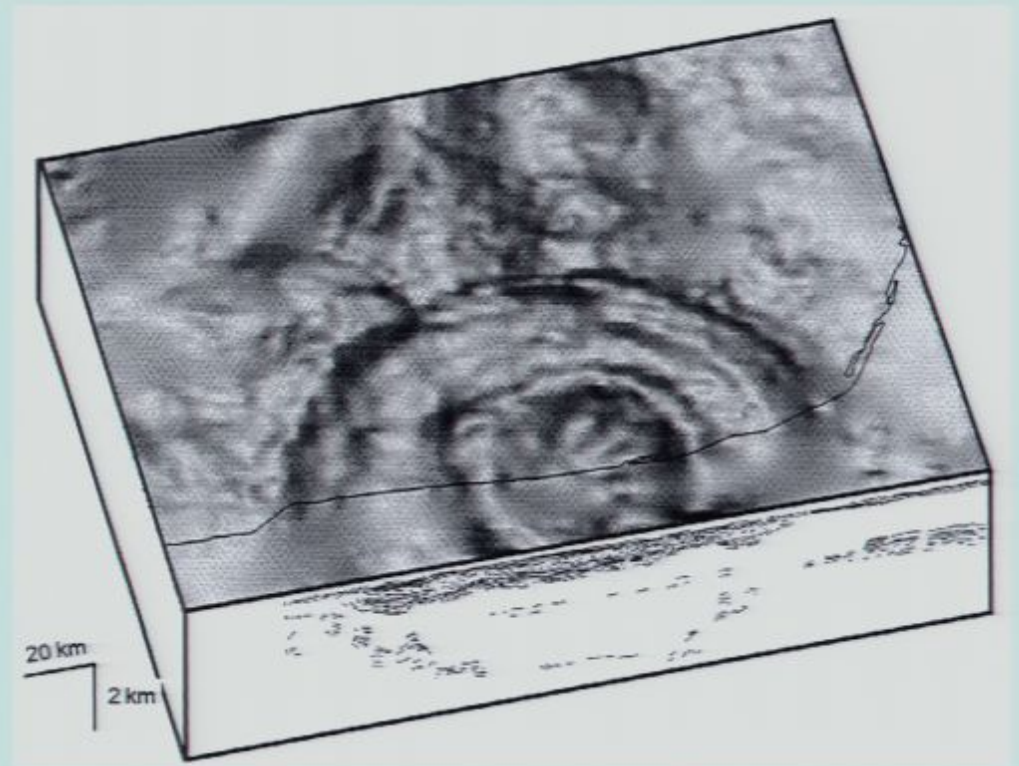
The boundary
clay also
contains
massive
amounts of soot,
indicating global
wildfires



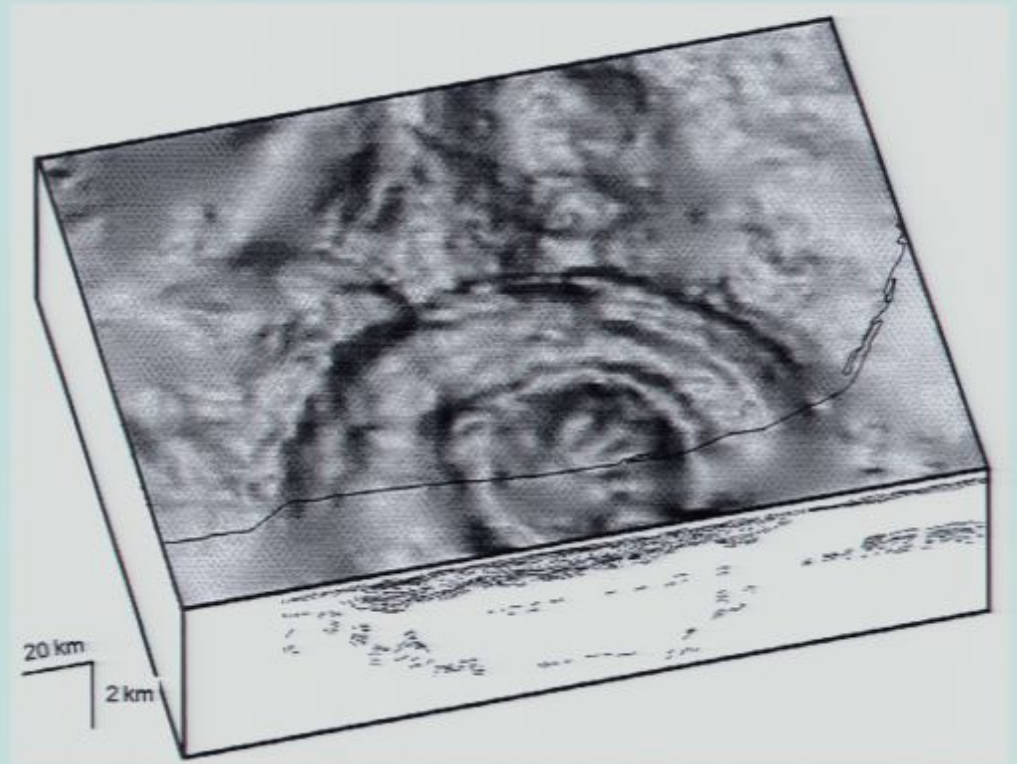
But if the extinction was caused by a big impact, where is the crater? It took a 10 year search until it was finally found--in Yucatán!



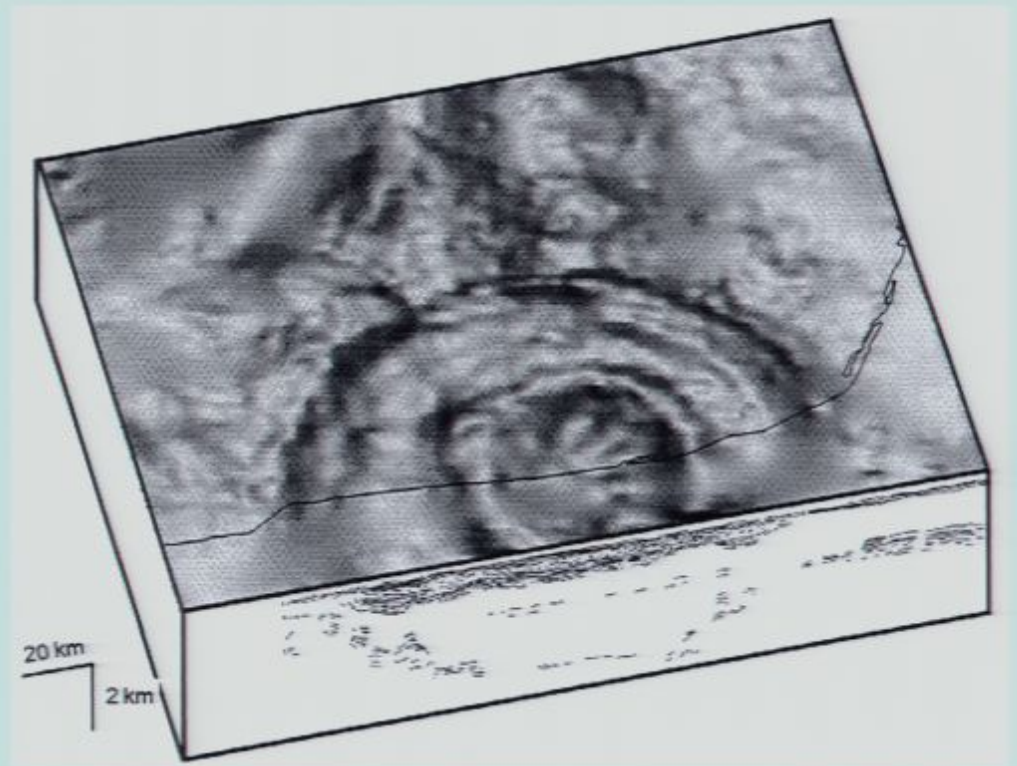
Buried beneath 1 km of younger rocks, the crater is now known as Chicxulub



Buried beneath 1 km of younger rocks, the crater is now known as Chicxulub

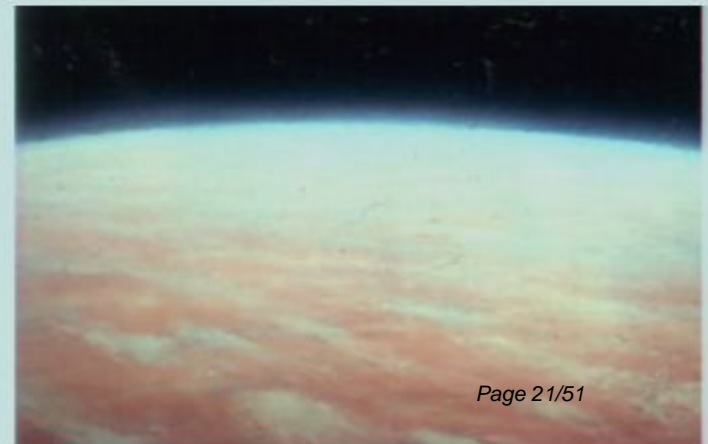


Buried beneath 1 km of younger rocks, the crater is now known as Chicxulub

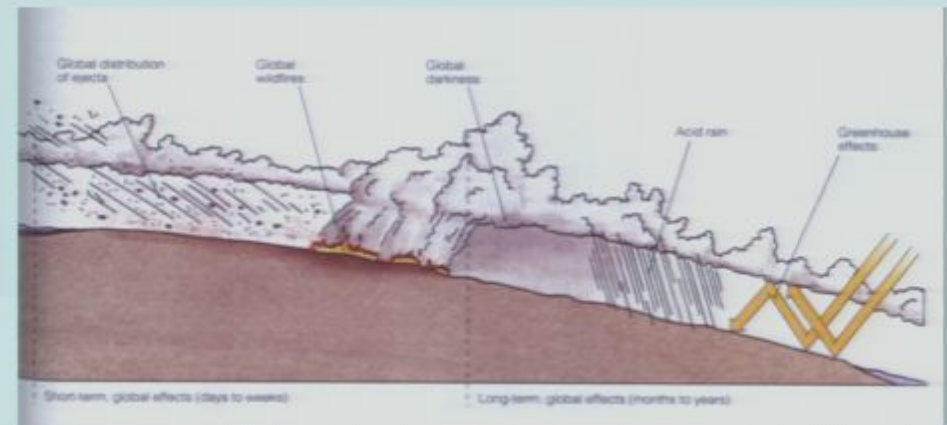
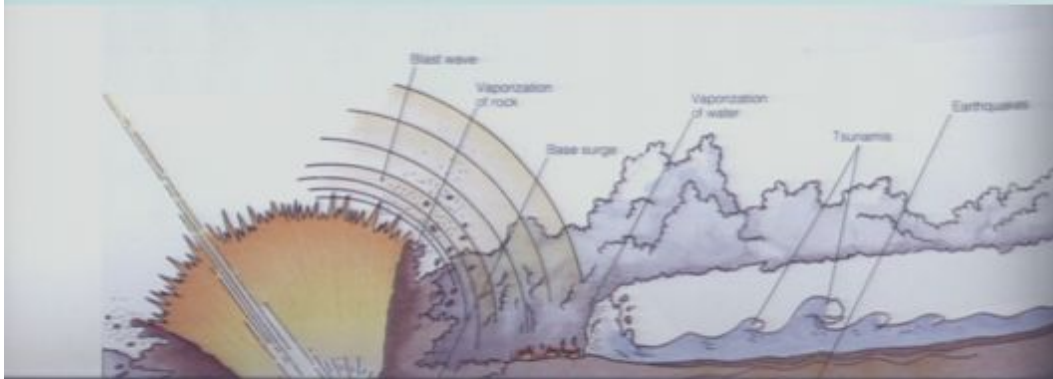


But if an impact did occur at the KT boundary, how could it kill such a large number of Earth's inhabitants?

In 1980 the Alvarez group could only think of one thing--
dust blasted into the stratosphere



Now, 30 years later, we recognize a plethora of impact effects, whose severity depends on distance from the impact



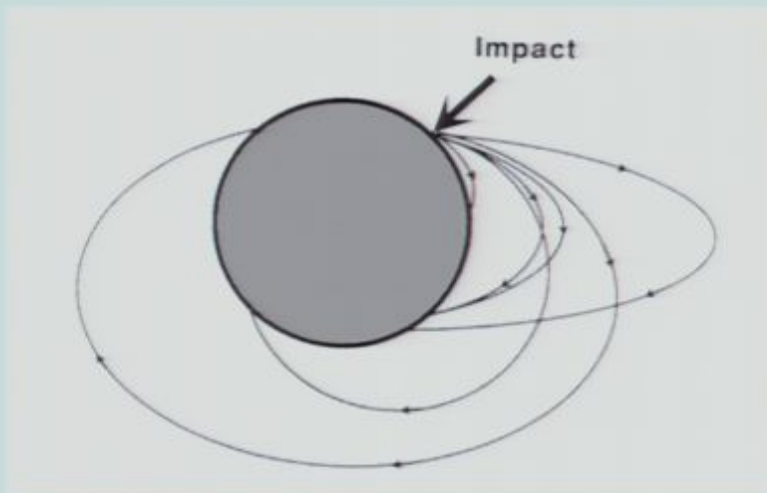
Nearby, Earth suffers:

- Thermal Radiation from the fireball
- Seismic shaking
- Ejecta deposition and burial
- Airblast
- Tsunamis

Far Away:

- Reentry heating and wildfires
- Aerosol blockage of sunlight
- Ozone depletion
- Acid Rain
- Climate response to biological extinctions

Ejecta deposition was recognized because the boundary layer contains spherules too big to float over the entire globe. That leaves only one mechanism for transport--ballistics



Argyle, 1989

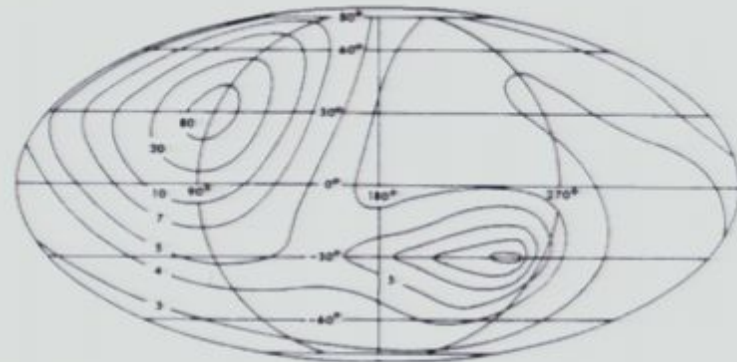
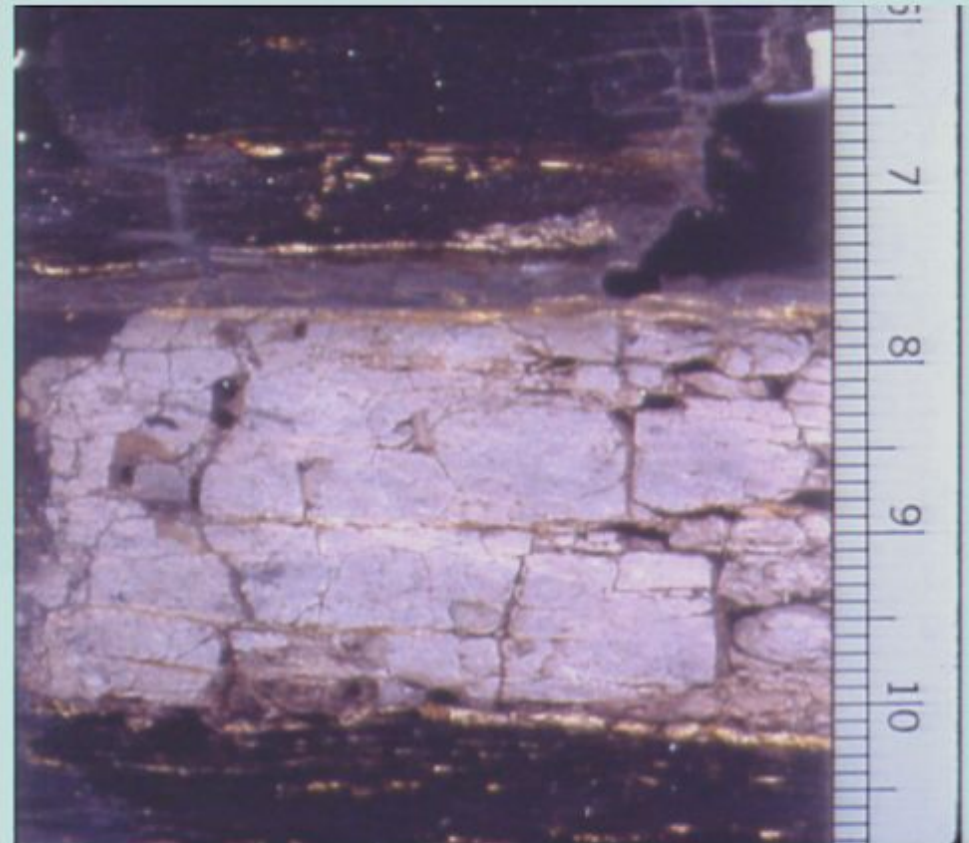


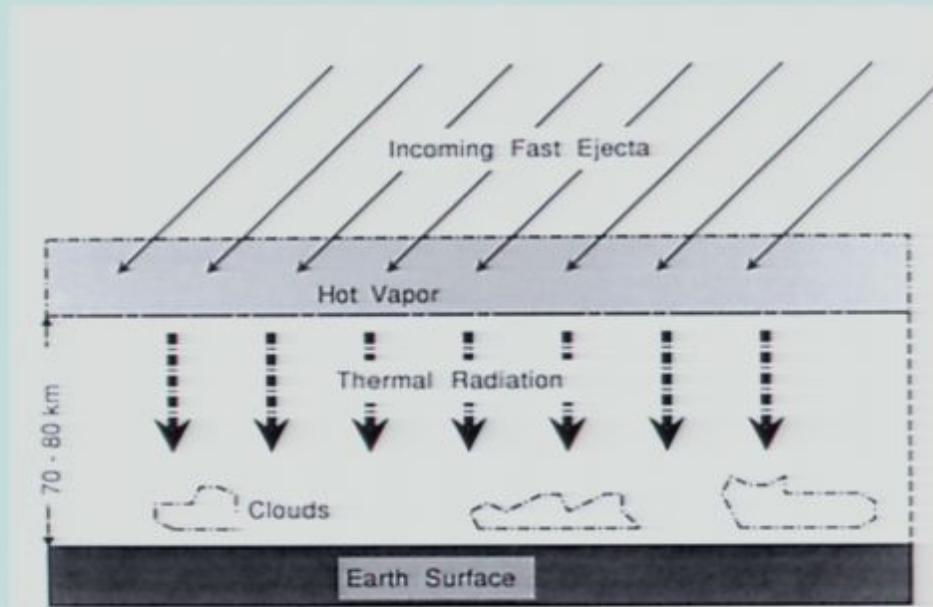
FIG. 1. World contour map of thickness, in millimeters, of the K-T bolide impact fallout layer on the elliptical equal-area projection.

This reentry pattern produces the two-layer structure observed in the North American interior basins



Raton Basin, Colorado

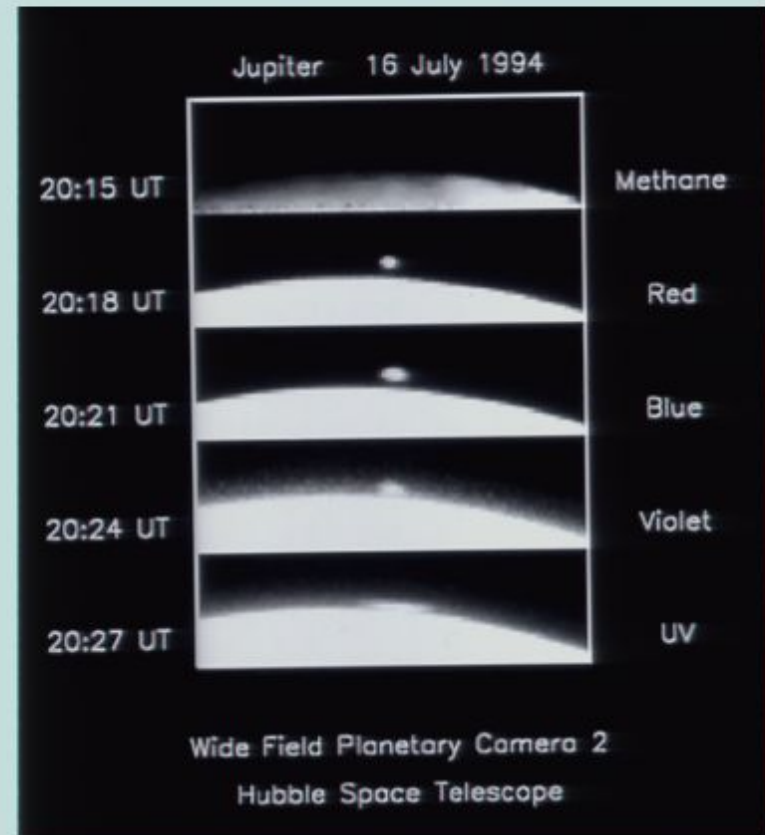
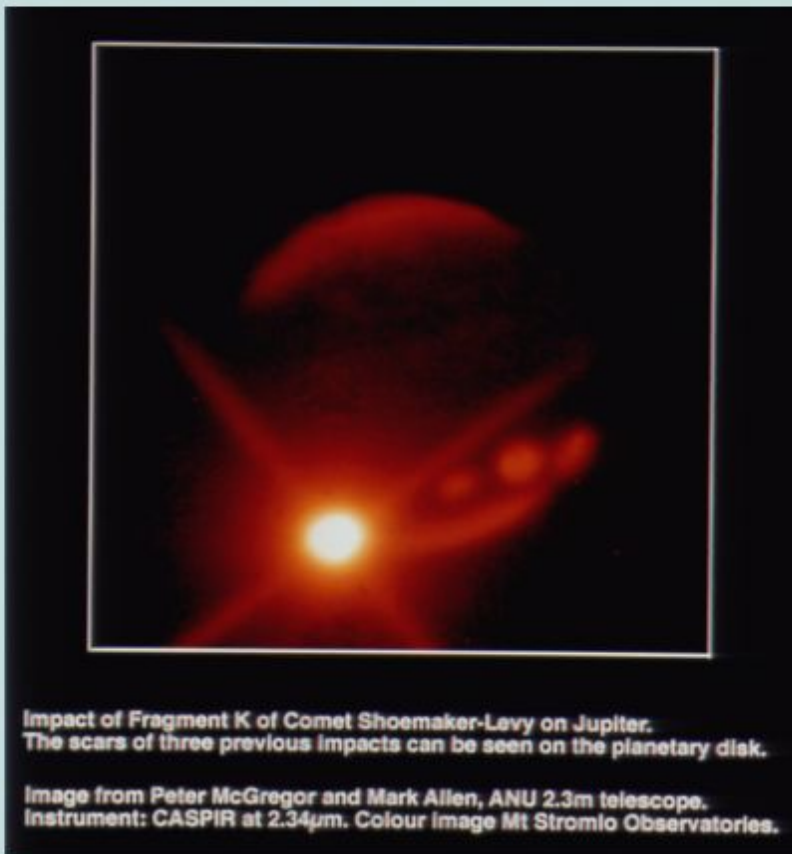
Reentry of the ejecta caused immediate wildfires



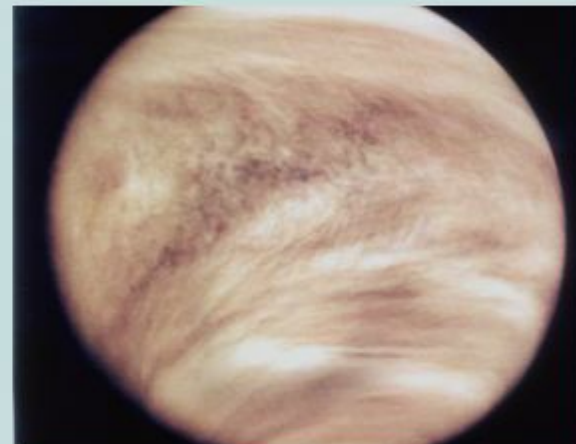
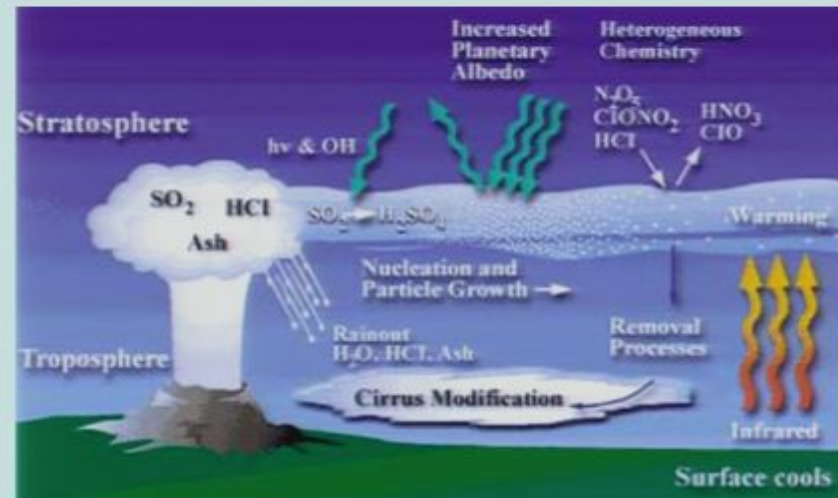
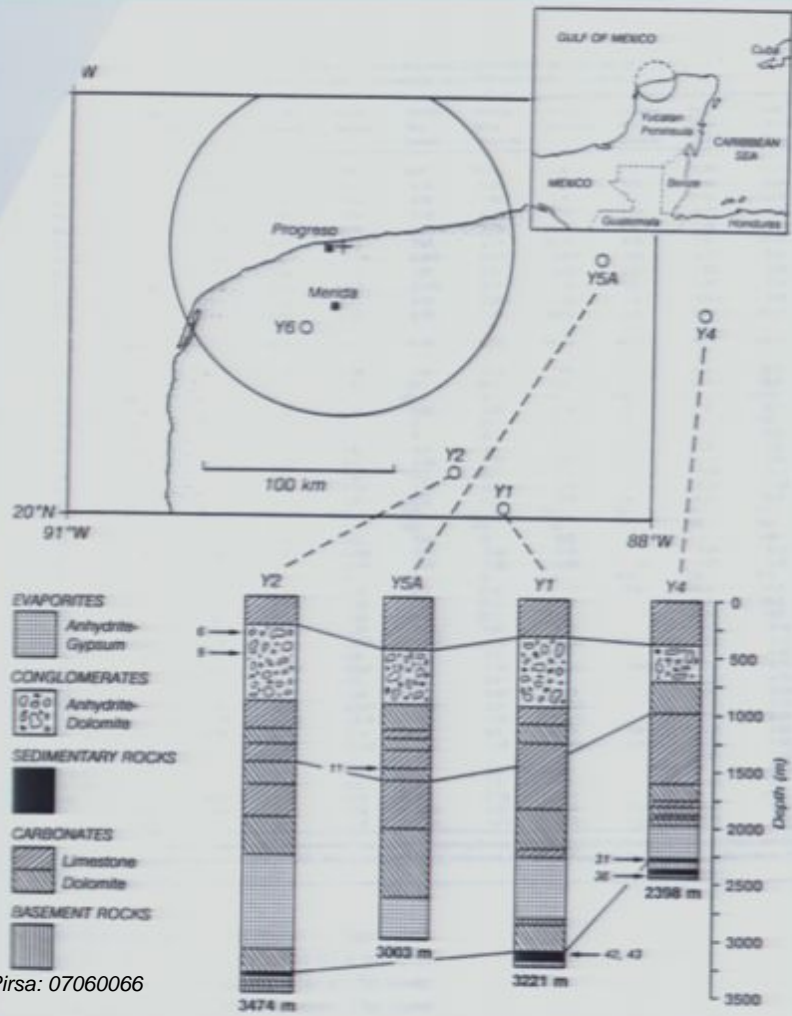
All over the Earth, the sky turned bright red and burned like a pizza oven for hours after the impact.

The dinosaurs were roasted alive!

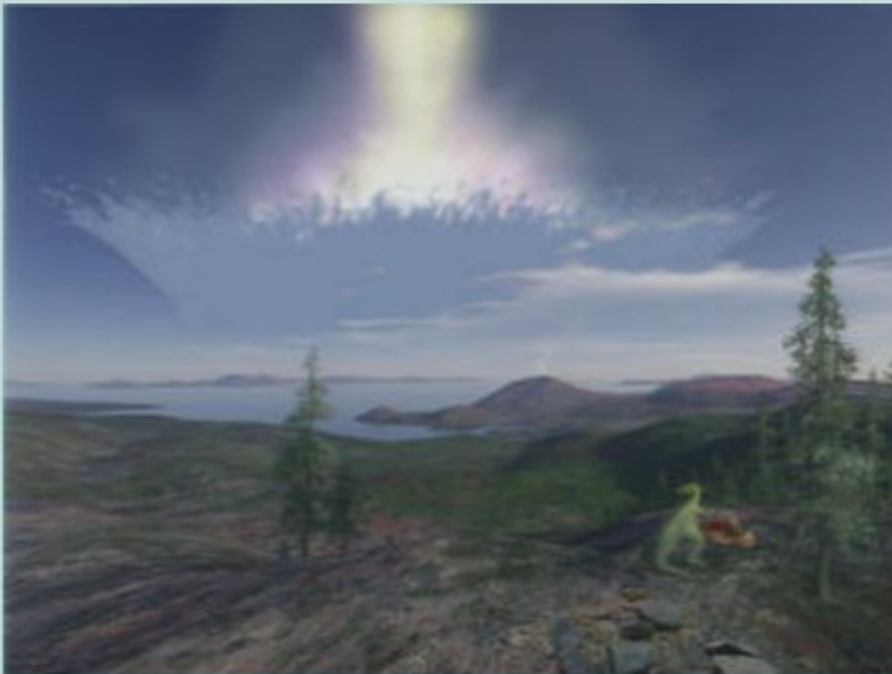
The ejecta rainback process is not just a theory. It was directly observed in 1994 during the S/L 9 impacts on Jupiter



The Chicxulub impact may have been especially lethal because of an especially unlucky choice of target-- Sulfur-rich rocks



Oceanic Tsunamis, although locally important, did not cause global extinctions



Scenes from the Brazos river, Texas
65 Million years ago



Immediate fires



Years of cold

Dinosaurs did not survive

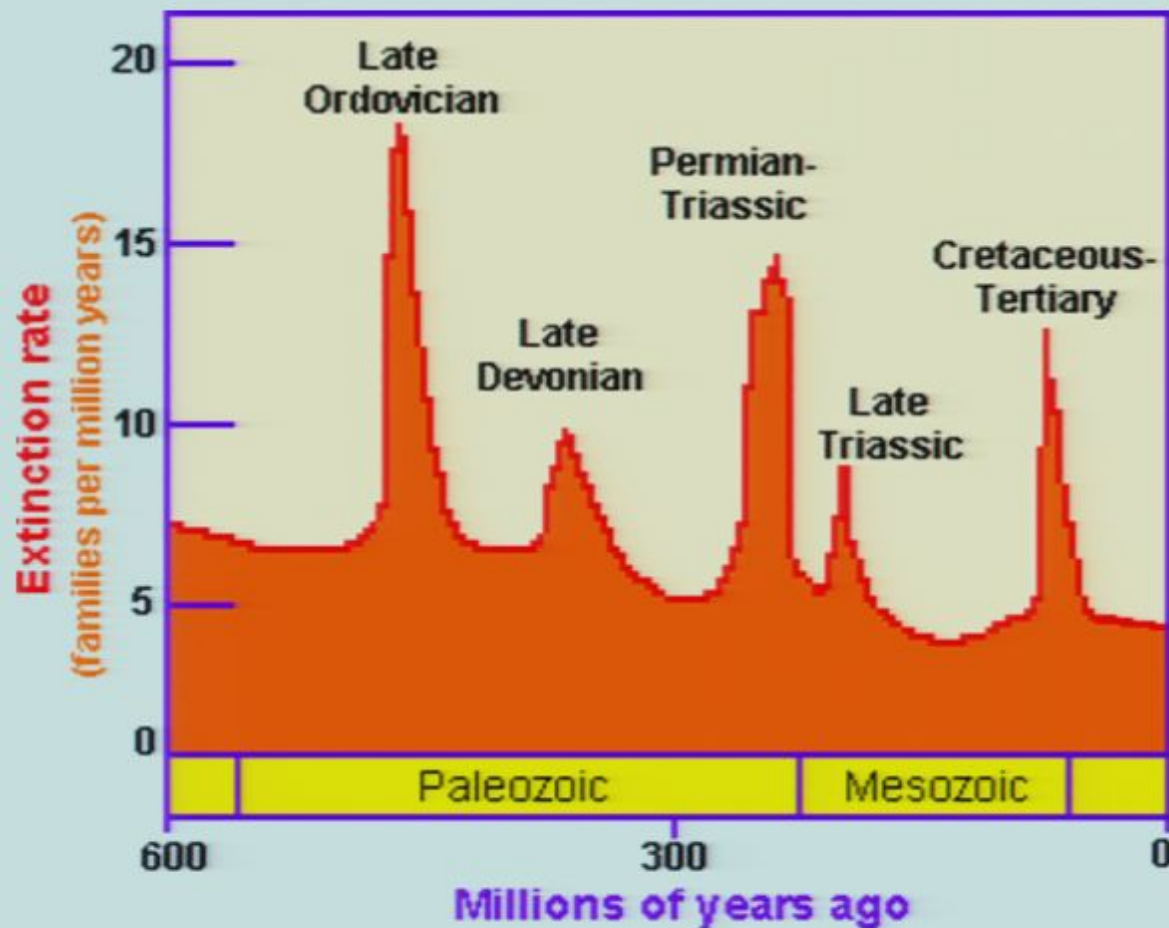


After the immediate firestorms subsided, sulfur-rich aerosols caused acid rain and freezing temperatures, creating massive dieoffs in the oceans as well as on land. The only survivors on land were small animals that could have sheltered from the firestorm, and oceanic organisms that could tolerate acid.

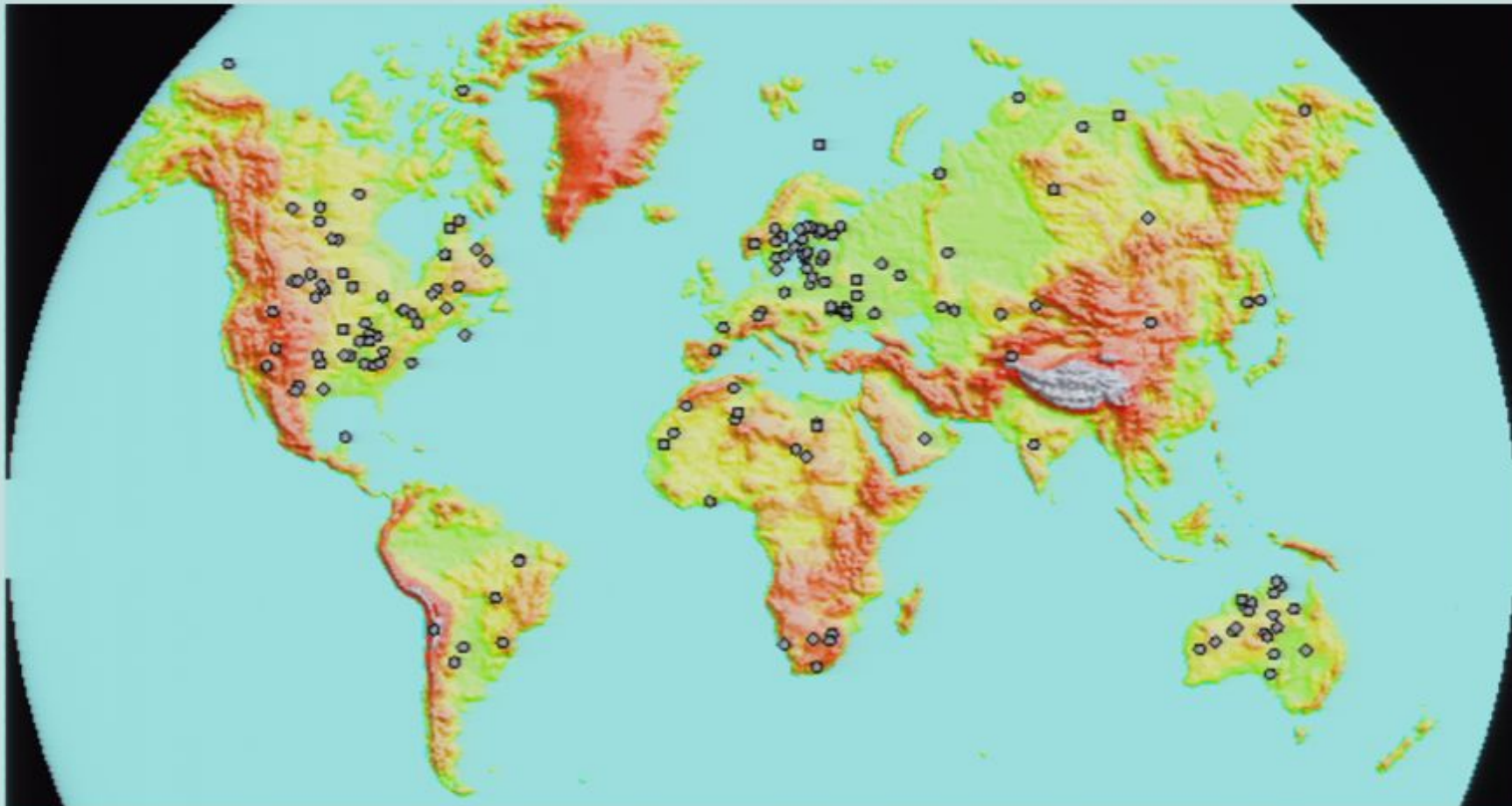
The major effects of the impact subsided after a few thousand years, leaving the way open for the mammalian survivors to repopulate the Earth



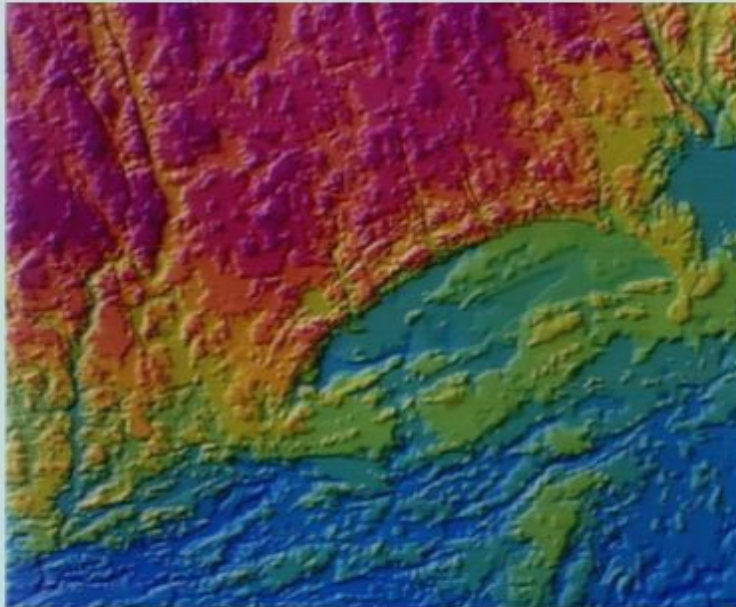
Although the KT extinction was one of the biggest in recent geologic history, it was not the only one, or even the biggest one



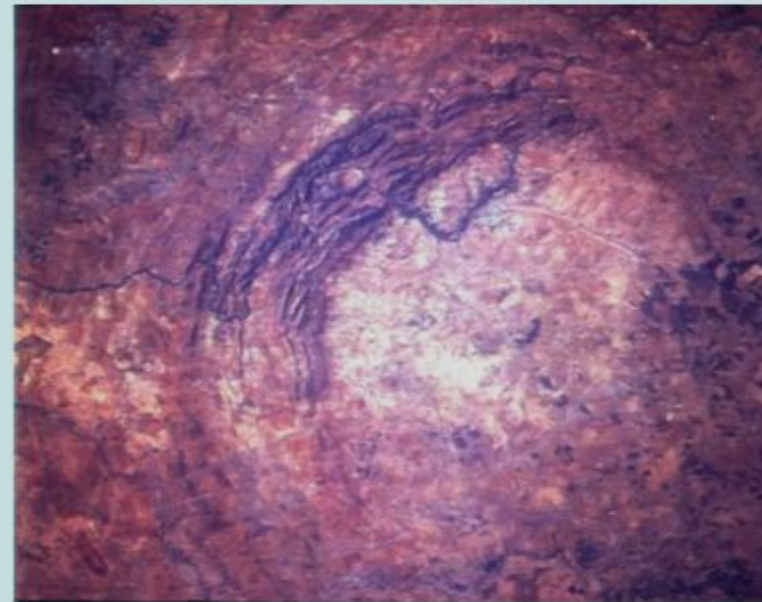
Impact craters are rare, but not unknown on the Earth □



Aside from Chicxulub, the other two largest known craters are Sudbury and Vredefort, but both are too old to have caused the known extinctions...



Sudbury, Ontario
250 km diameter
1850 Million Years

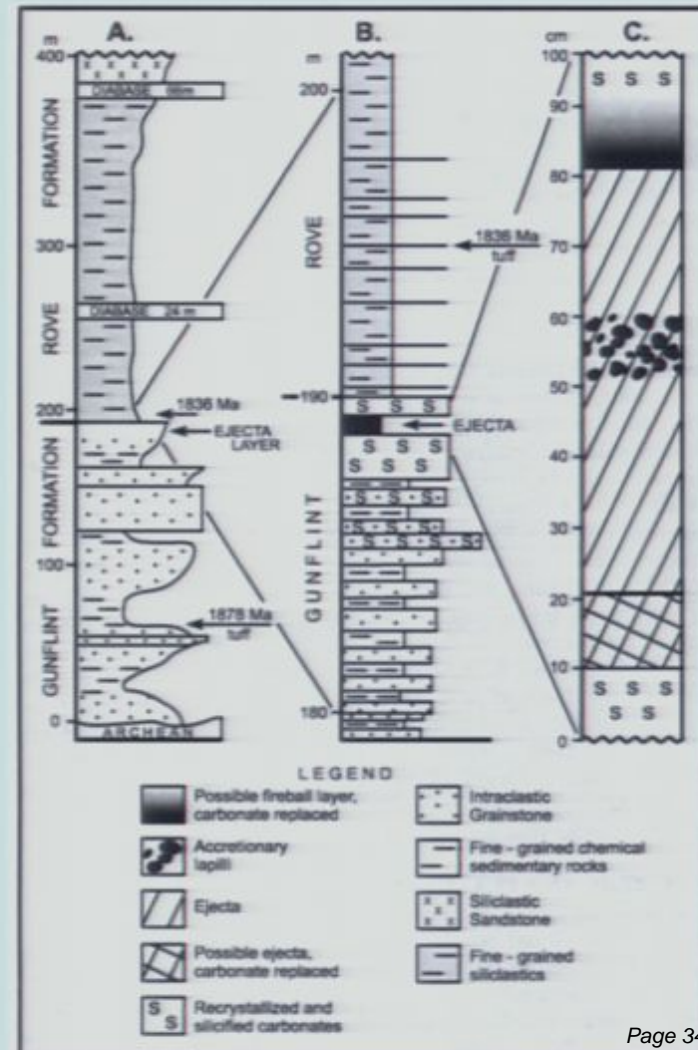


Vredefort, South Africa
300 km diameter
2020 Million Years

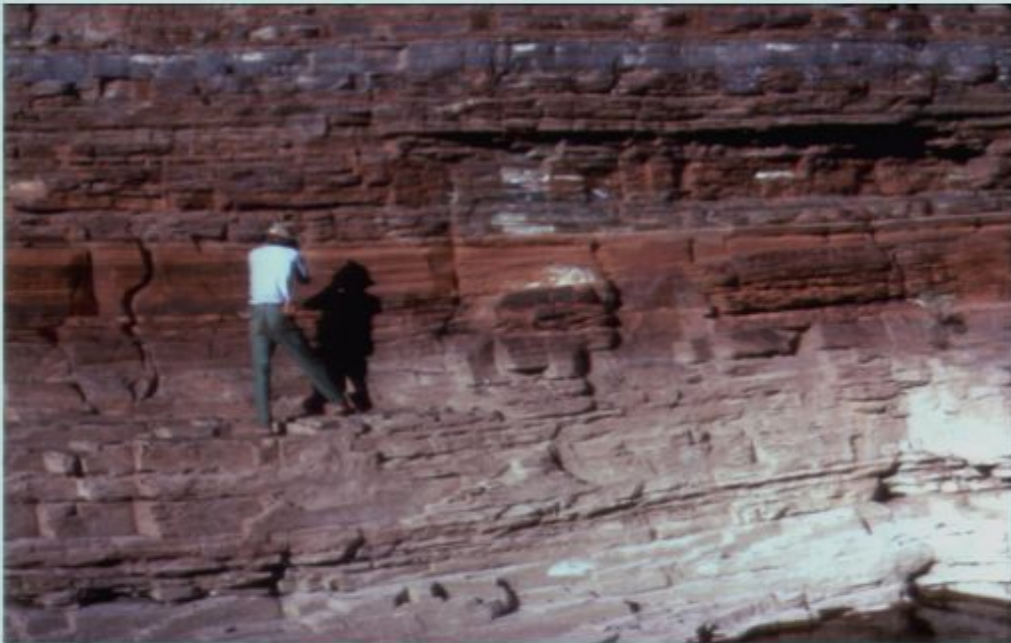
...or maybe Sudbury did?

Discovery of distal ejecta from the 1850 Ma Sudbury impact event

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 Gregory R. Brumpton 211 Henry Street, Thunder Bay, Ontario P7E 4Y7, Canada
 Daniela A. Vallini } Centre for Global Metallogeny, School of Earth and Geographic Sciences, University of Western
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 Philip W. Fralick } Department of Geology, Lakehead University, Thunder Bay, Ontario P7B 5E1, Canada
 Anne L. Hammond }

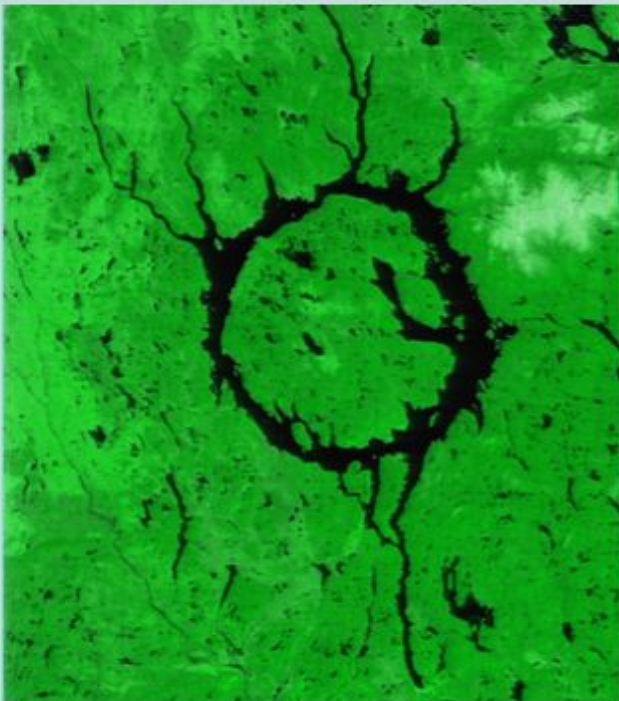


Many ancient craters must have formed. We know of a few around 3500 Million years old only from their distal ejecta deposits.

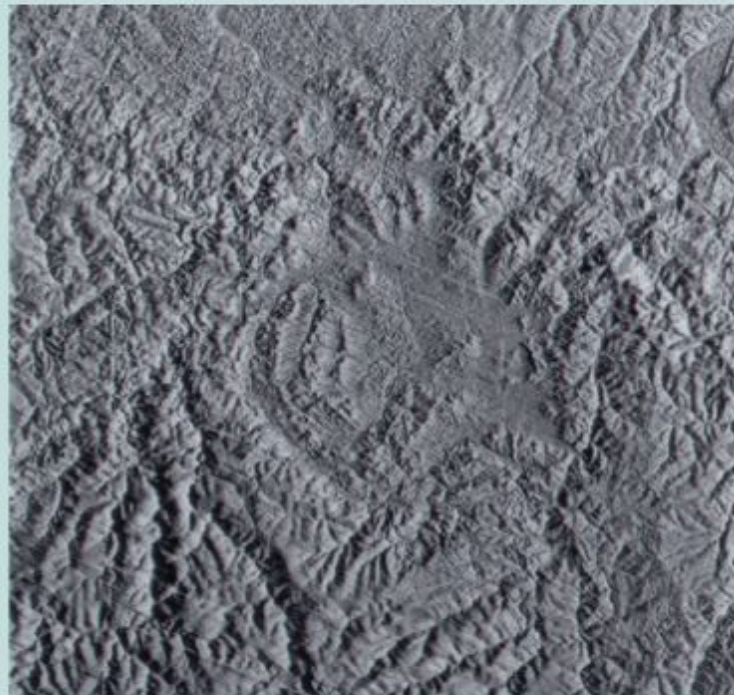


Courtesy Bruce Simonson

Impact craters smaller than Chicxulub have no extinctions associated with them

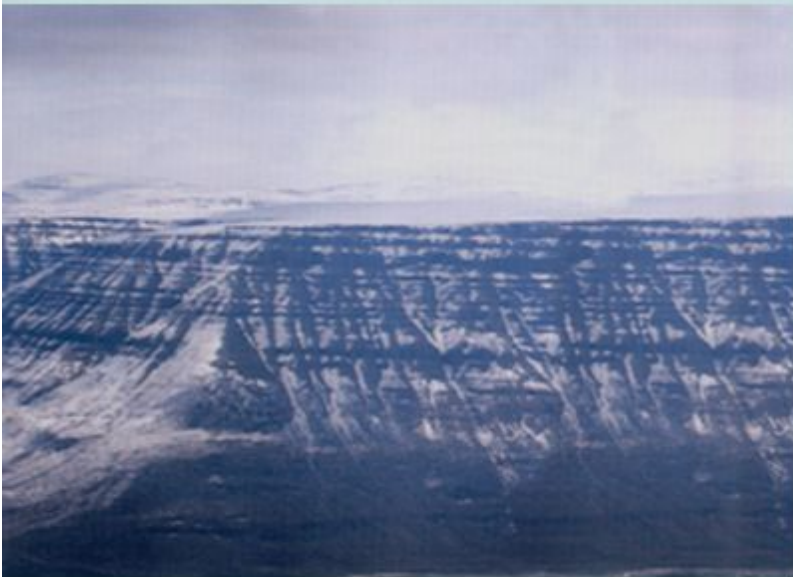


Manicouagan Quebec
100 km diameter
214 Million Years

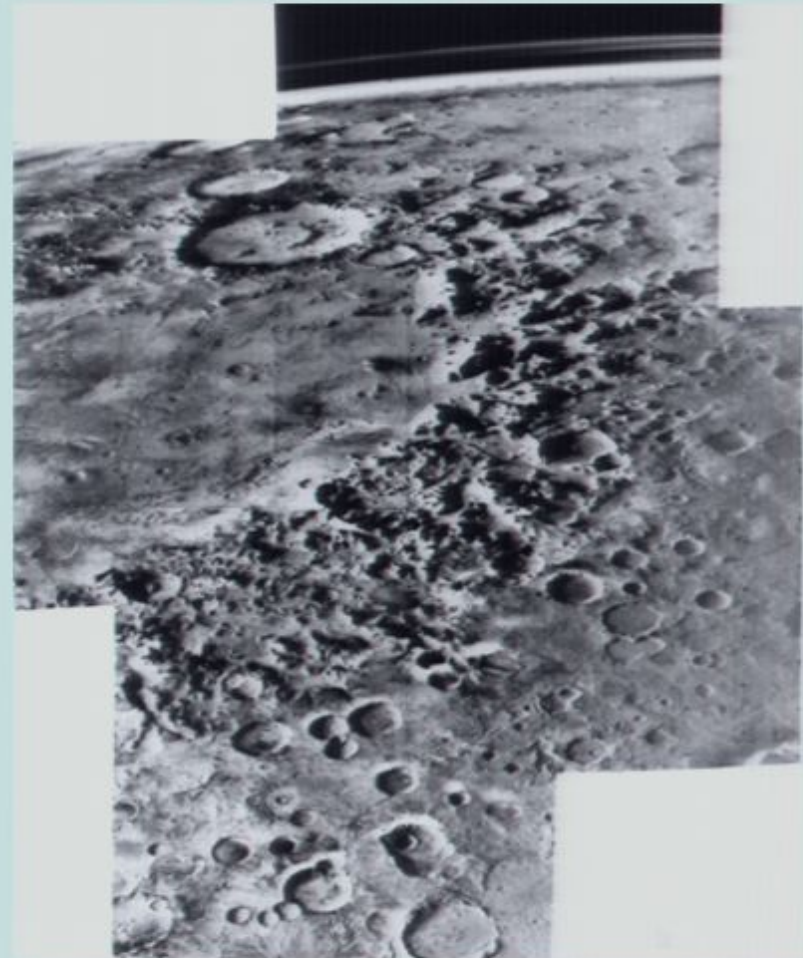


Popigai, Russia
100 km diameter
35.7 Million Years

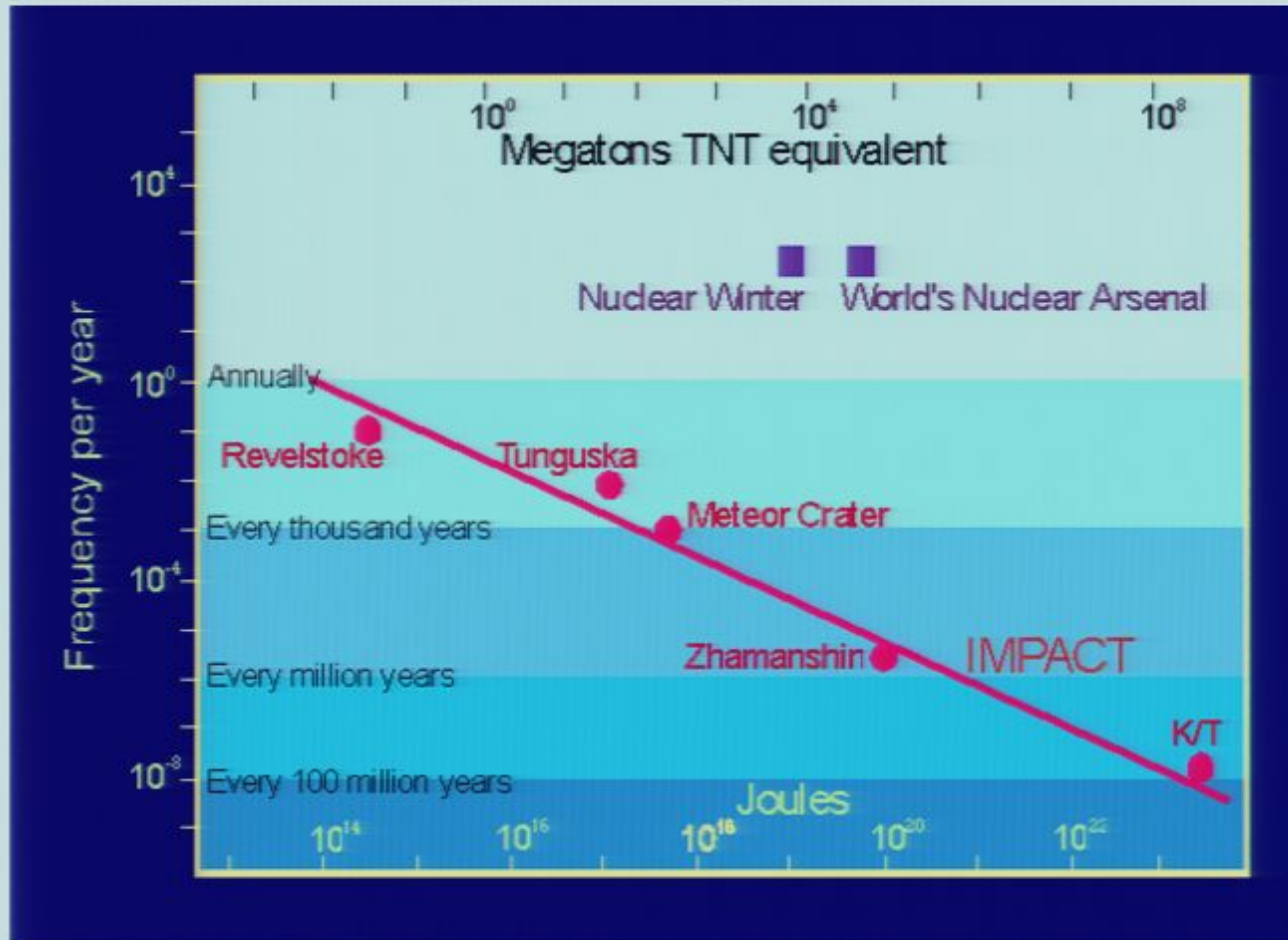
So far, however, impact has not been proven for any other extinction. The massive Permian-Triassic extinction seems to correlate best with a huge basaltic eruption in Siberia 251 Million Years ago



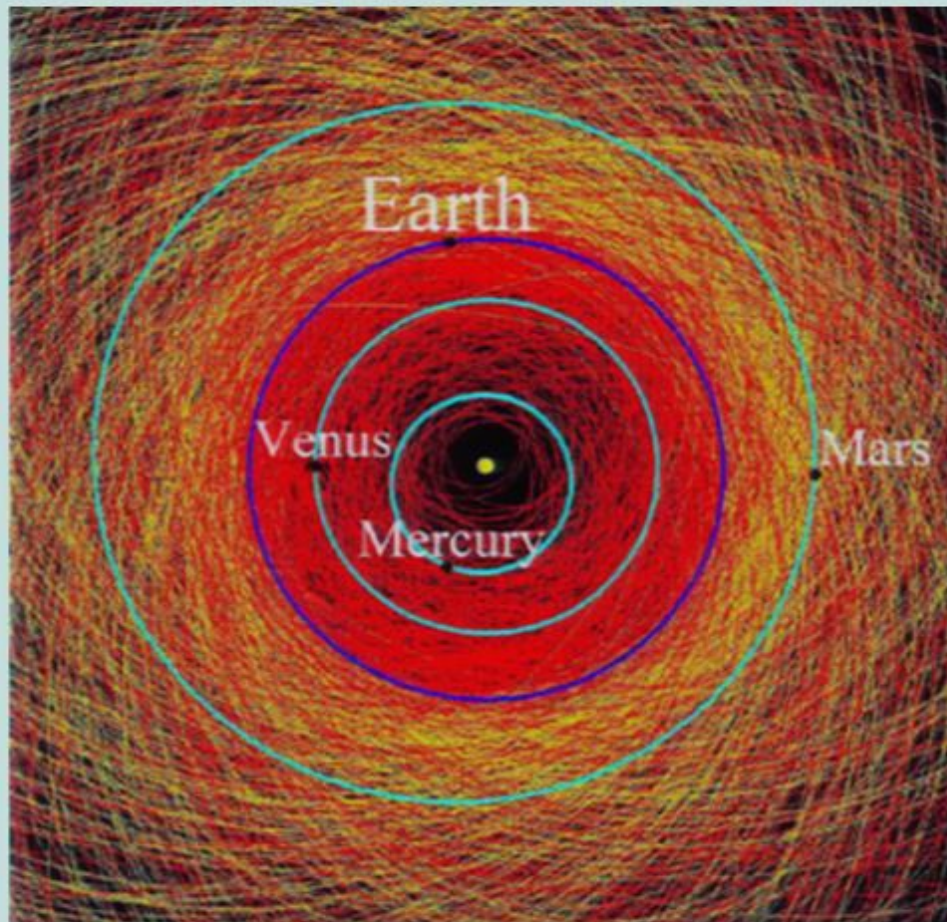
But the surfaces of the other planets show clearly that impacts are inevitable



Big impacts are less probable than small ones,
but given enough time a large impact is
inevitable



The solar system is swarming with asteroids, many of which regularly cross the Earth's orbit



What would we do if a large asteroid were about to strike the Earth?



Should we be getting ready for what is, after all, a rather distant possibility?



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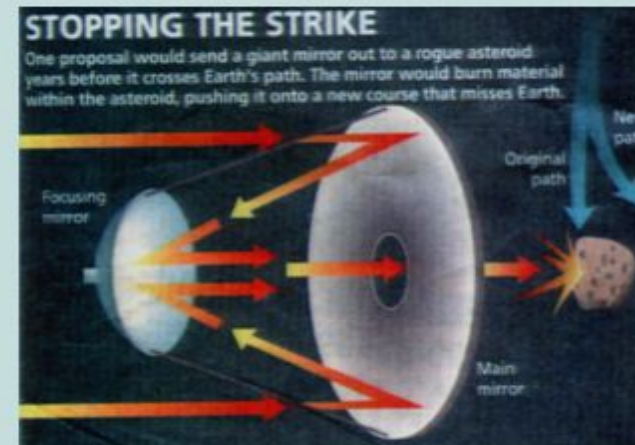
"All I'm saying is now is the time to develop the technology to deflect an asteroid."



Concerns about a possible asteroid strike have led to a number of plans of action



Stand-off nuclear detonation



Solar evaporation jet



Kinetic deflection



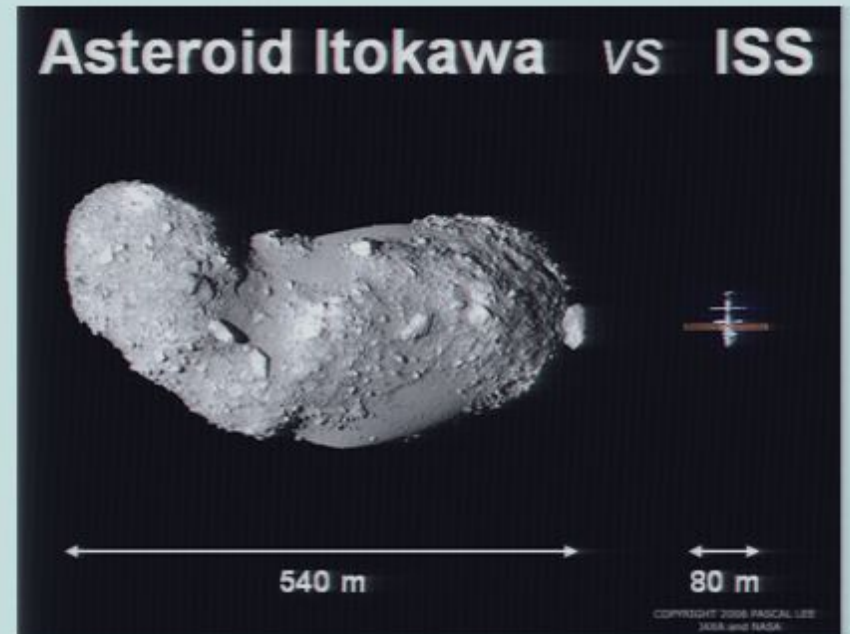
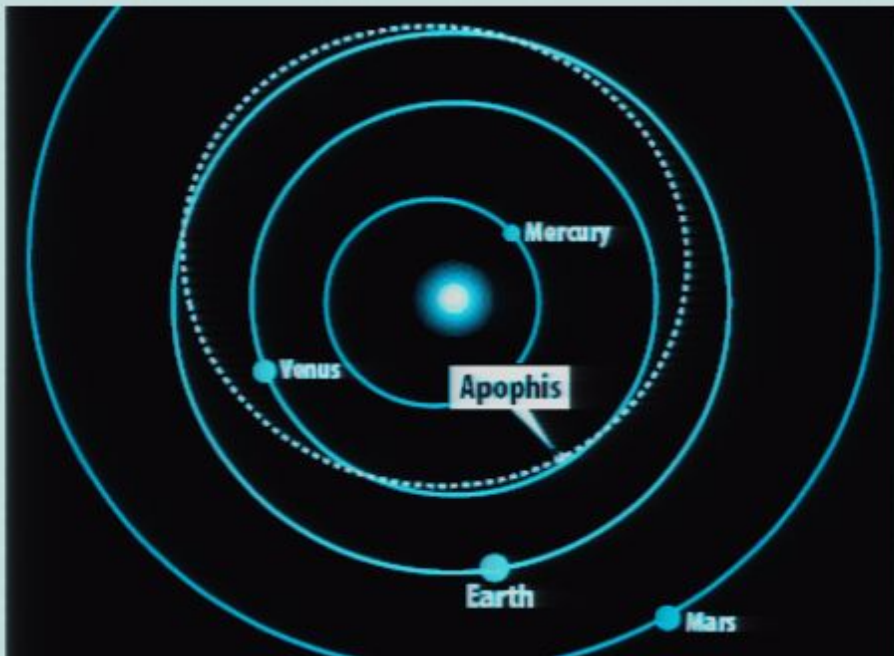
Plasma jet/gravity tractor

But for now, the best strategy seems to be a comprehensive survey of all Earth-crossing asteroids. A survey that is already in progress



Catalina Sky Survey in Arizona, one of about 8 NEO searches NASA has taken on the task of finding 90% of Earth-crossing asteroids greater than 1 km in diameter by 2008. The survey is presently about 75% complete. There are about 1100 such objects.

So far, we are not targeted by any large asteroids. The most serious threat is asteroid Apophis, which will make a close flyby in 2029 and has a tiny chance of impacting in 2036. Apophis is about 500 m across, similar to asteroid Itokawa in size



Impacts by interplanetary debris are an inevitable fact of life on Earth. Impacts have occurred in the past, and they will occur again in the future.



Barringer Crater, AZ, 50,000 Years



Tunguska
Airburst, 1908



Sterlitamak, Siberia, May 10, 1990

Impacts are not all bad:

A gigantic impact of a Mars-size body created the Earth's moon



The Earth itself was assembled from the impacts of swarms of planetesimals, and was largely melted in the process, forming our core and crust



However, only after the fusillade of early impacts could life have started on the Earth



Although, just maybe, impact may have brought life to Earth from somewhere else---Mars, for example



Although geologists accepted the reality of impacts by large extraterrestrial bodies only about 50 years ago, we now know that they have played a central role in the history of our planet.



Pisa: 07060000

