Mass-Extinctions at the K/Pg boundary:
Caused by climate changes.
Induced by the Chicxulub impact,
or the Deccan trap eruptions?


La Comète arrivait, grandissant de jour en jour.

CAMILLE FLAMMARION

LA

FIN DU MONDE

Illustrations par Jean-Paul Laurens, Rochegrosse, E. Bayard, Robida, A.-P. Laurens, Schwabe, Grasset, Saunier, Meunier, Vogel, Bach, Guillonnet, Rudaux, Myrbach, Crovin.
Gravure par Méaulle.

Je vis ensuite un ciel nouveau et une terre nouvelle; car le premier ciel et la première terre étaient passés.
Apocalypse, xxi, 1.

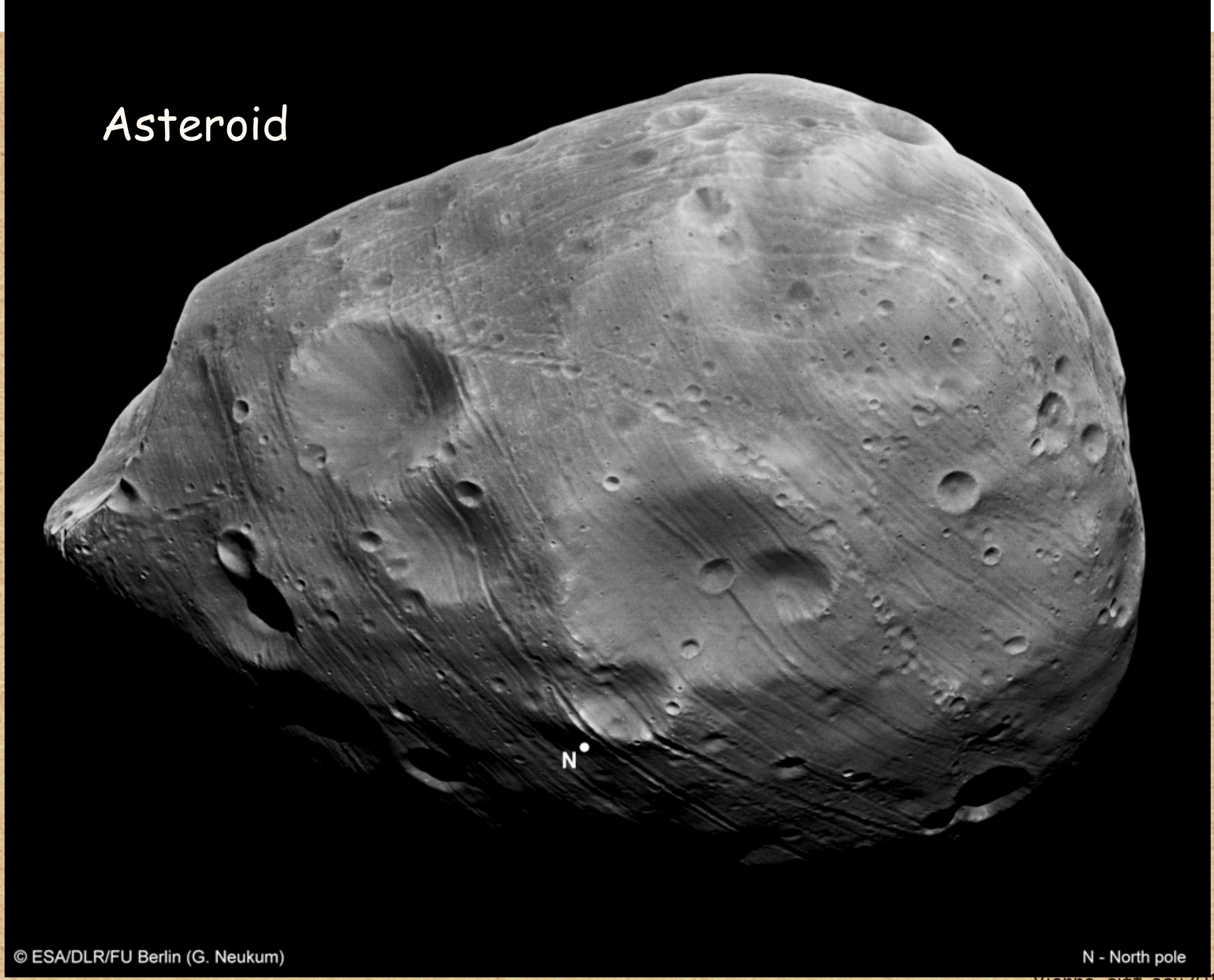
ERNEST FLAMMARION, ÉDITEUR
26, rue Racine, Paris

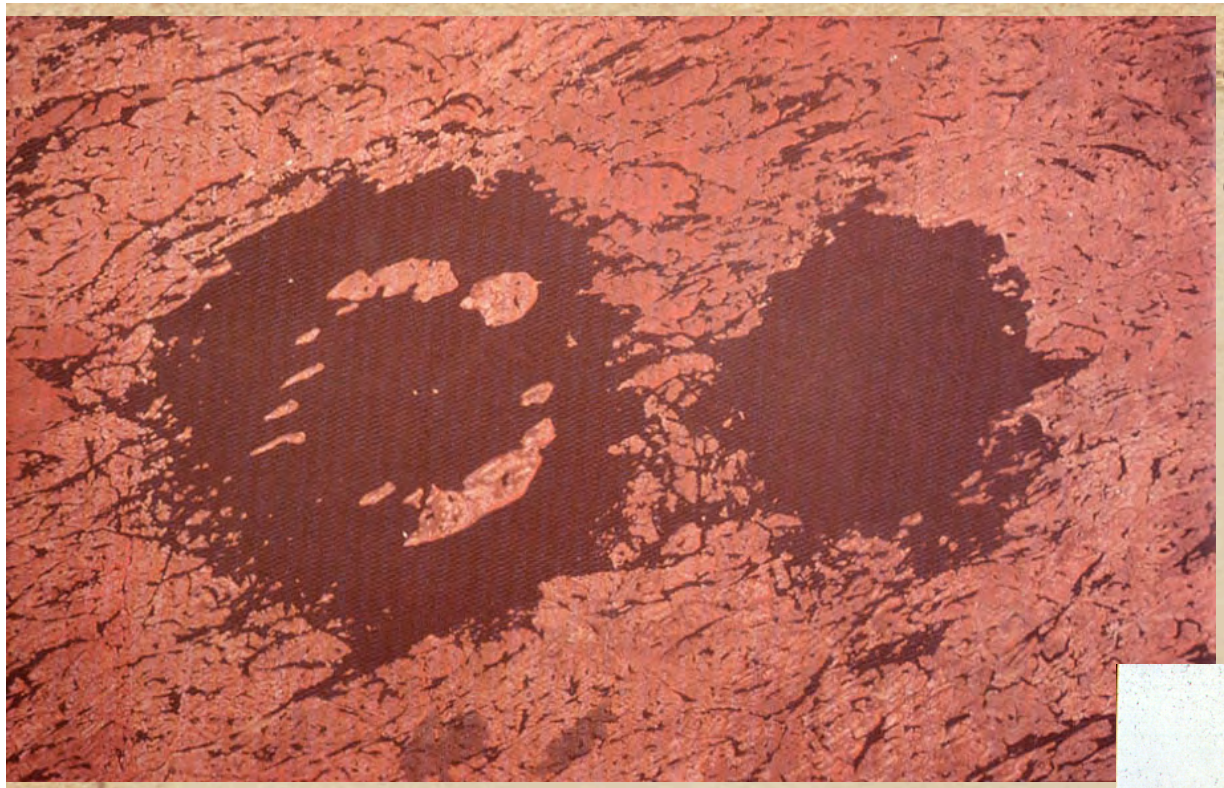
Tous droits de traduction, d'adaptation et de reproduction réservés pour tous les pays.
(Vingt-cinquième mille)

THE DELICATE BALANCE BETWEEN CHICXULUB IMPACT AND/OR DECCAN TRAPS INDUCED MASS-EXTINCTIONS AT THE K-PG BOUNDARY Jan Smit (Free University Amsterdam, The Netherlands)

2011

Asteroid

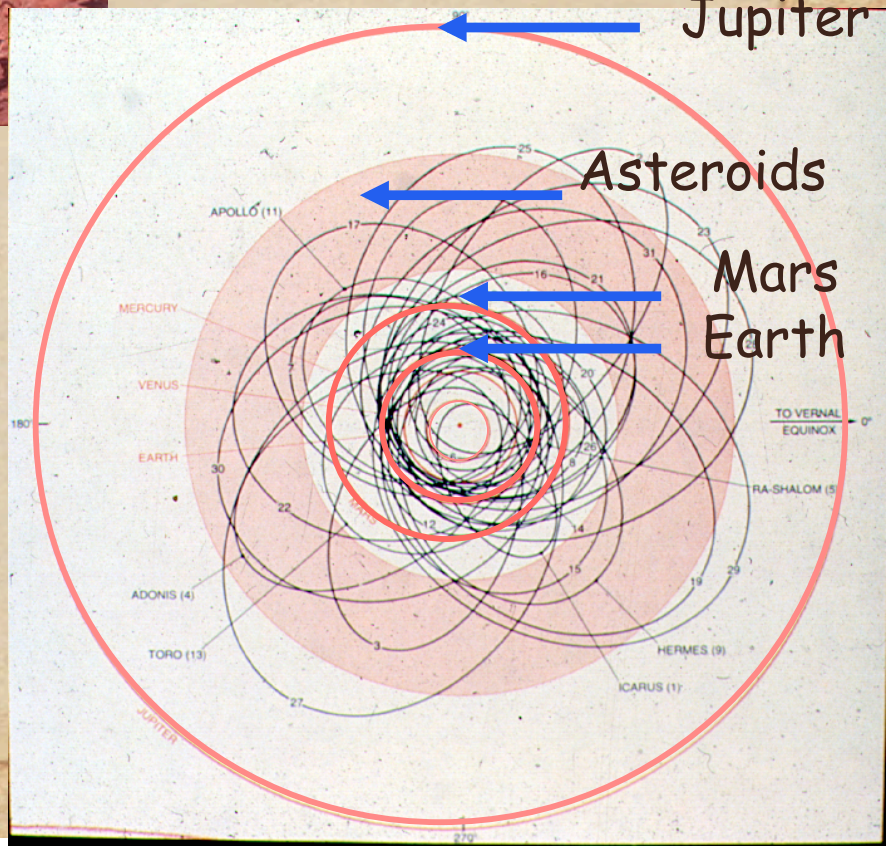


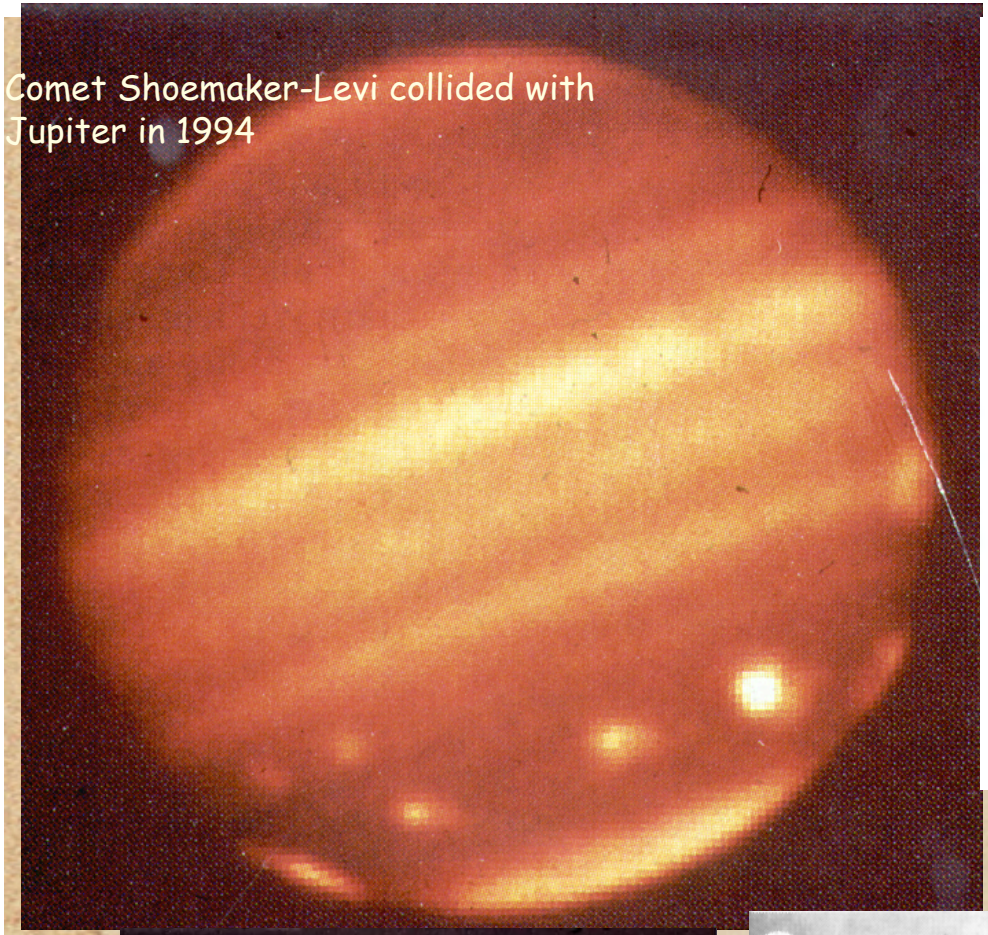


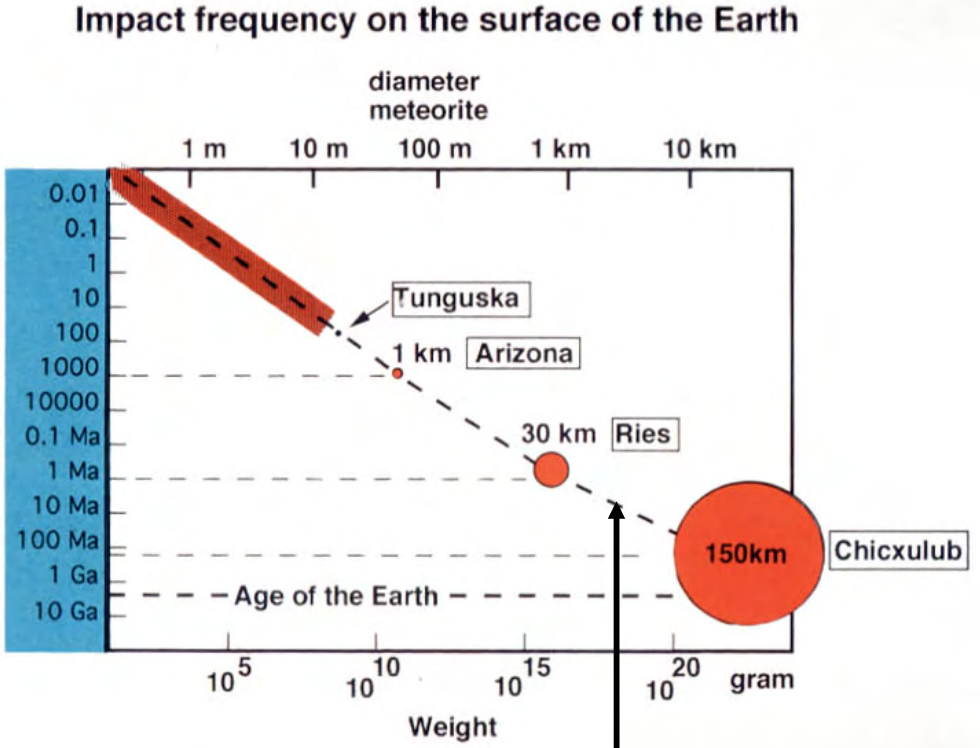
Clearwater Lake impact craters,
Canada
320 million years ago

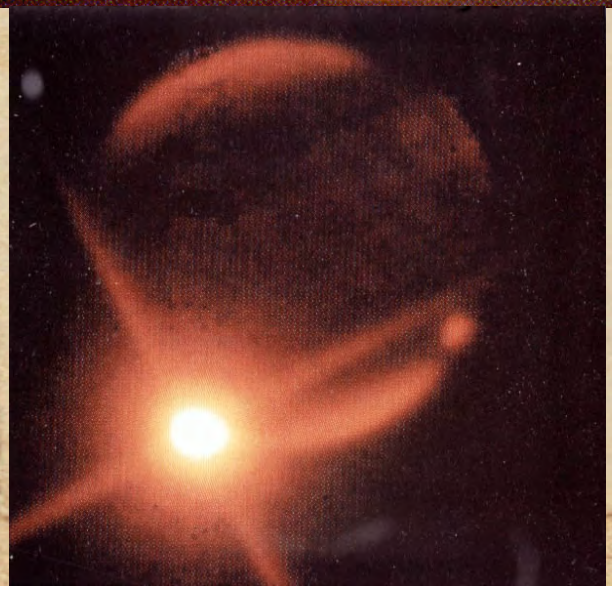
Large asteroid impacts occur frequently in earth history

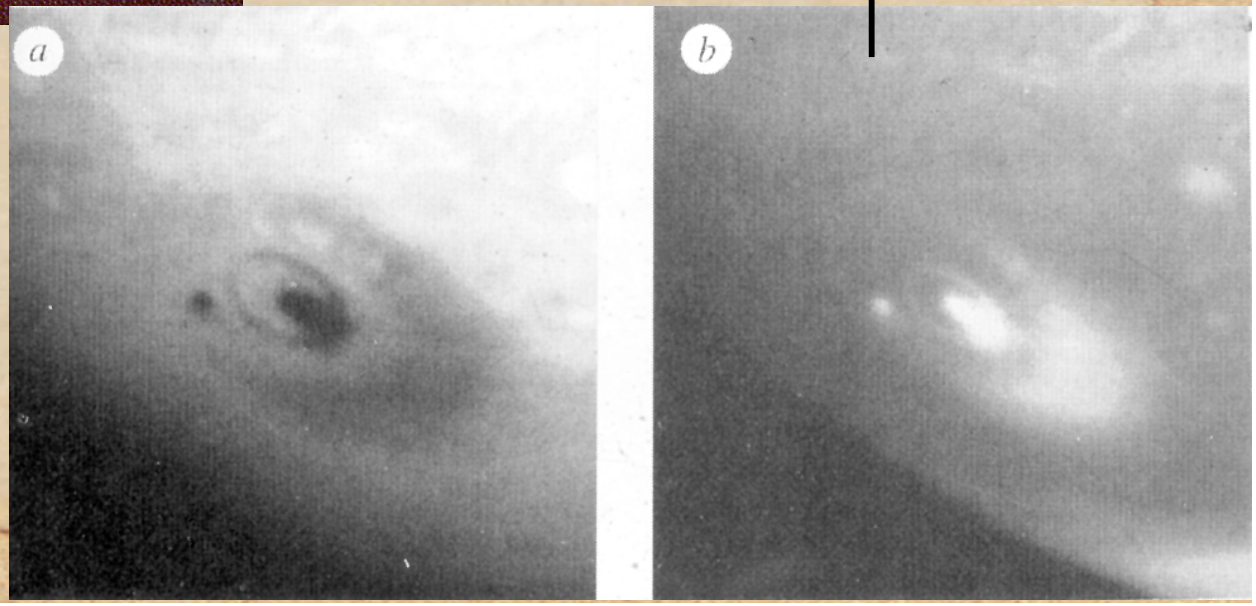
Apollo Asteroids



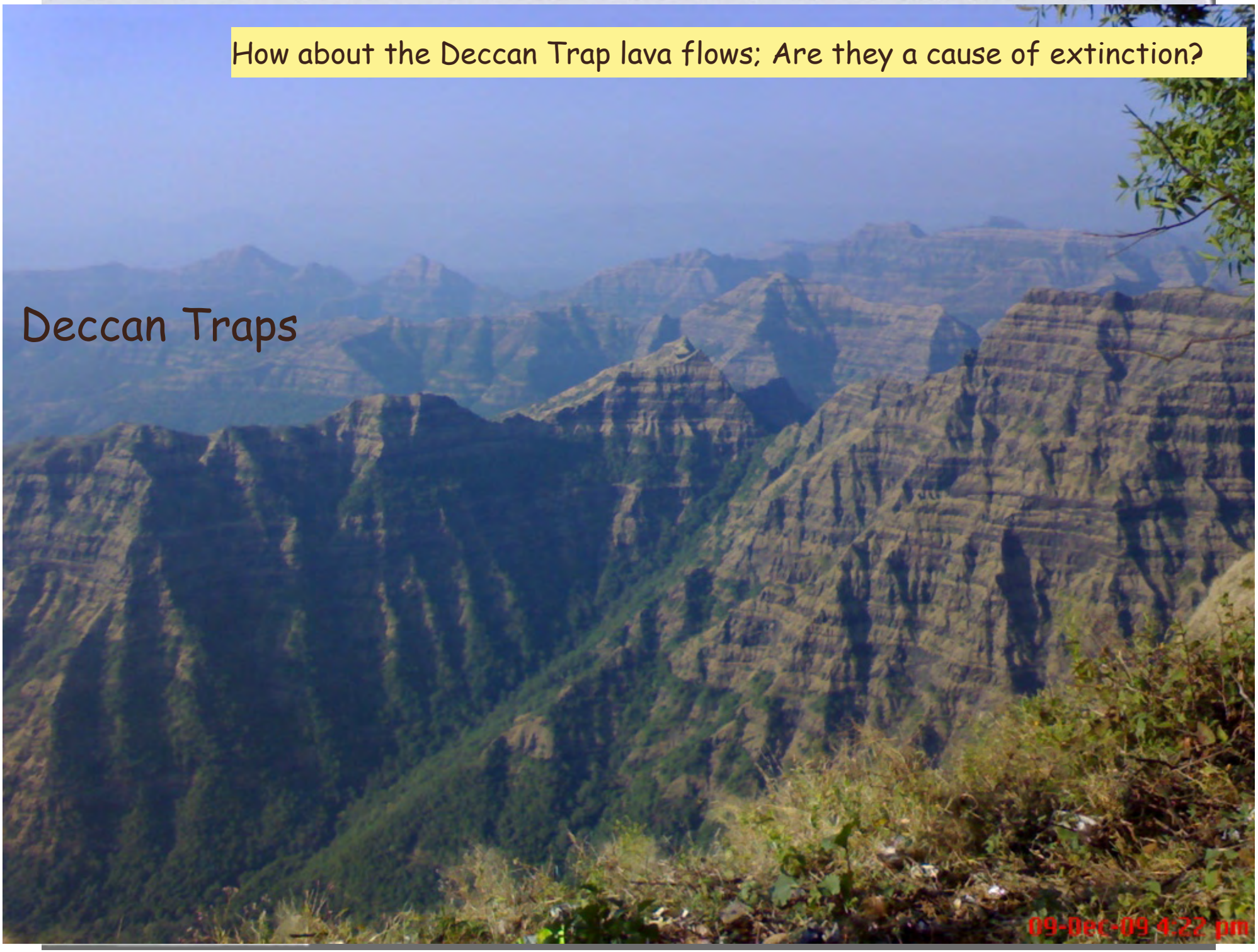

Comet Shoemaker-Levi collided with
Jupiter in 1994


Impact frequency on the surface of the Earth
diameter
meteorite
1 m
10 m
100 m
1 km
10 km
0.01
0.1
1
10
100
1000
10000
0.1 Ma
1 Ma
10 Ma
100 Ma
1 Ga
10 Ga
Tunguska
1 km
Arizona
30 km
Ries
150km
Chicxulub
Age of the Earth
10^5
10^10
10^15
10^20
gram
Weight



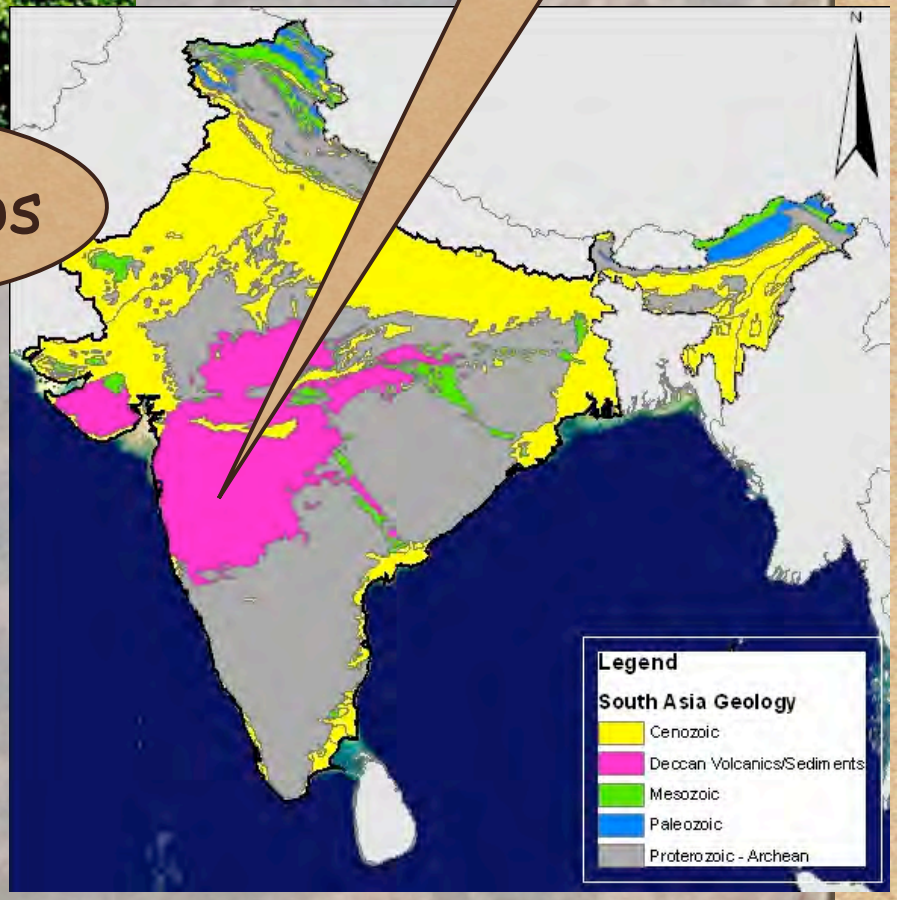

a
b

How about the Deccan Trap lava flows; Are they a cause of extinction?

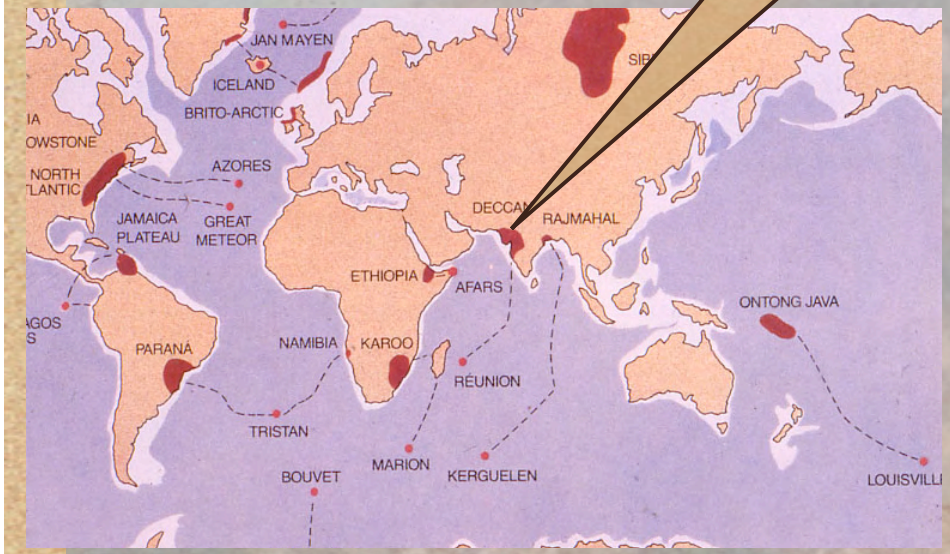


How about the Deccan Trap lava flows; Are they a cause of extinction?

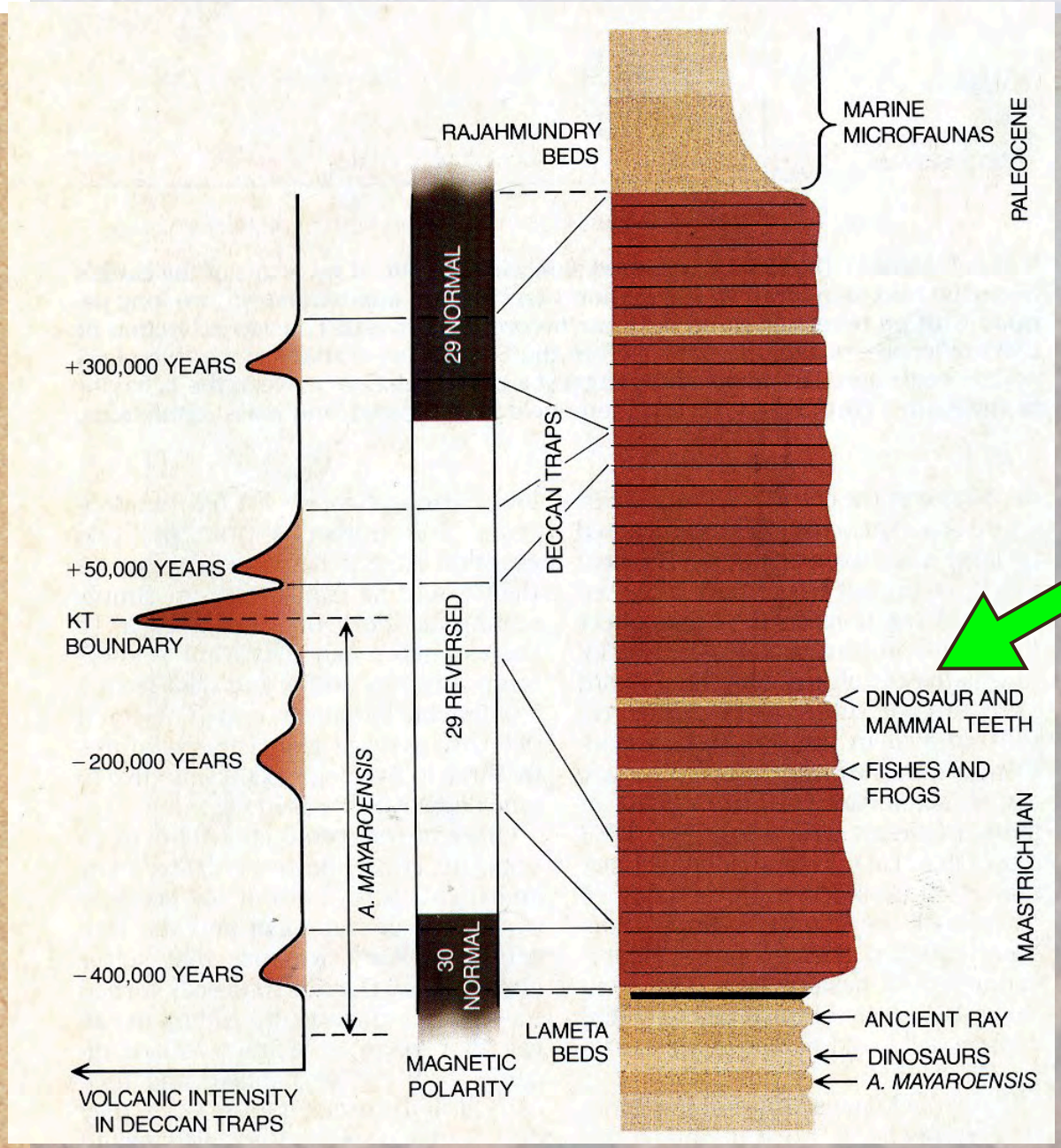
Deccan traps



Deccan traps

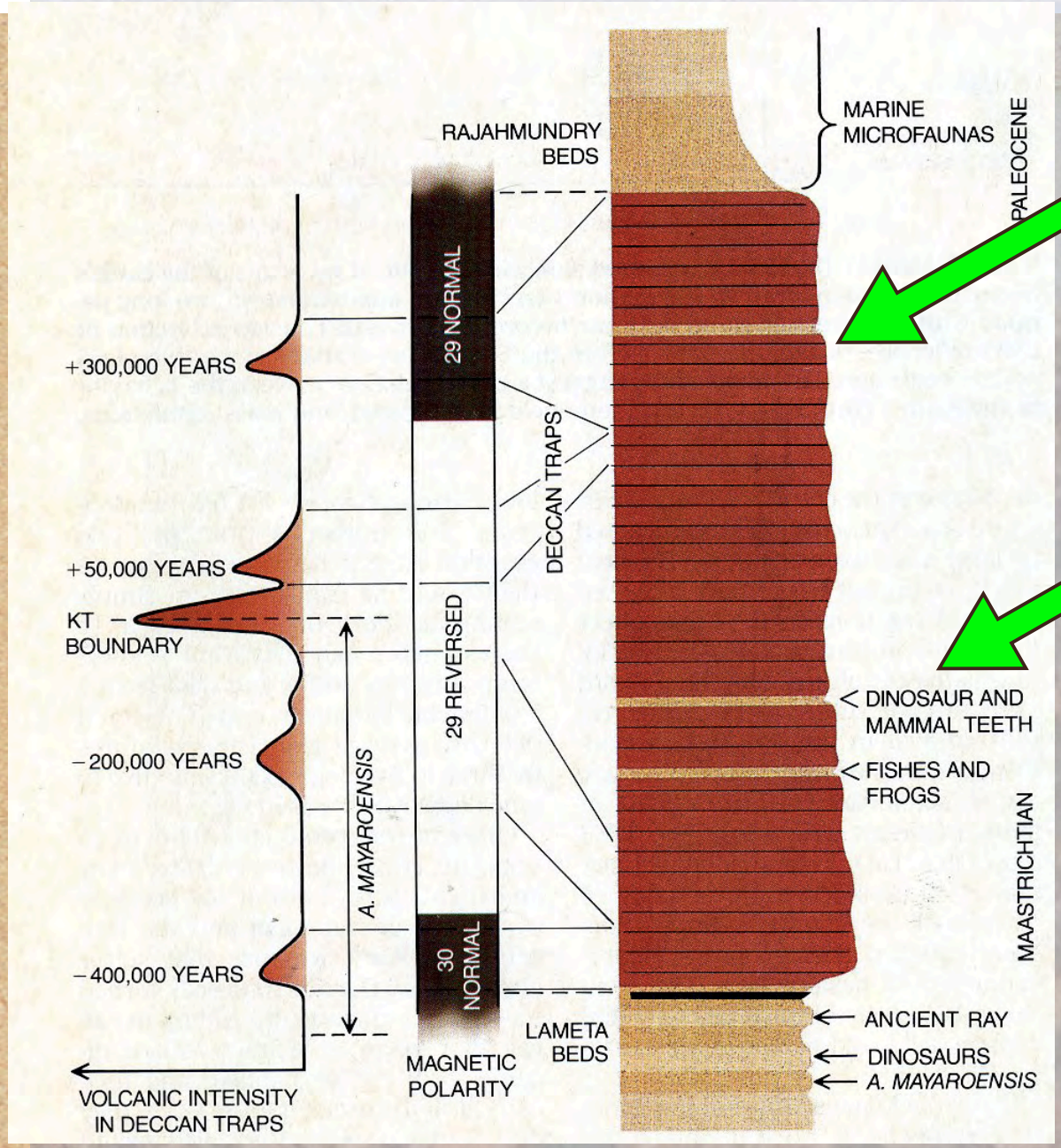


Vienna, gift-egu2011



In India, dinosaurs walked during the eruptions. Shouldn't they have experienced the deleterious effets of volcanism?

What can we say about the extinctions?
Due to Chicxulub Impact or Deccan traps?



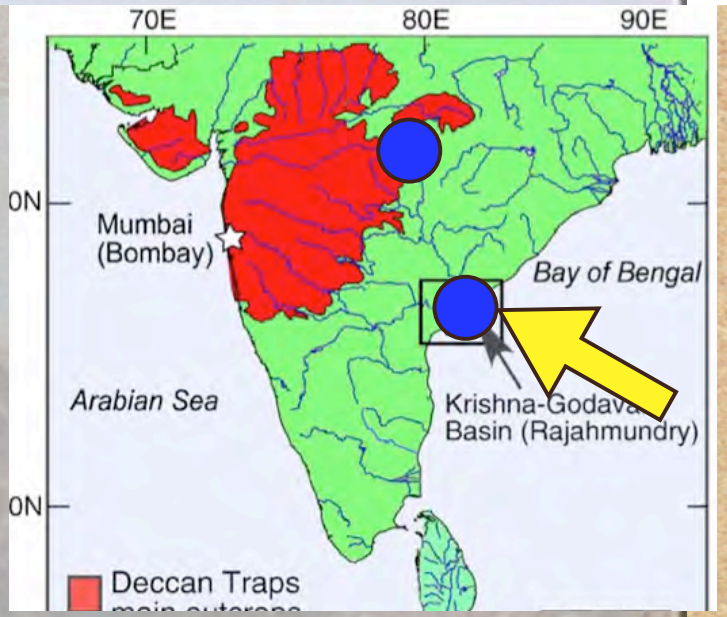
Paleocene fossils

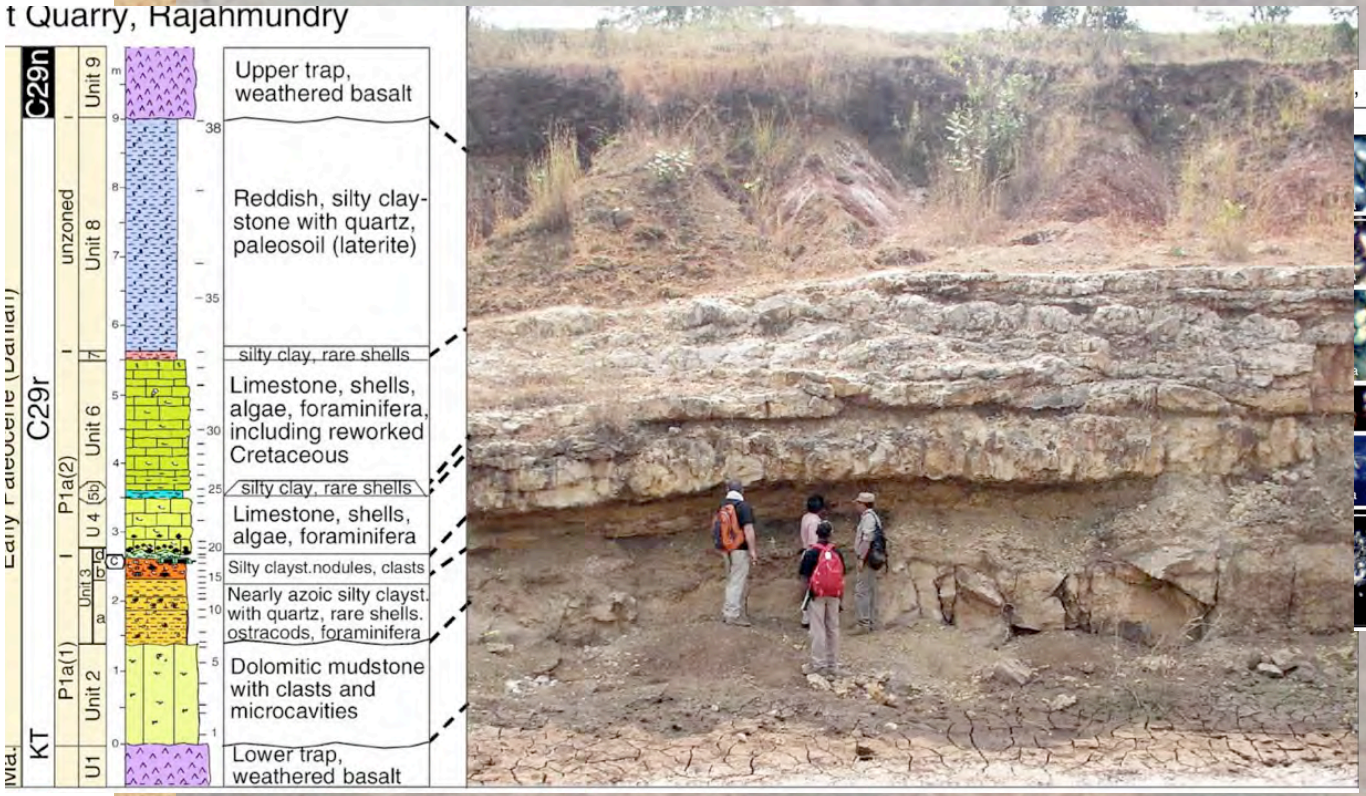
In India, dinosaurs walked during the eruptions. Shouldn't they have experienced the deleterious effets of volcanism?

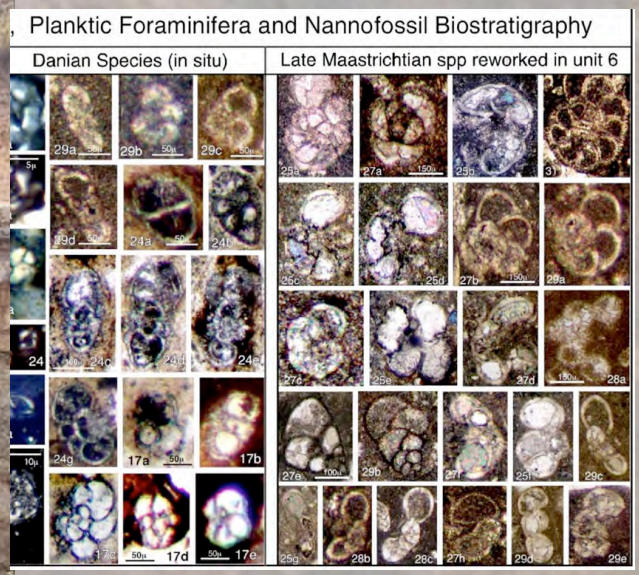
What can we say about the extinctions?
Due to Chicxulub Impact or Deccan traps?

Keller 2008, Rajahmundry traps

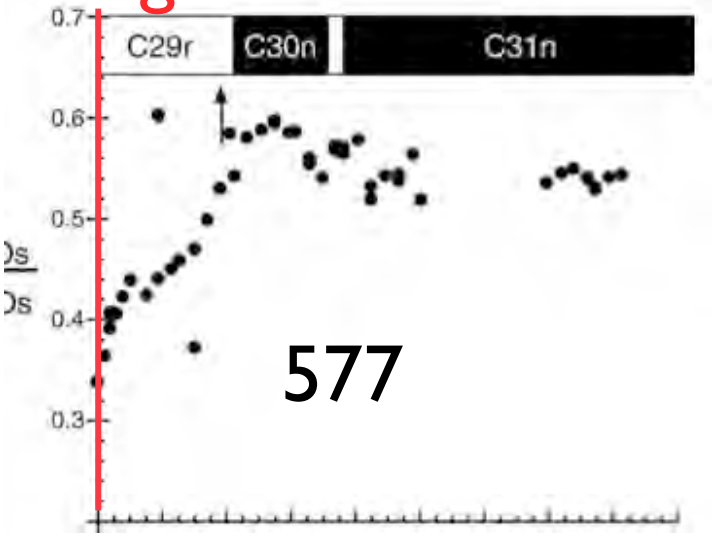
Not only dinosaurs, but also Paleocene foraminifera



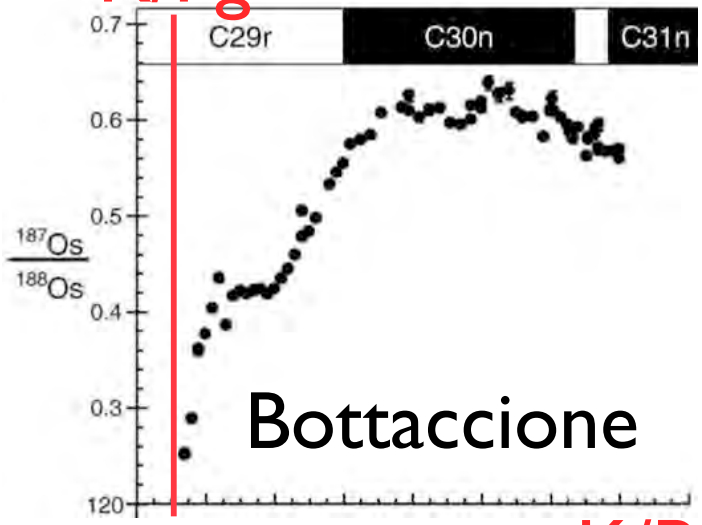




K/Pg



K/Pg

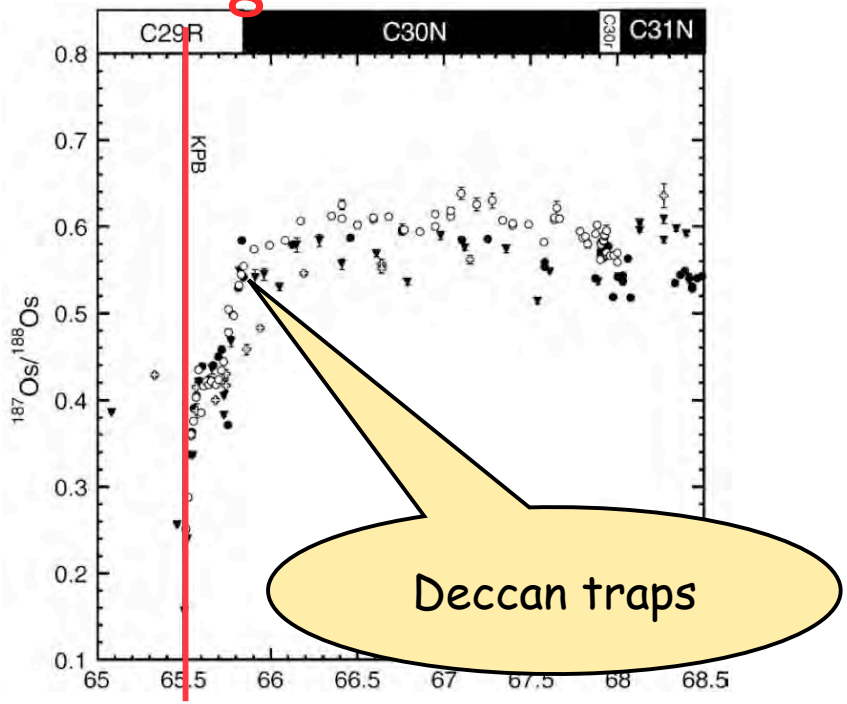


Ravizza et al

We see the extrusion of the Deccan trap lavaflows because of a shift in Osmium $^{187}Os/^{188}Os$ Isotope ratio in Ocean water

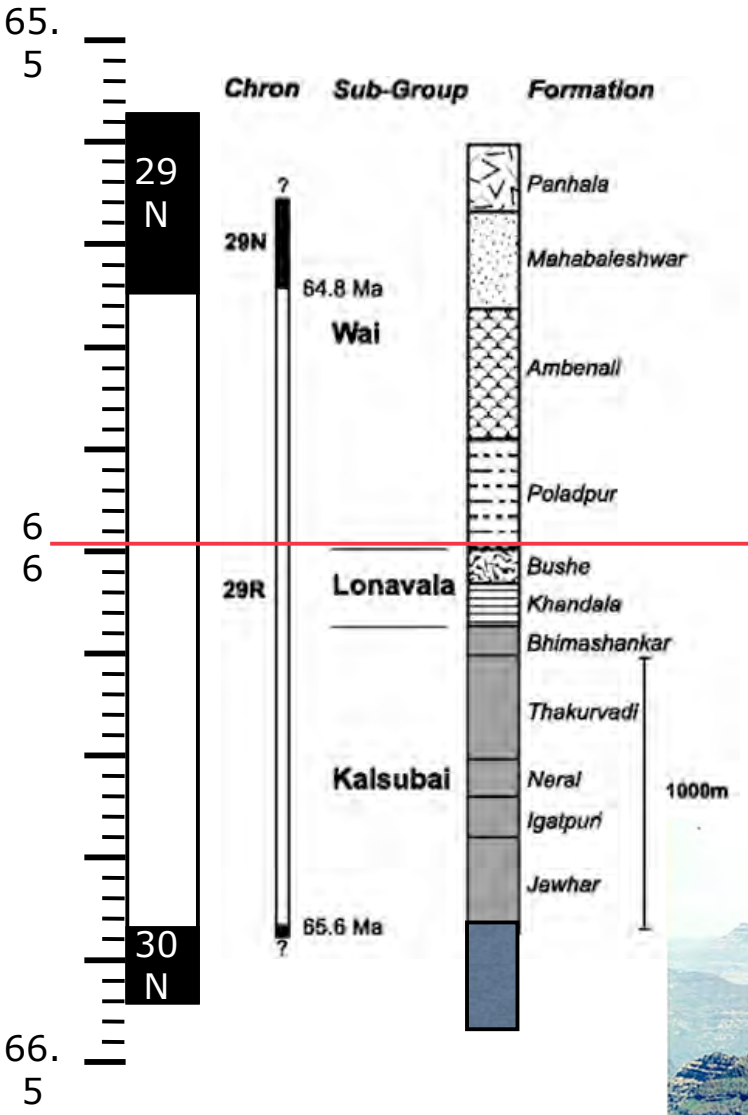
High dissolution of basaltic rock in ocean

K/Pg



Deccan Traps

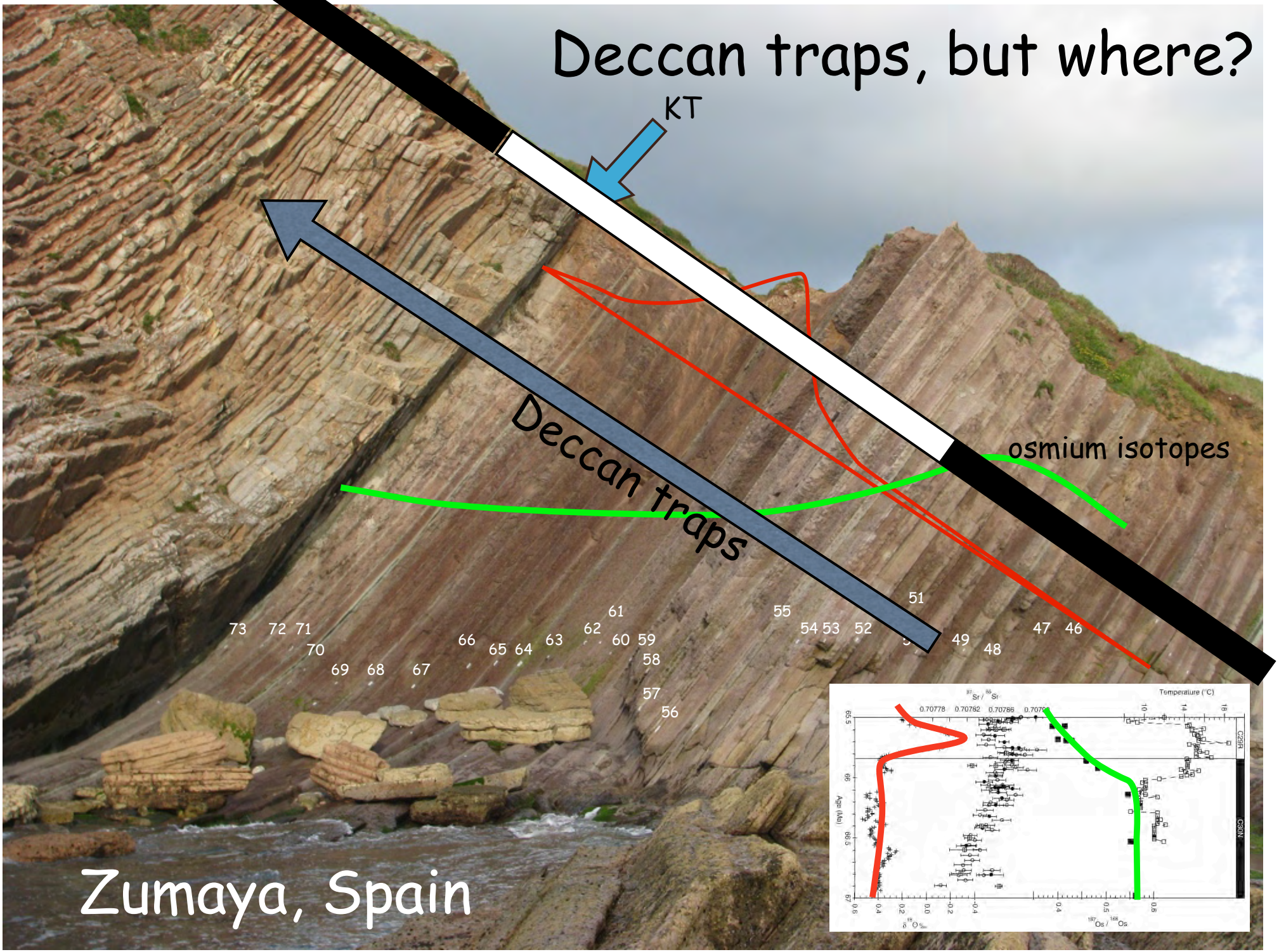
Osmium $^{187}Os/^{188}Os$ shift of seawater reflects dissolution of Deccan traps in ocean water




Deccan traps, but where?
K/Pg
73
72
71
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Zumaya, Spain

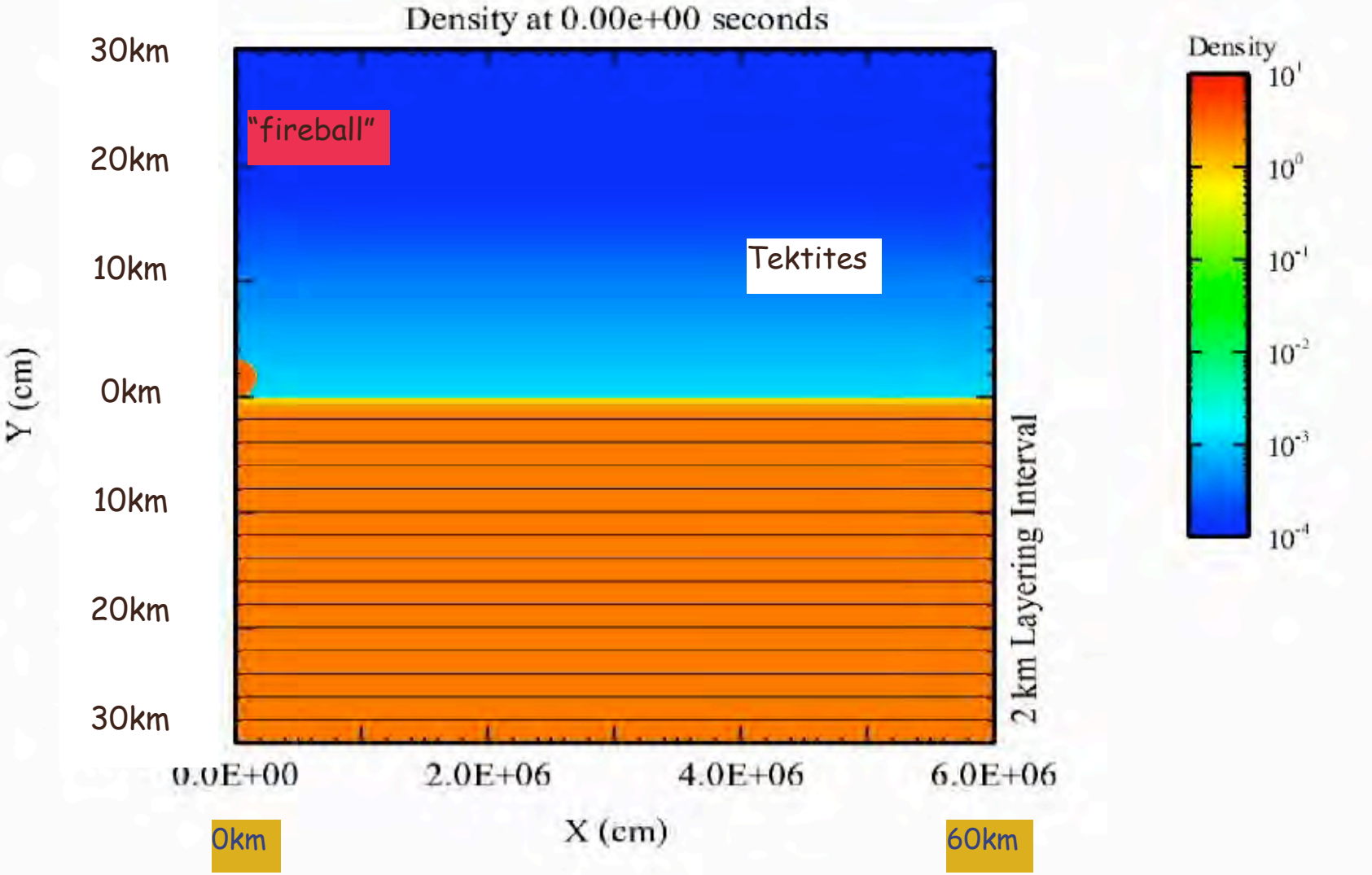

Deccan traps, but where?
K/Pg
precession cycles(+/- 21000yr
73
72
71
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Zumaya, Spain

Deccan traps, but where?



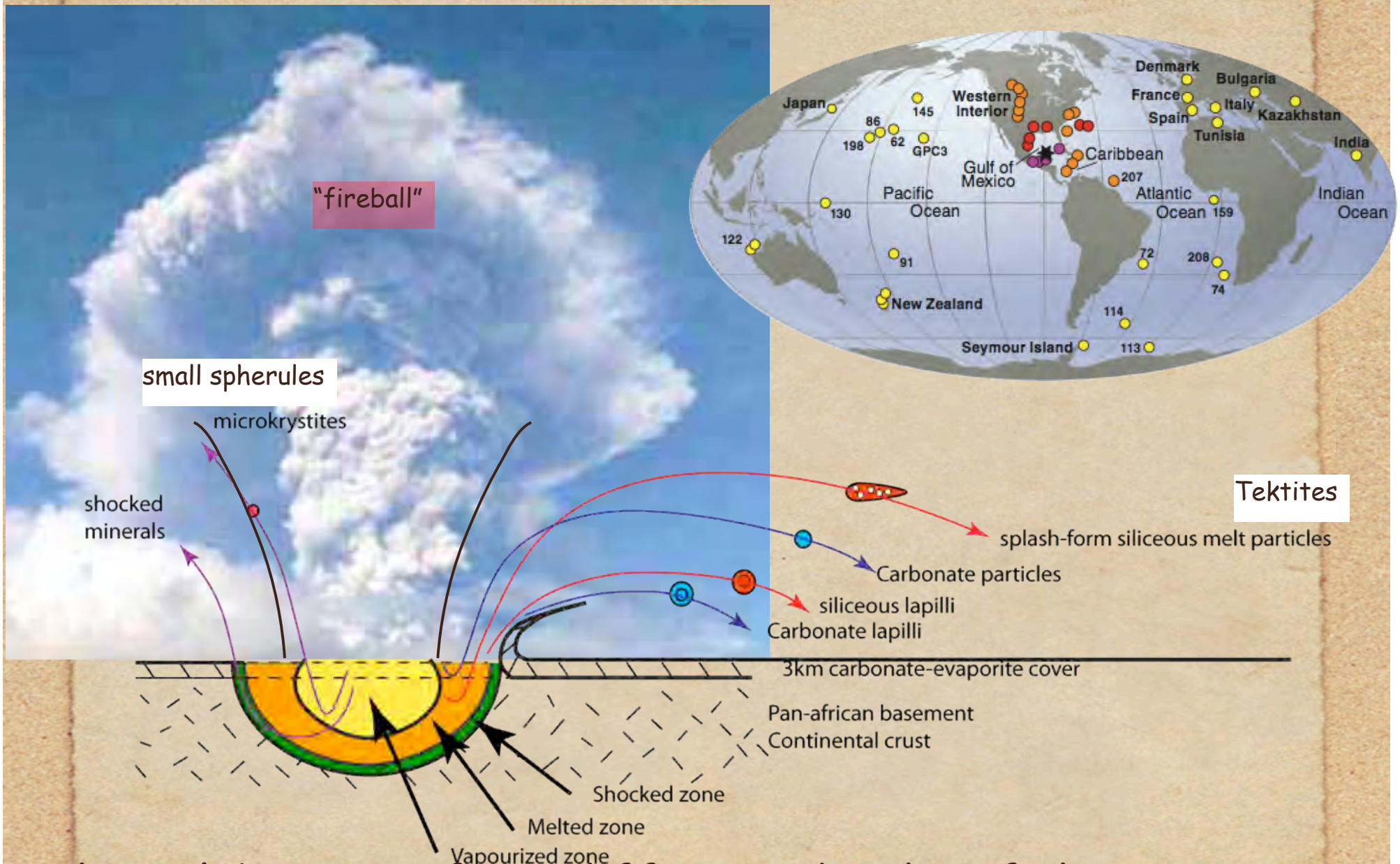
What kind of impact evidence?

Model of an impact of a 3.3km diameter asteroid



3.3 km Diameter Asteroid

What kind of impact evidence?

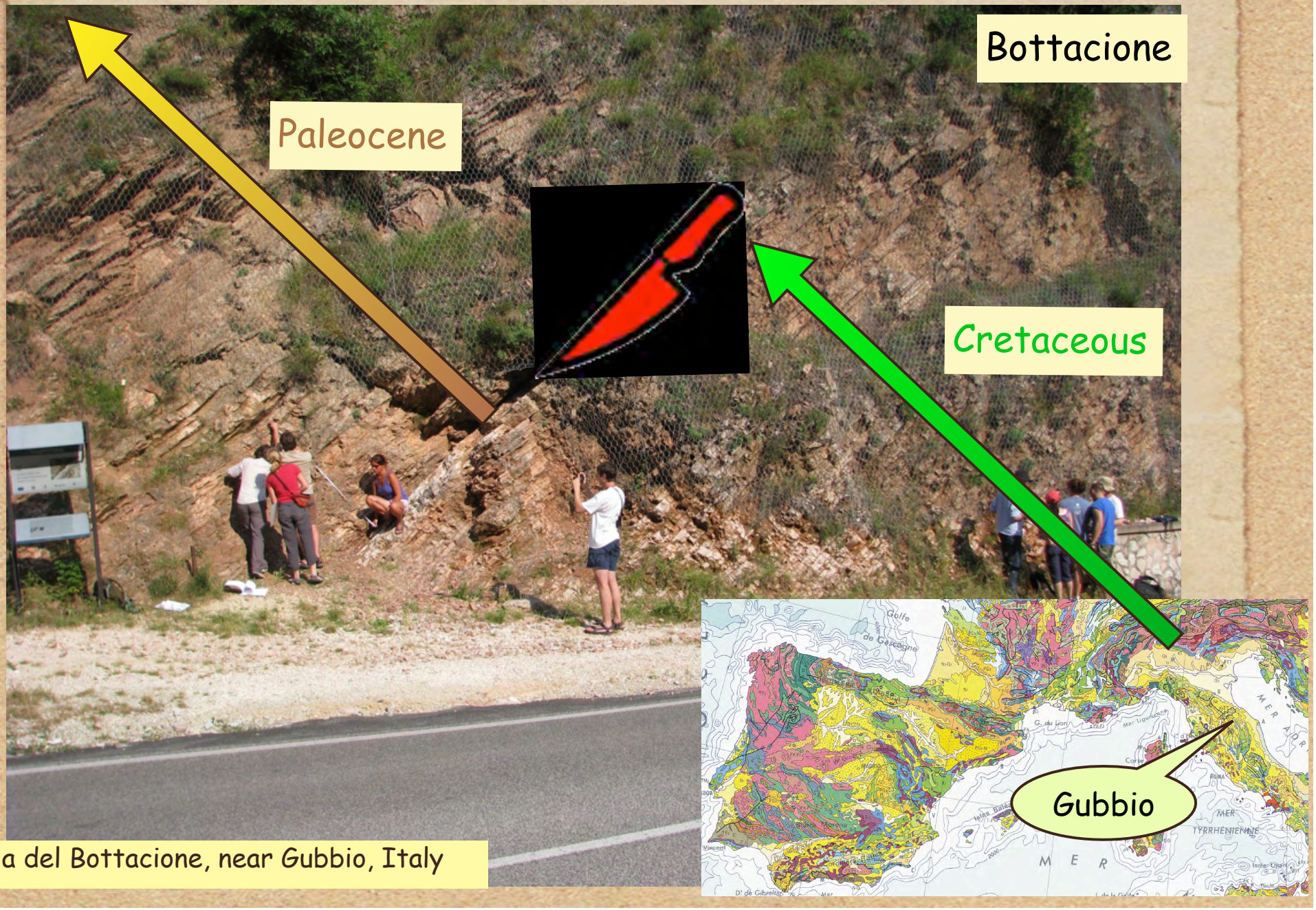


Chicxulub ejecta from different depths of the crust

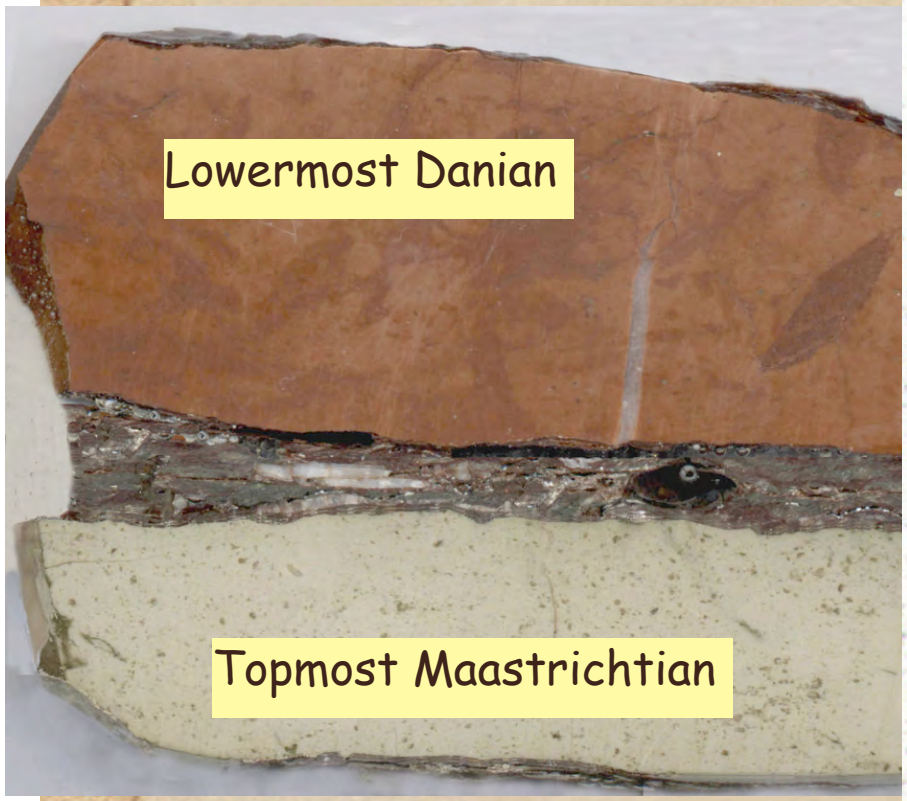
Global spread of several types of impact ejecta

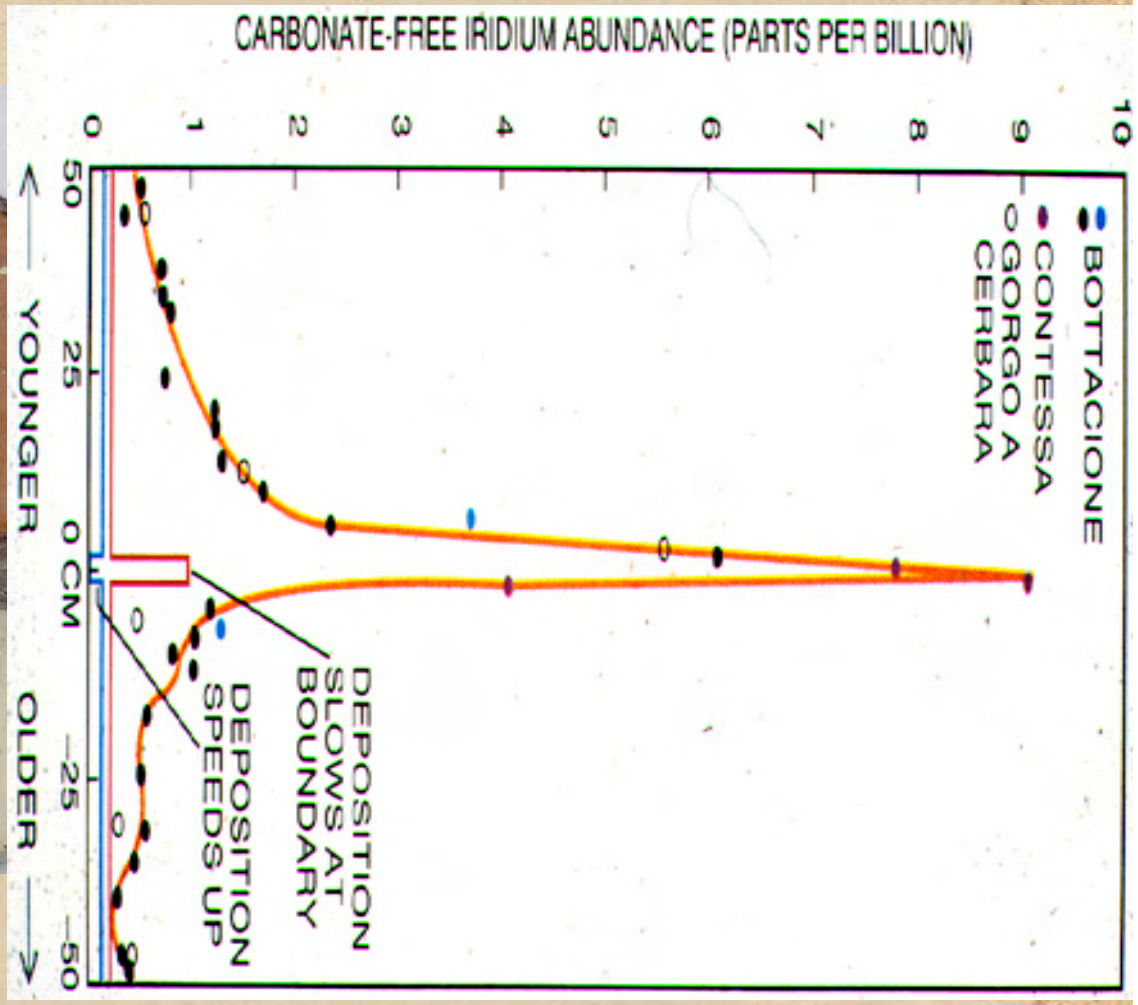
Schulte et al., Science 2010

Let's have a look at the 2000m deep bottom of the former Tethys ocean



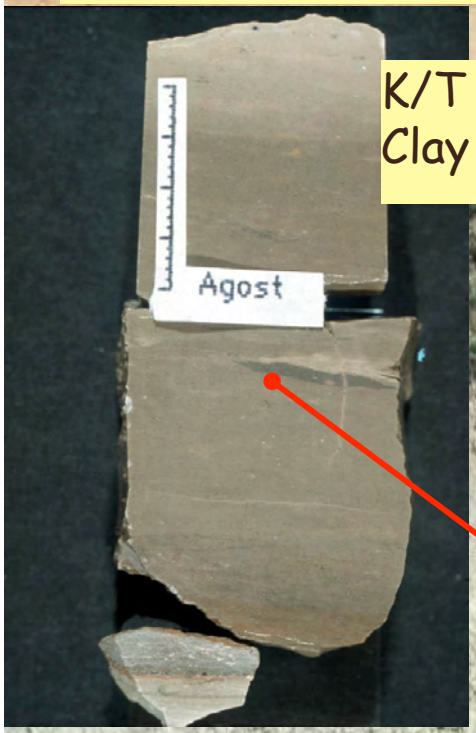
Gola del Bottacione, near Gubbio, Italy





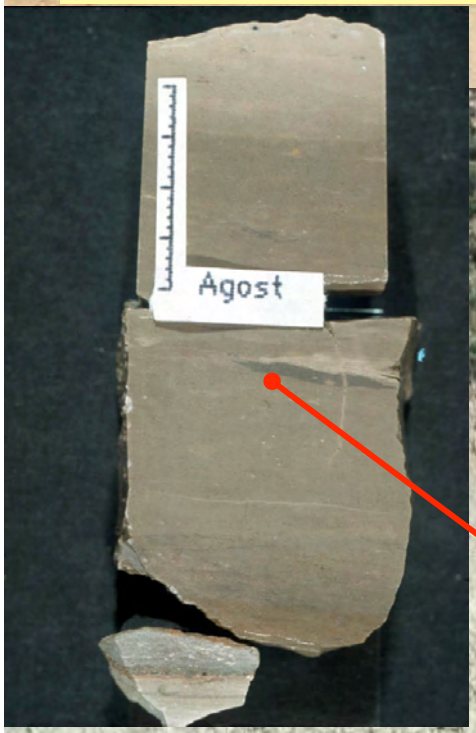
Iridium anomaly at Gubbio, Italy

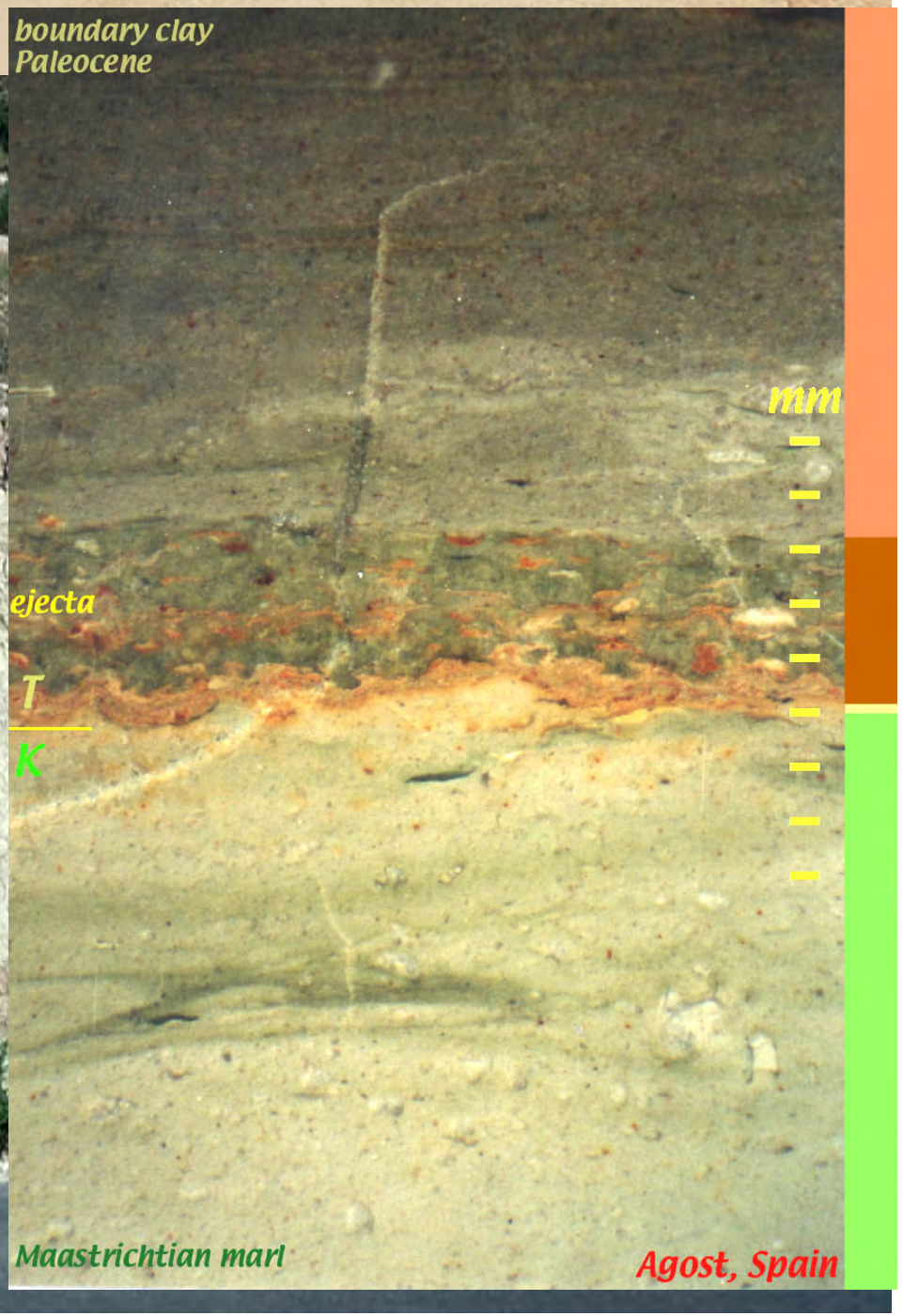
Agost, Zumaya and Caravaca, Spain: example of a detailed distal K/Pg transition



K/T boundary
Clay

Agost, Zumaya and Caravaca, Spain: example of a detailed distal K/Pg transition



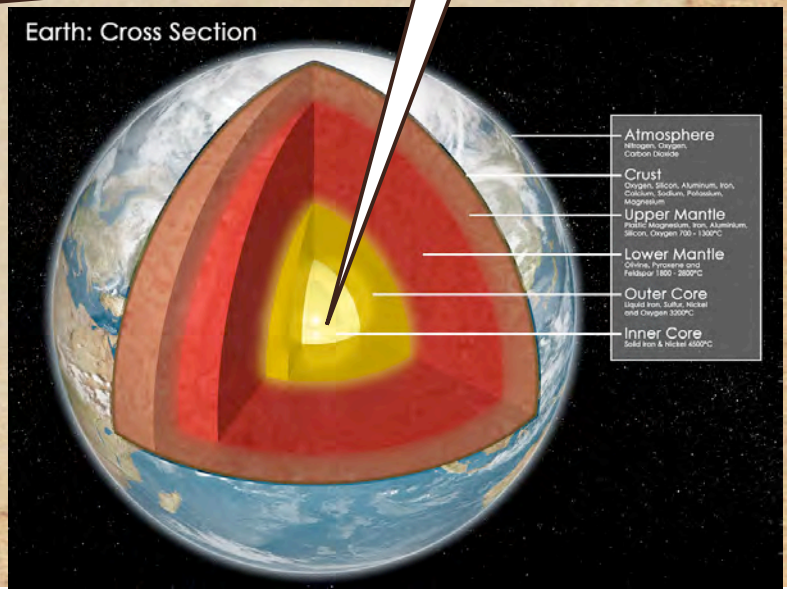


Impact evidence: iridium

0 10 20 ppb

iridium

iridium



Impact evidence: iridium, microkrystites)

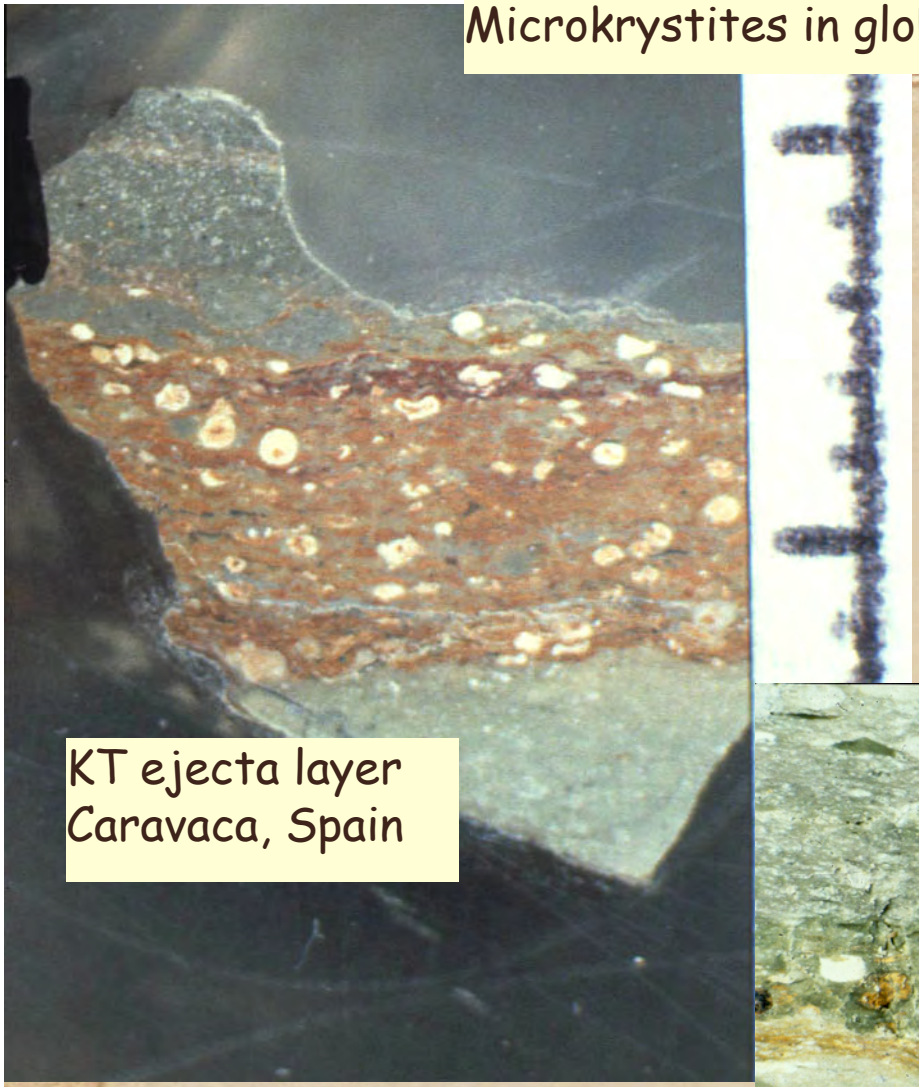
10 20 ppb

iridium

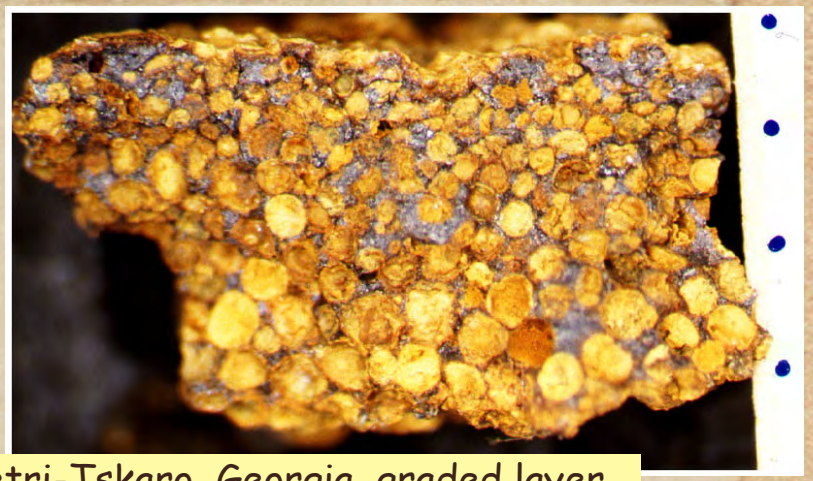
Microkrystites in ejecta layer

Caravaca, Spain

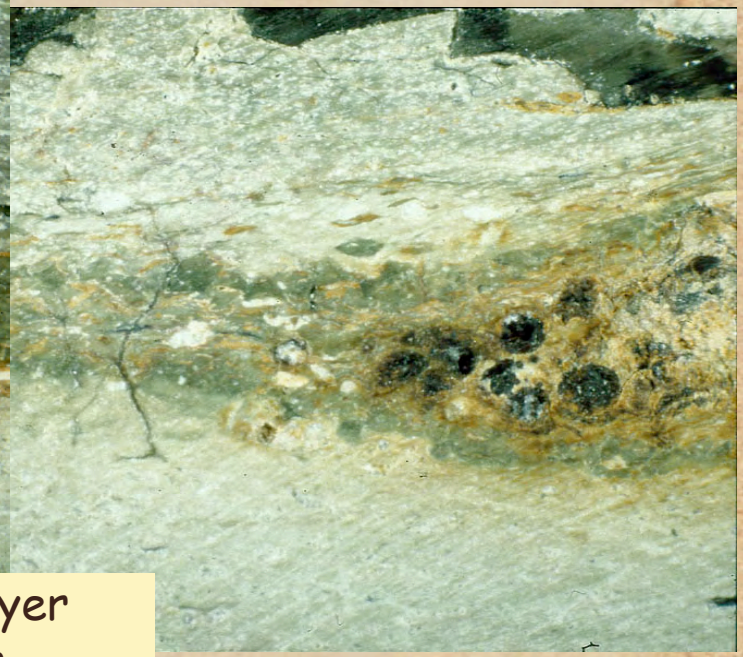
Microkrystites in global ejecta layer



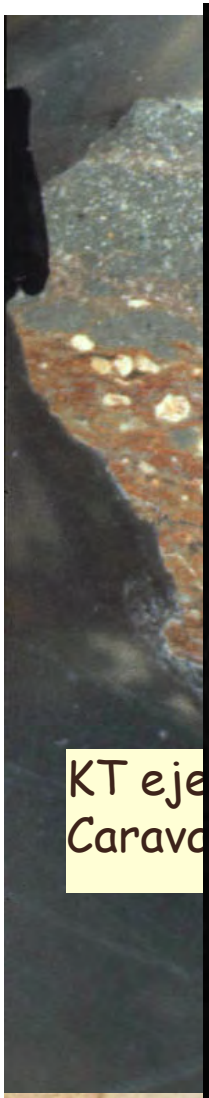
KT ejecta layer
Caravaca, Spain



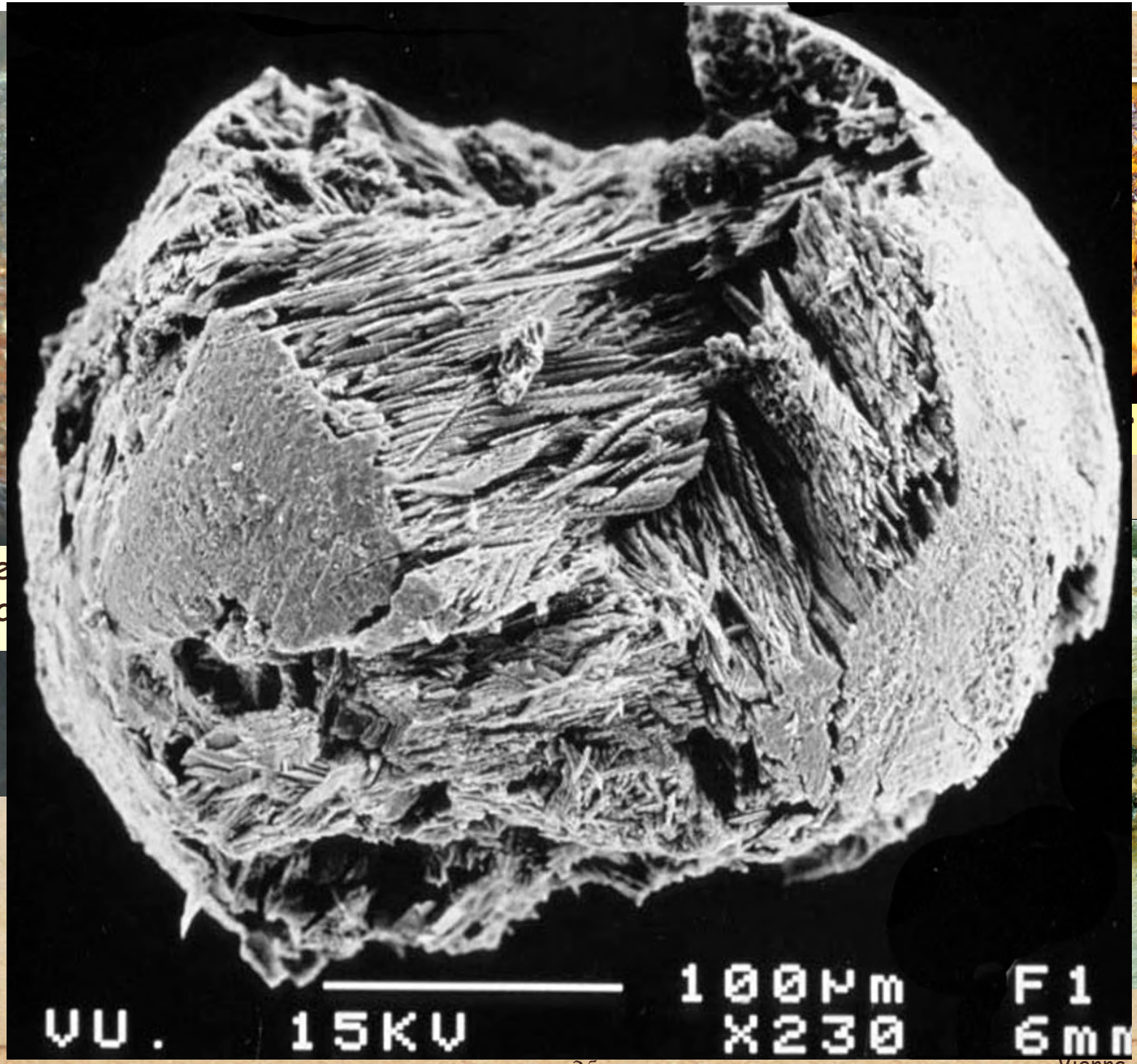
Tetri-Tskaro, Georgia, graded layer

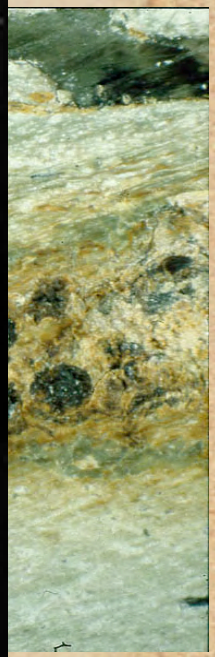


KT ejecta layer
Agost, Spain

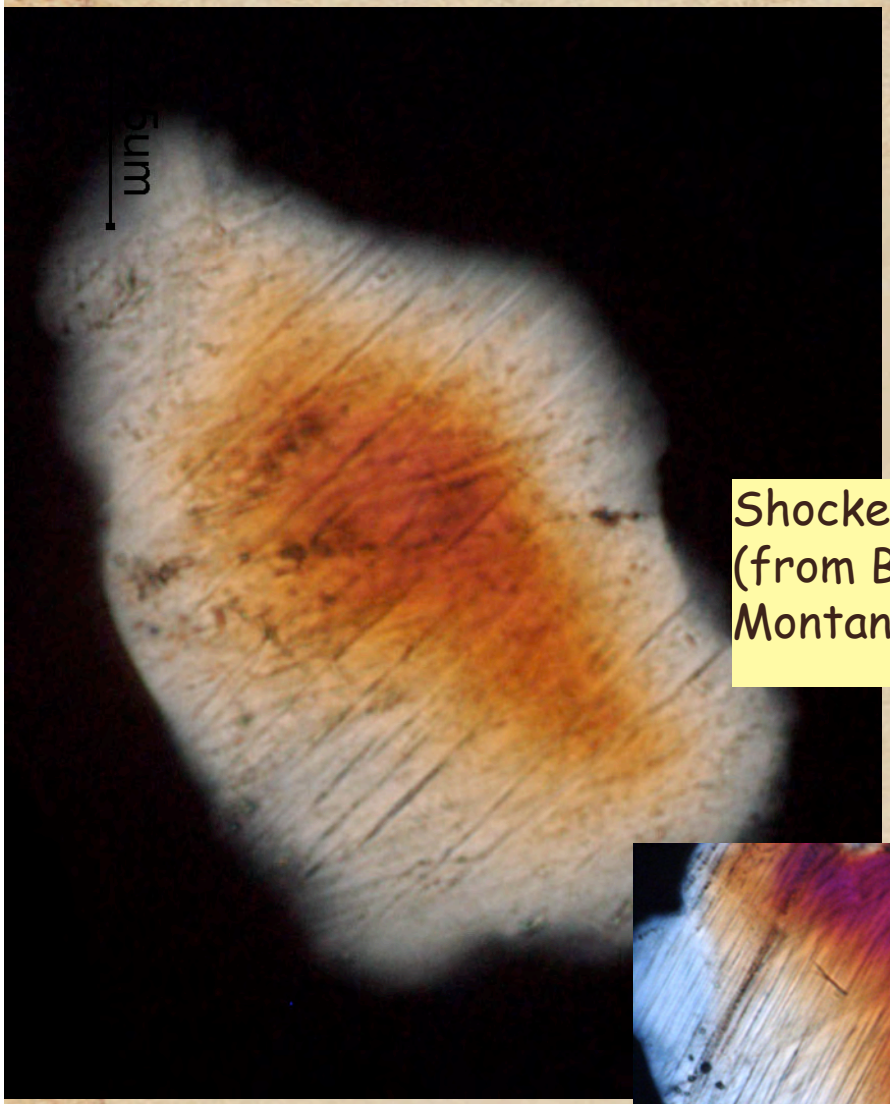


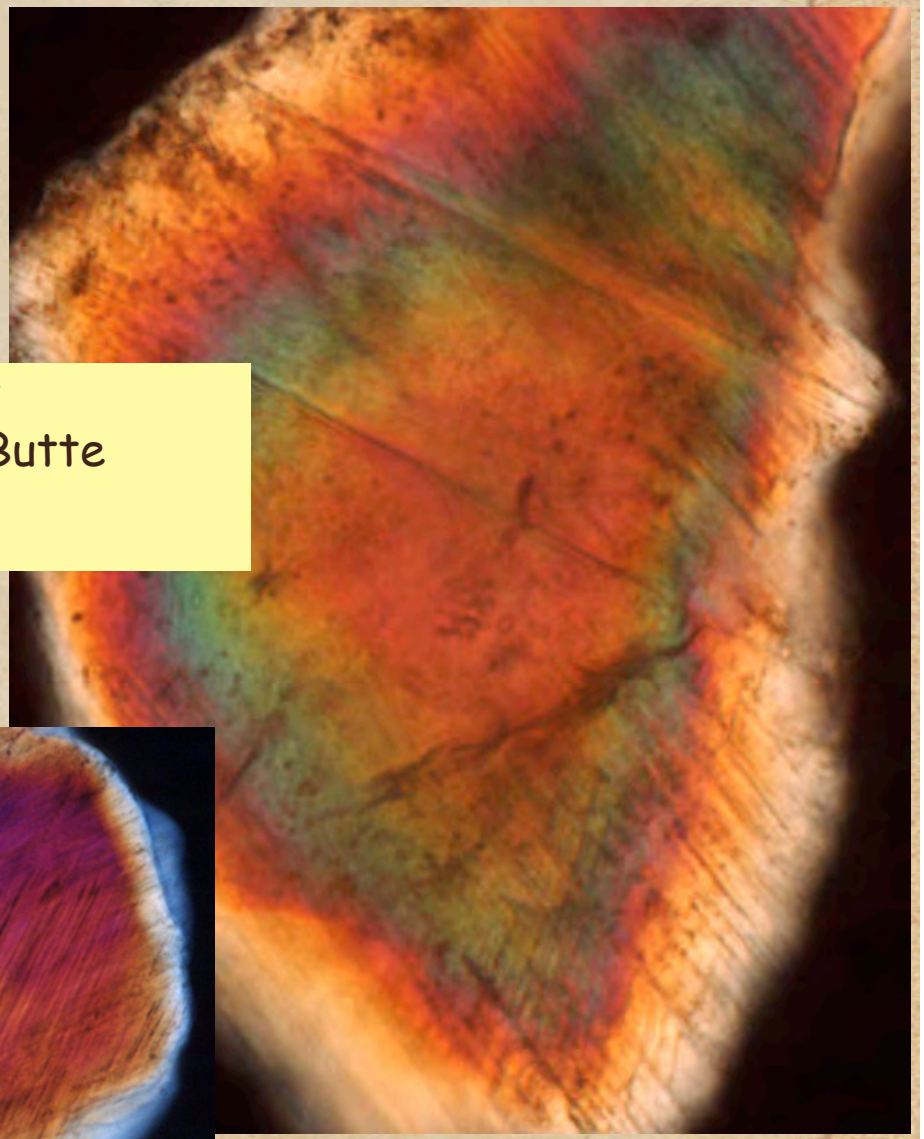
KT eje
Caravc

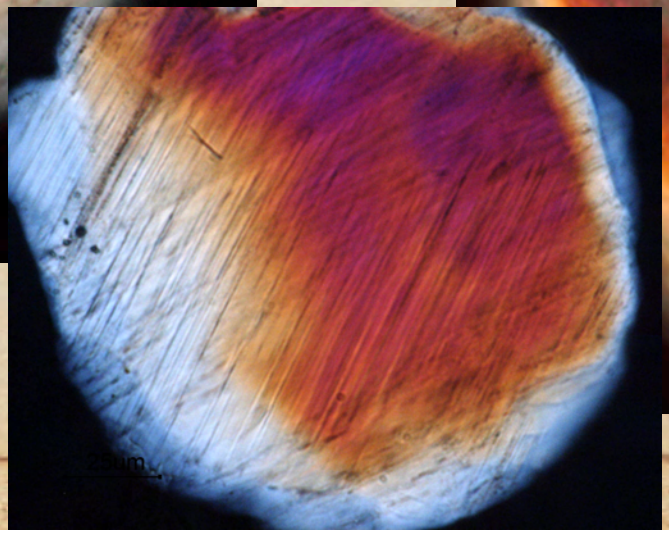




Impact evidence: iridium, Cr profile, microkrystites, shocked quartz

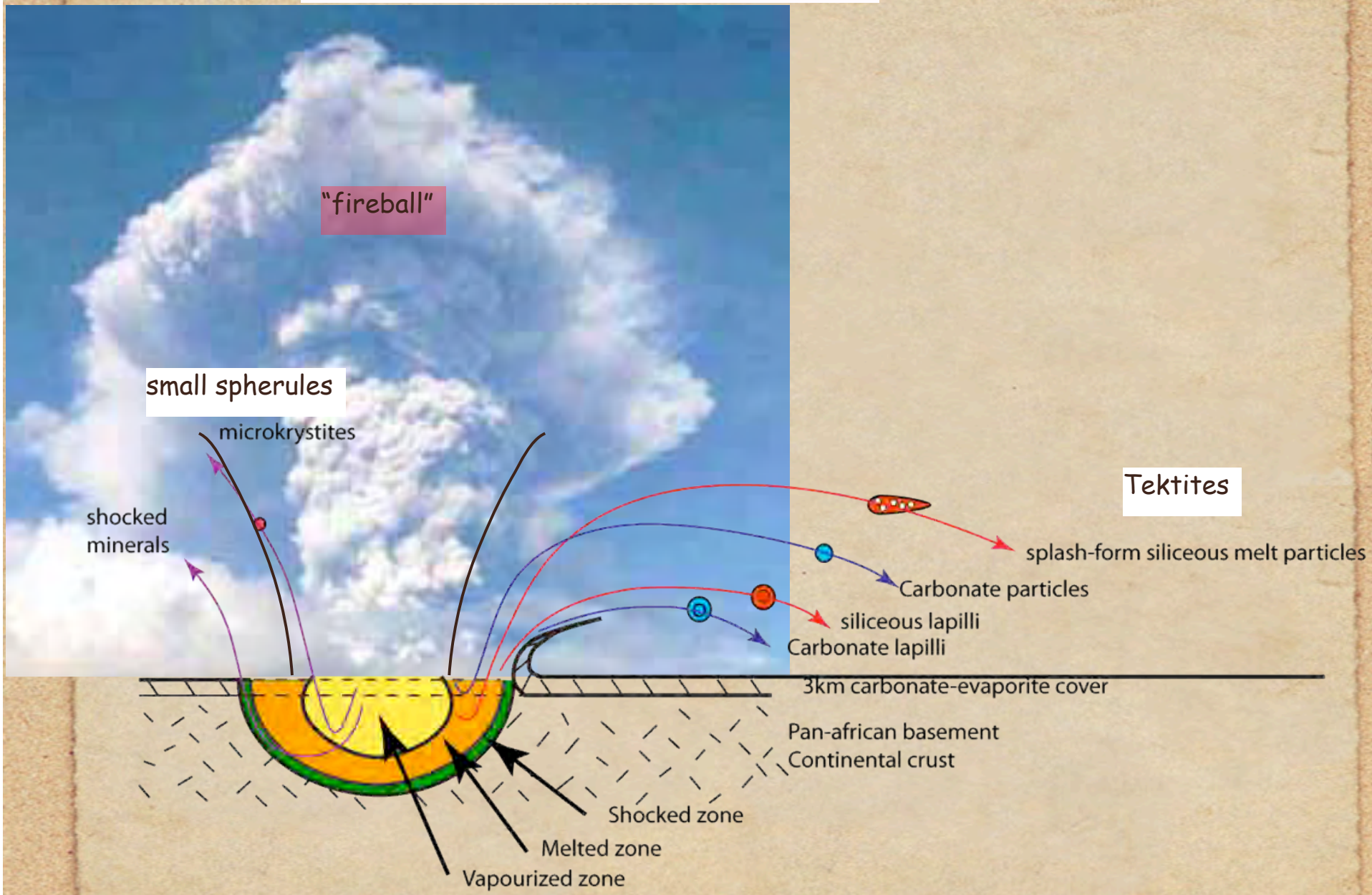




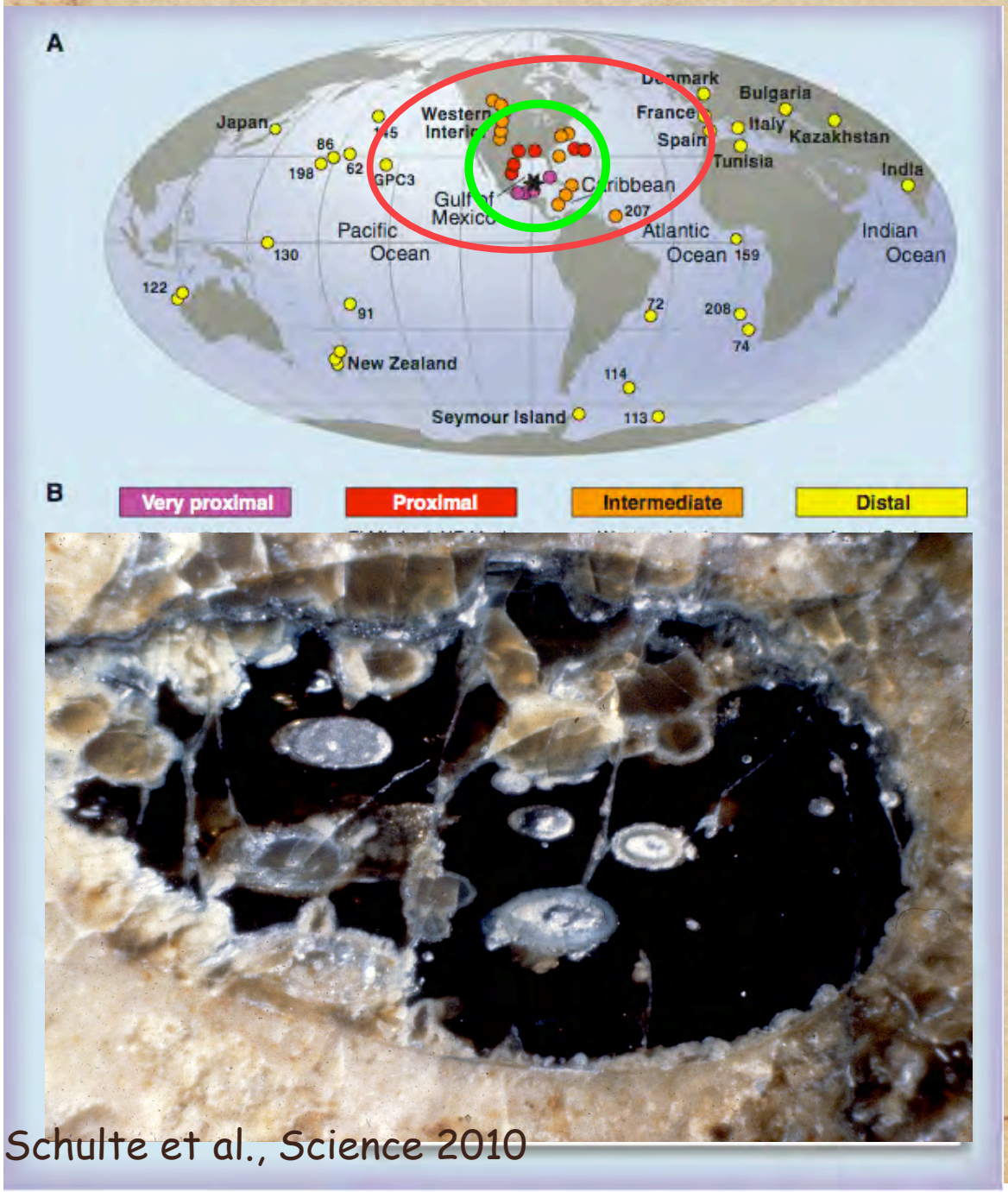


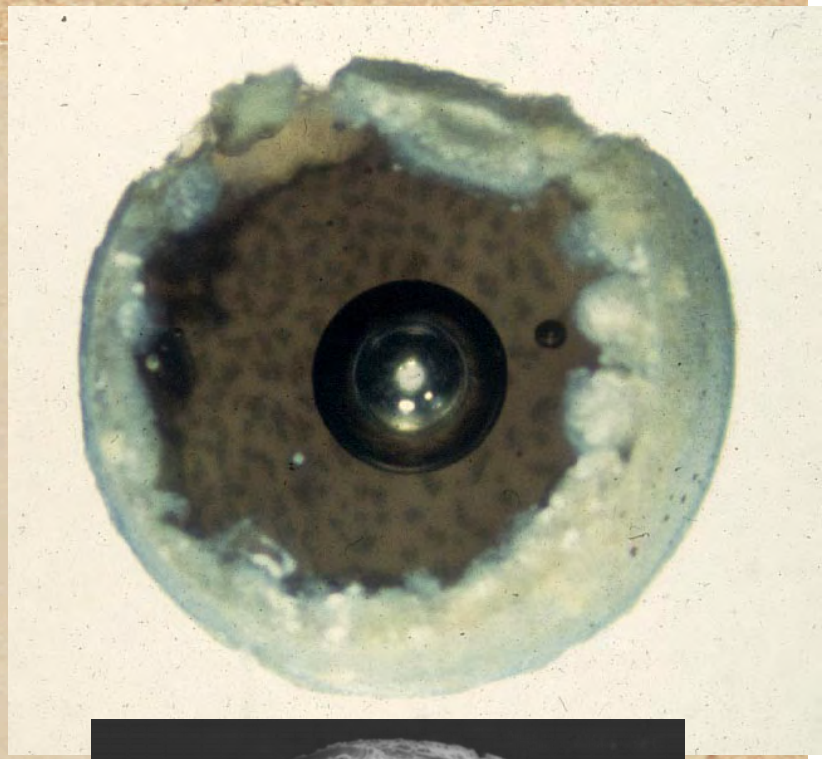
Shocked quartz
(from Brownie Butte
Montana)

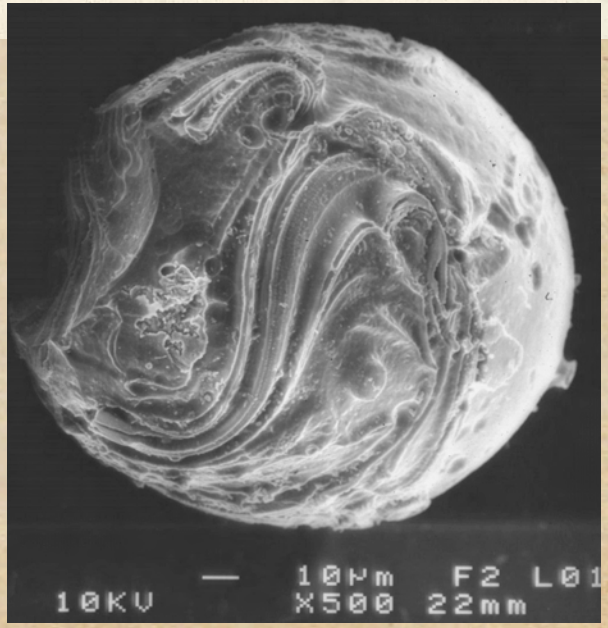
Chicxulub ejecta



Tektites



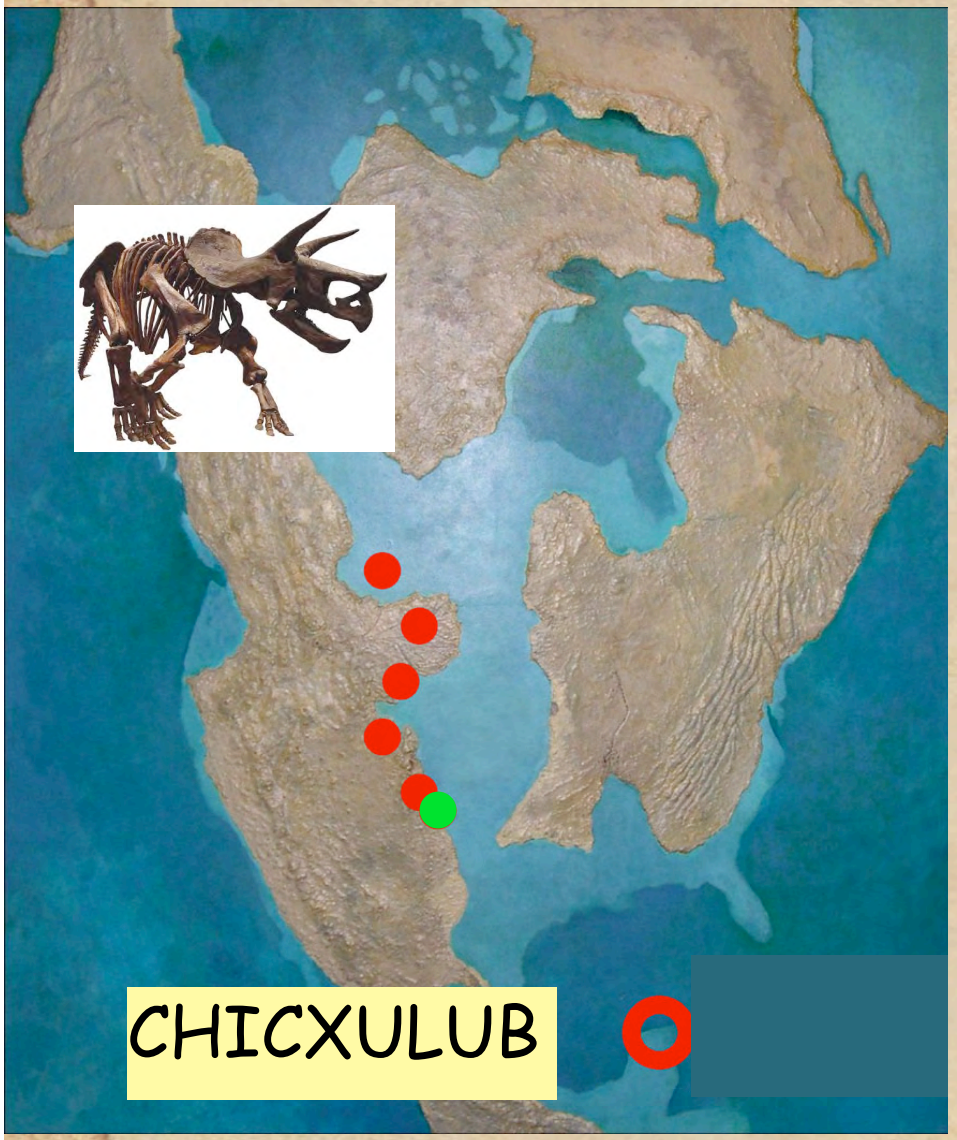




Schulte et al., Science 2010

Vienna, gift-egu2011

Closer to Chicxulub, thicker ejecta layer.



Raton Basin, New Mexico

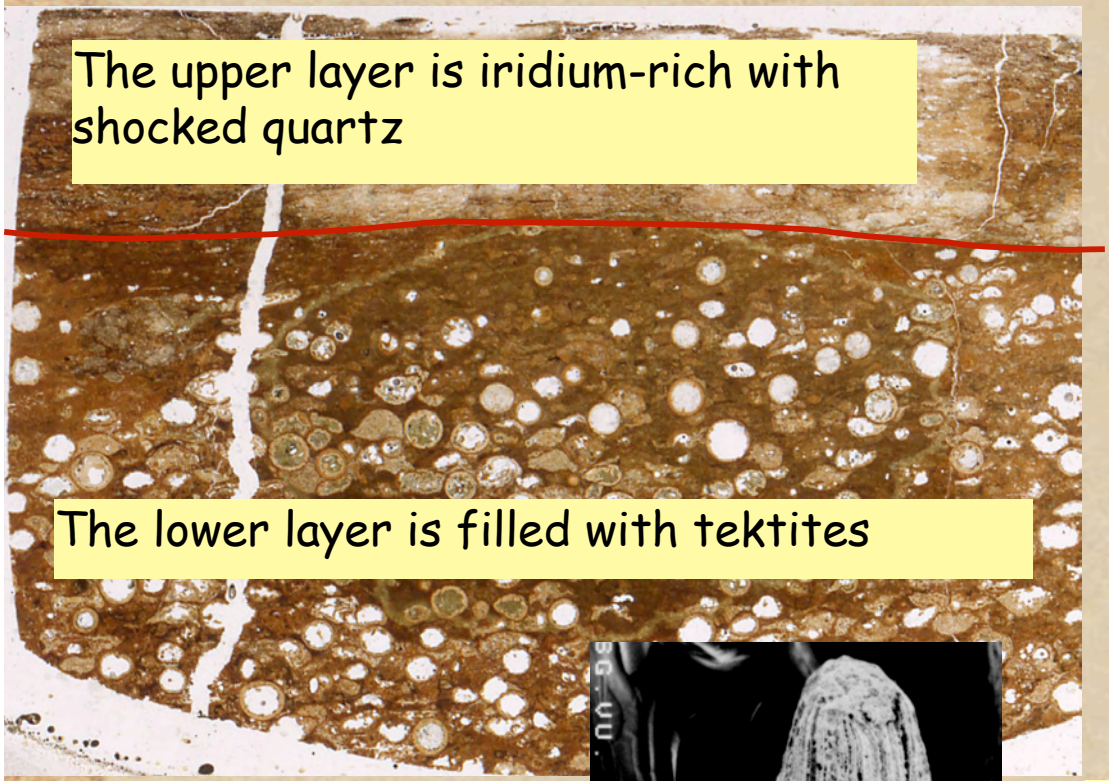
K/T boundary ejecta layer is a "Dual Layer"; exclusively in coals

In the Western Interior

Impact ejecta are always in coals

Madrid Railroad, Colorado

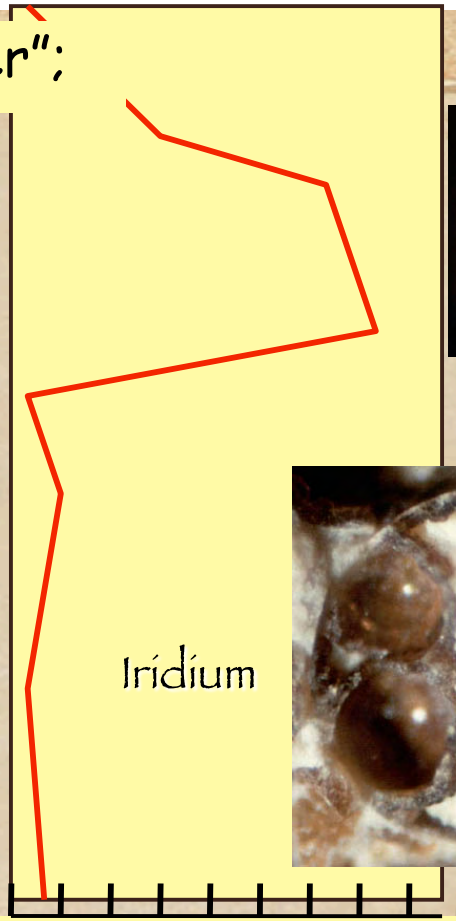
K/T boundary ejecta layer is a "Dual Layer";

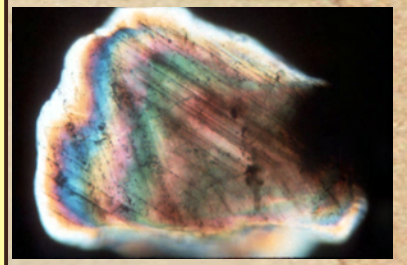


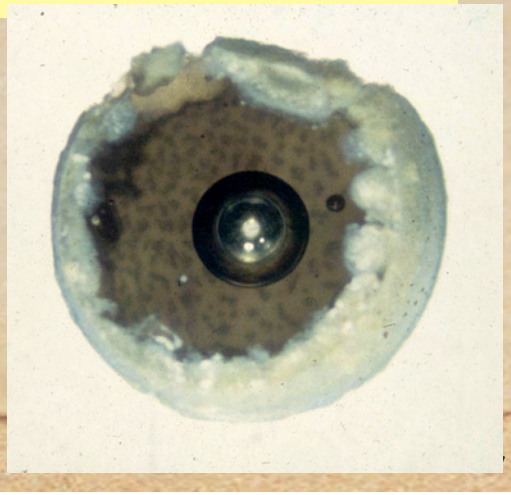
The upper layer is iridium-rich with shocked quartz

The lower layer is filled with tektites

Dogie Creek, Wyoming

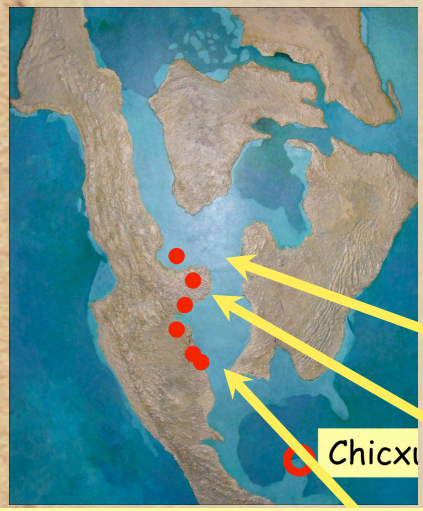






K/T boundary ejecta layer is a "Dual Layer";

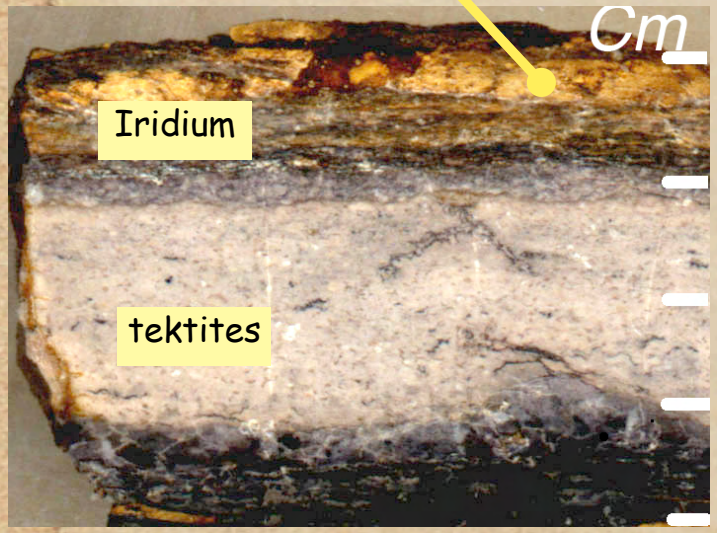
extends for over 2000km in the western interior

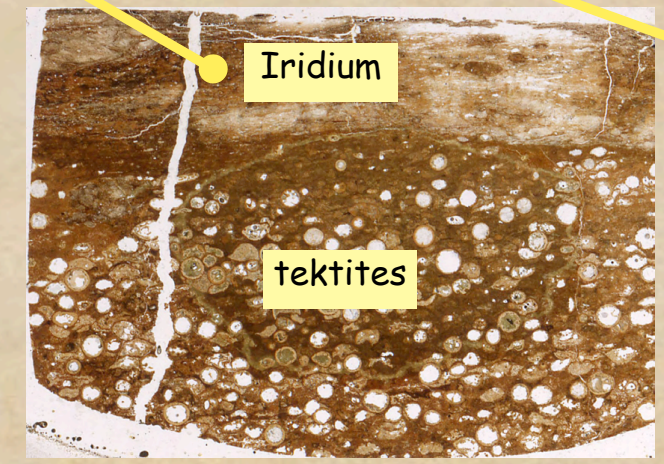


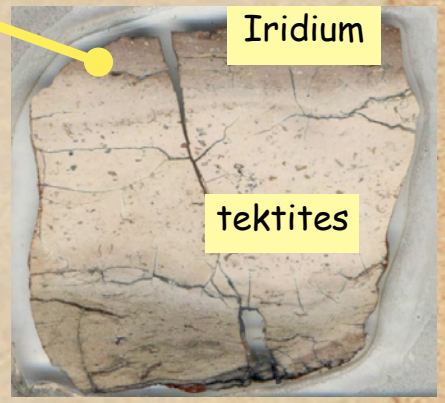
Raton, Nw Mexico

Dogie Creek, Wyoming

Brownie Butte, Montana



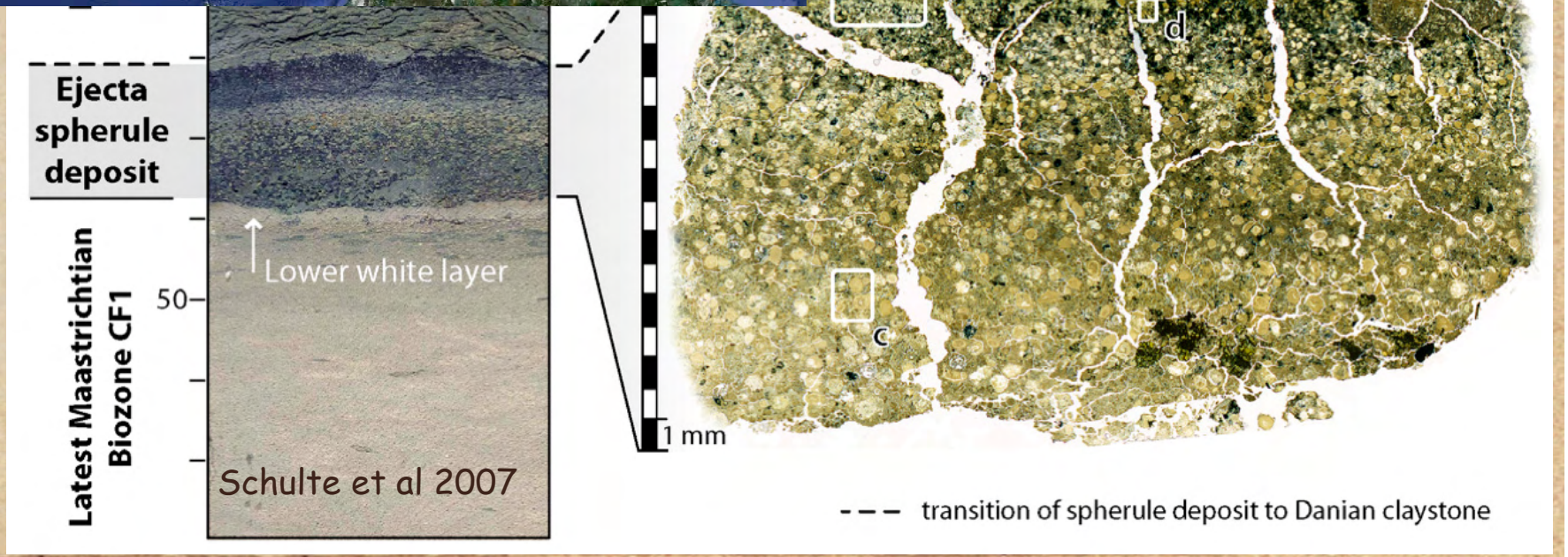




K/T boundary ejecta layer is a "Dual Layer";

and at ODP Leg 207 at the same distance from Chicxulub

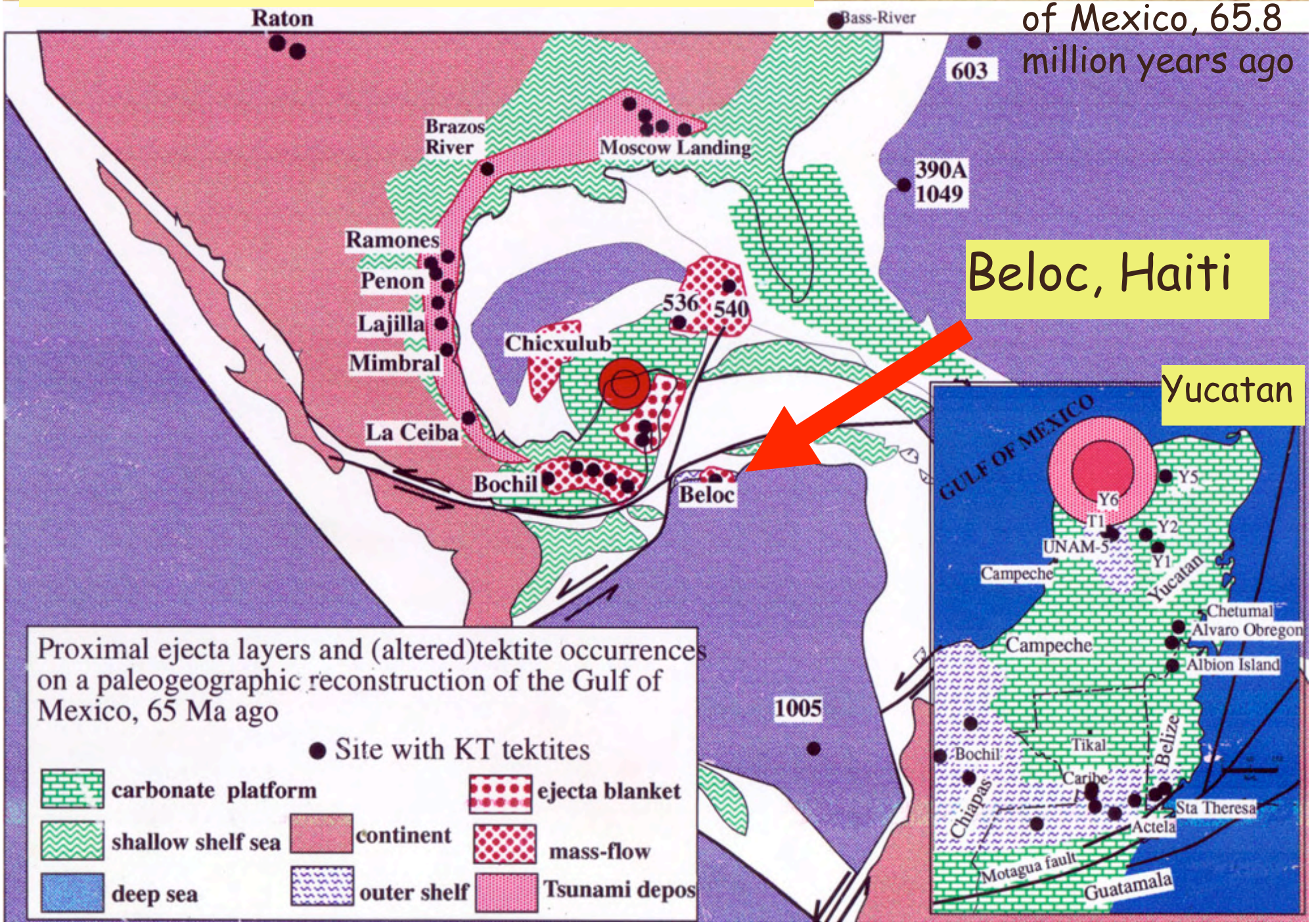
Schulte et al Geochimica2009



Vienna, gift-egu2011

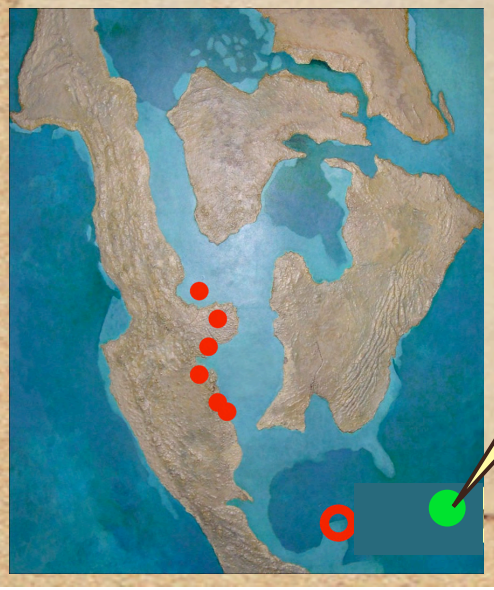
Closer to Chicxulub, thicker ejecta layer.

Map of the Gulf of Mexico, 65.8 million years ago

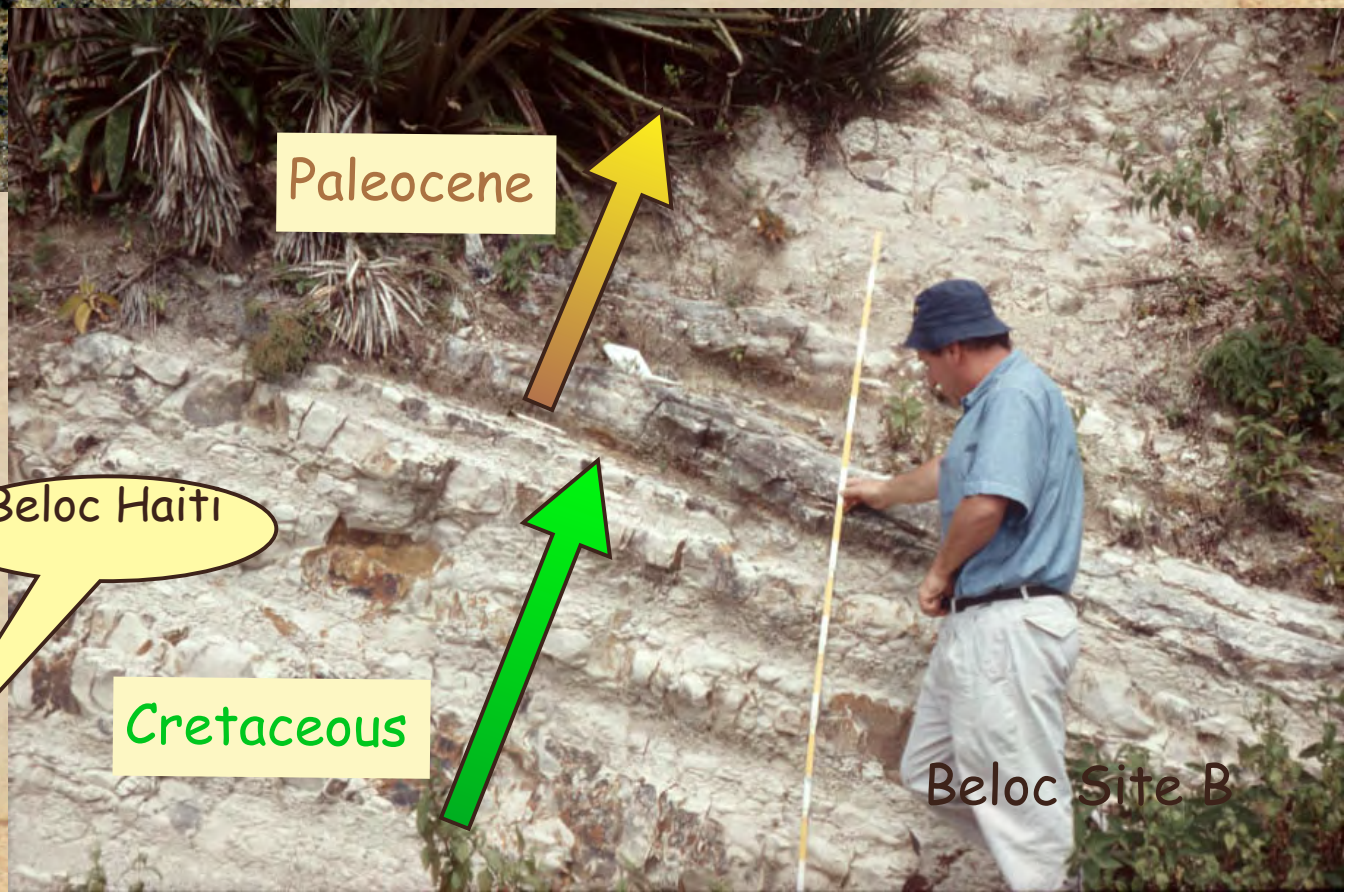


Closer to Chicxulub, thicker ejecta layer.

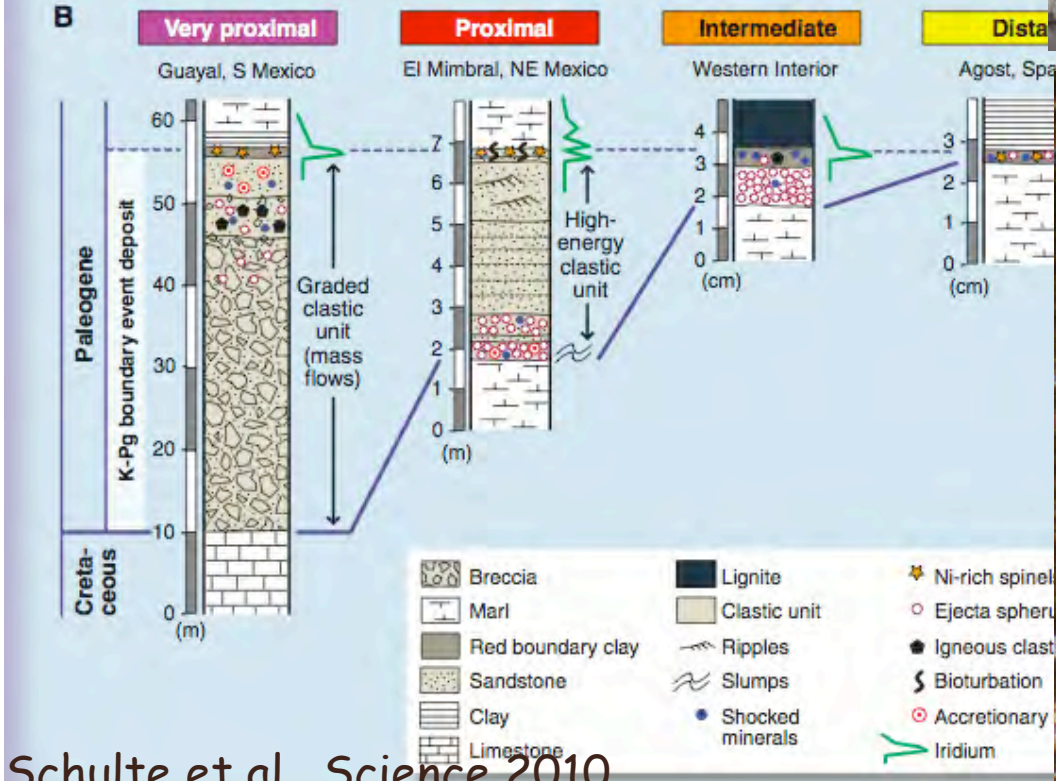
Tektites from Beloc, Haiti
Glass blebs ejected from
Chicxulub crater

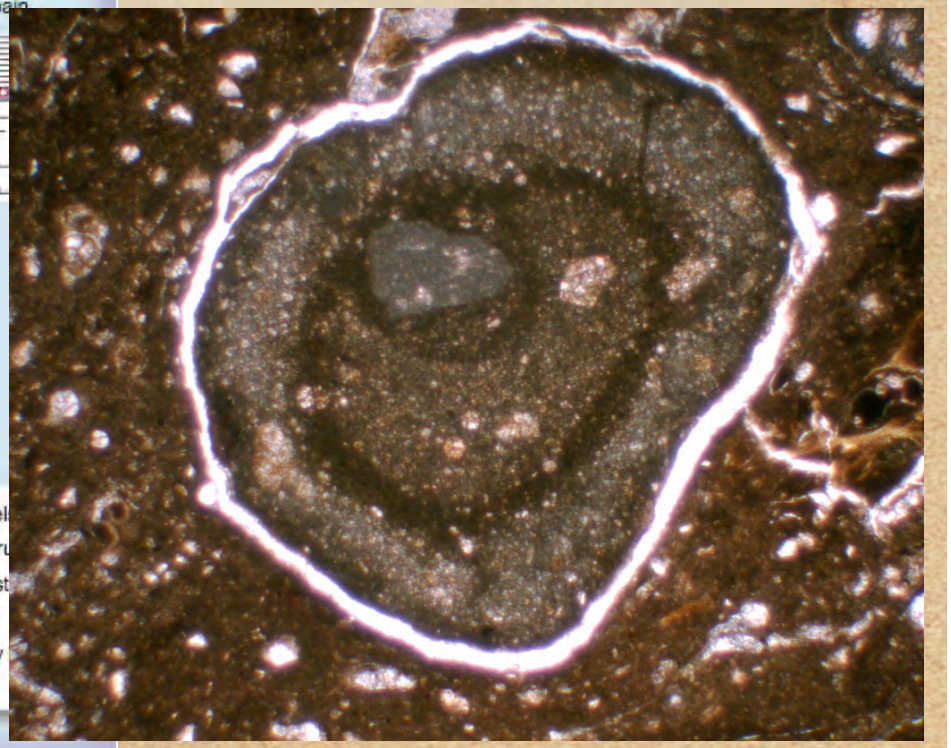


Beloc Haiti



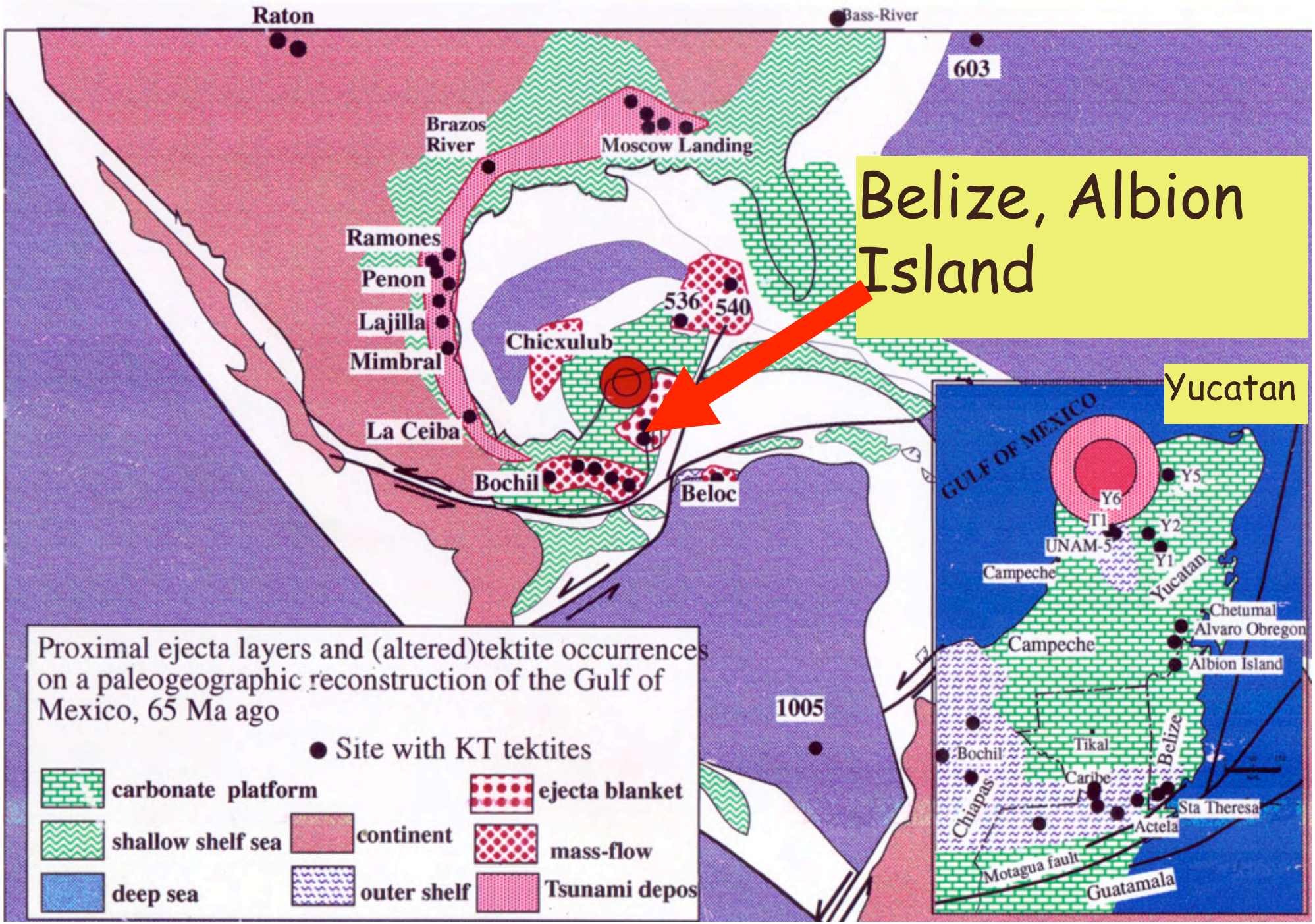
Accretionary lapilli



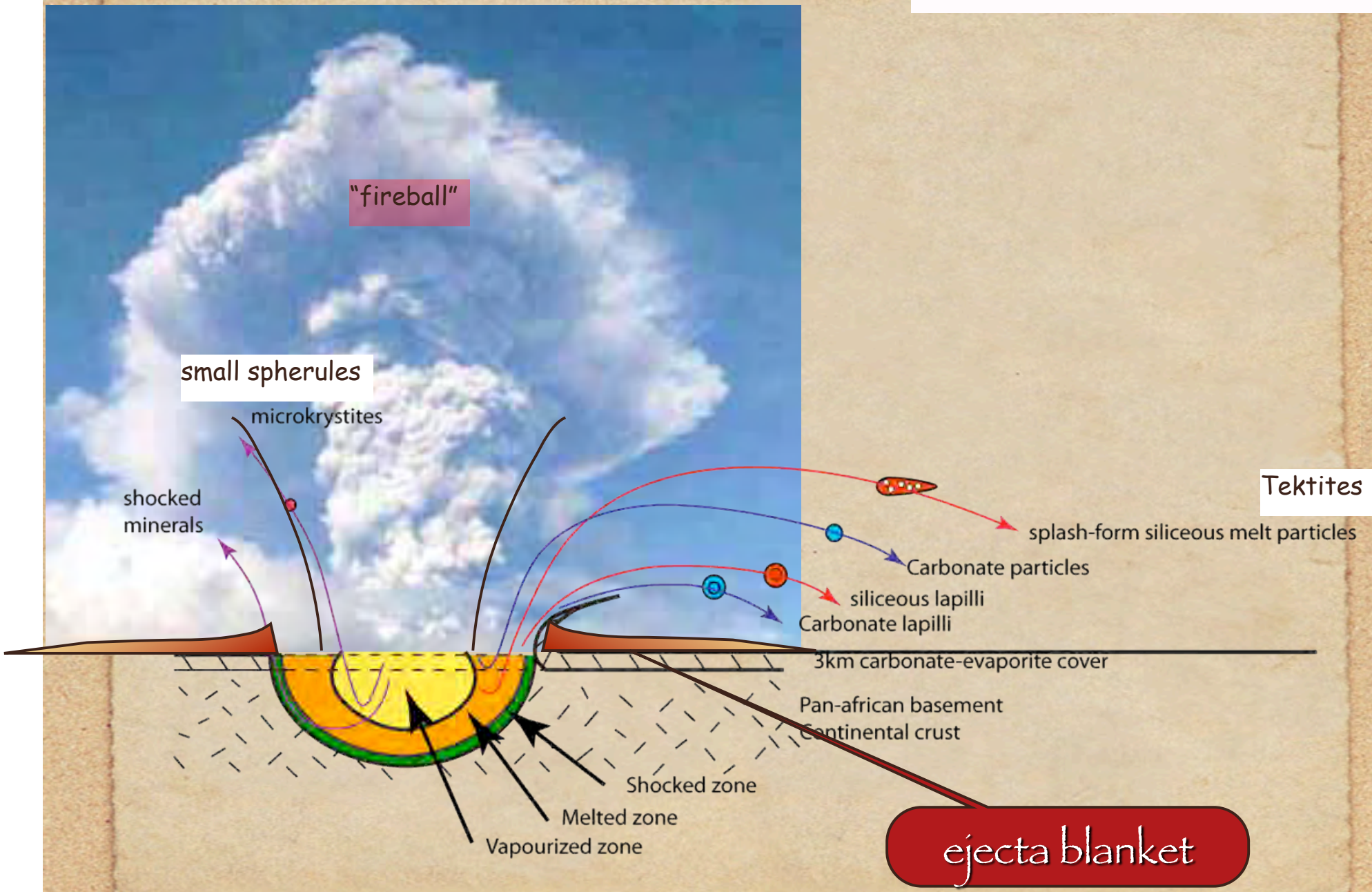


Schulte et al., Science 2010

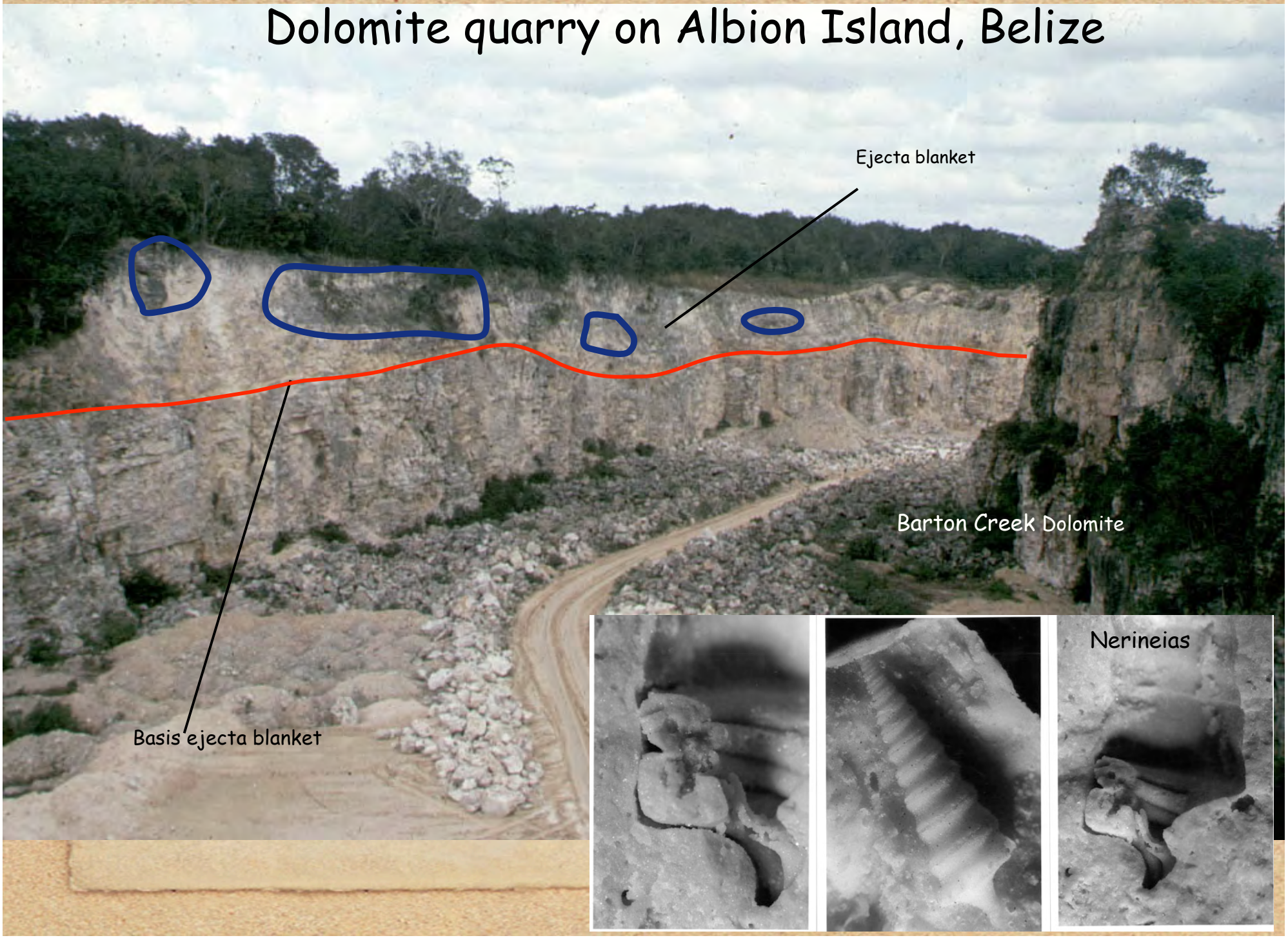
Map of the Golf of Mexico, 65.8 million years ago



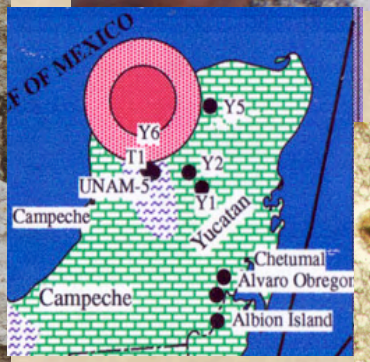
Chicxulub ejecta



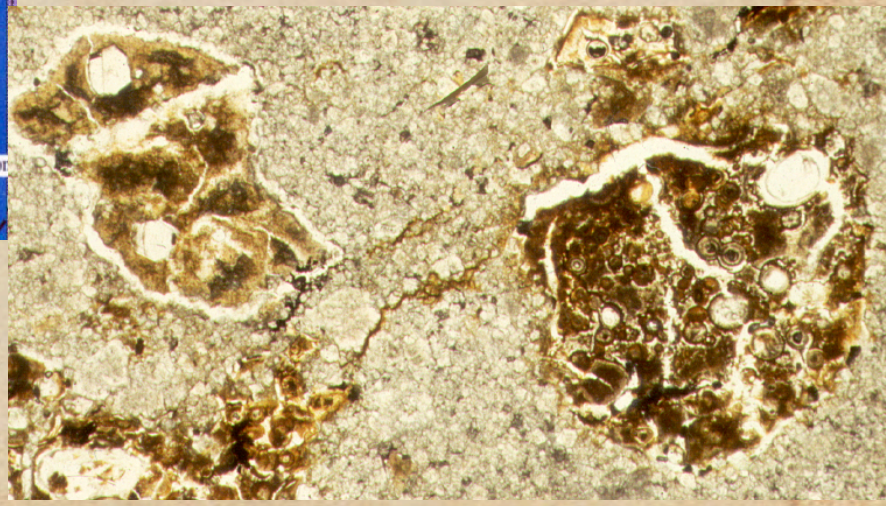
Dolomite quarry on Albion Island, Belize



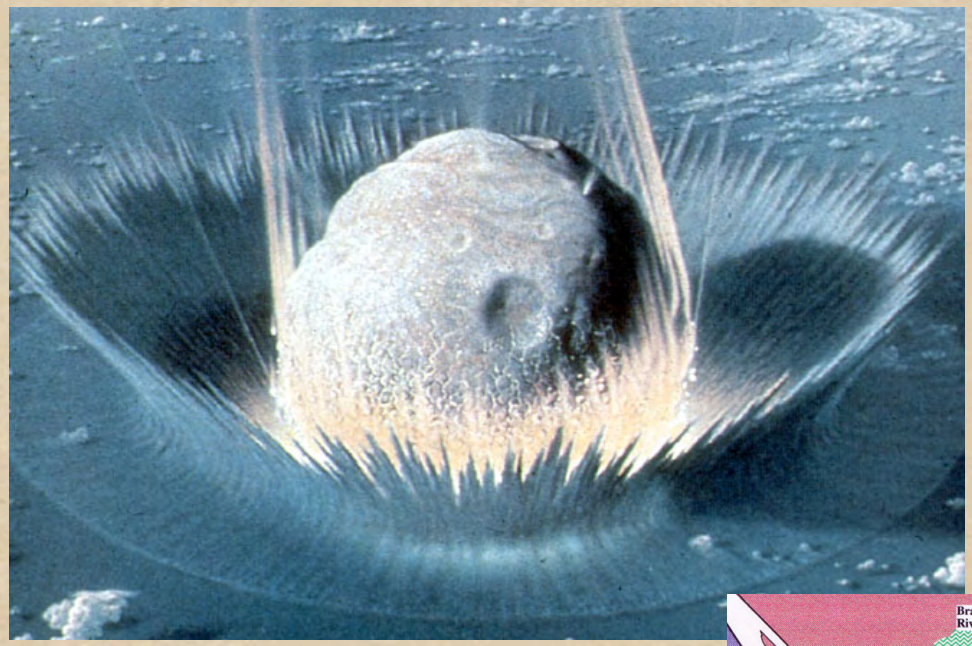
DIAMICTITE
Rio Hondo bij Chetumal

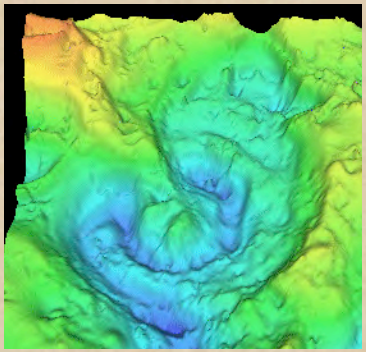


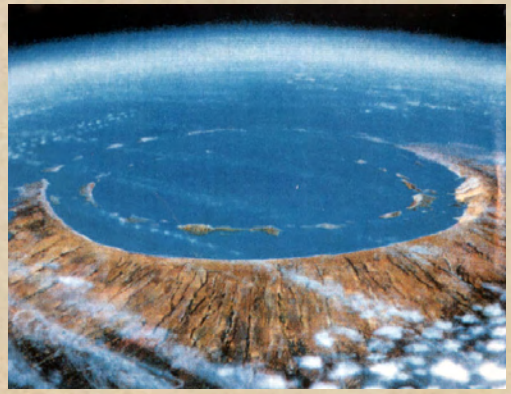
Green blebs of altered glass

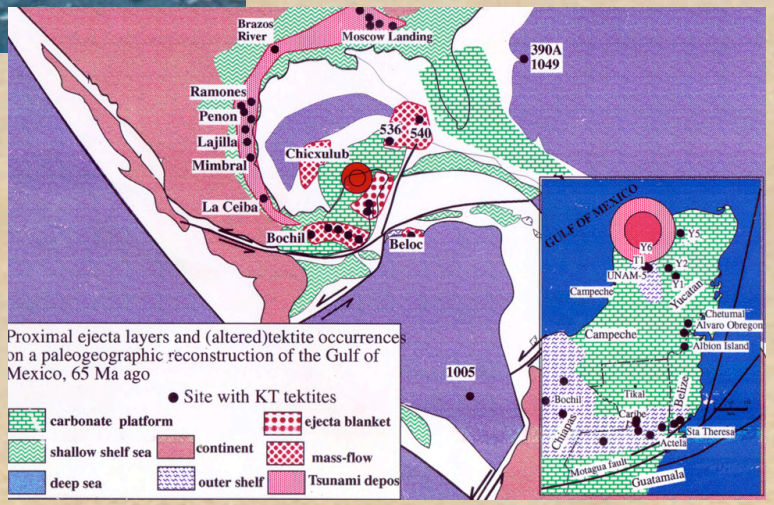


Finally: The Chicxulub crater

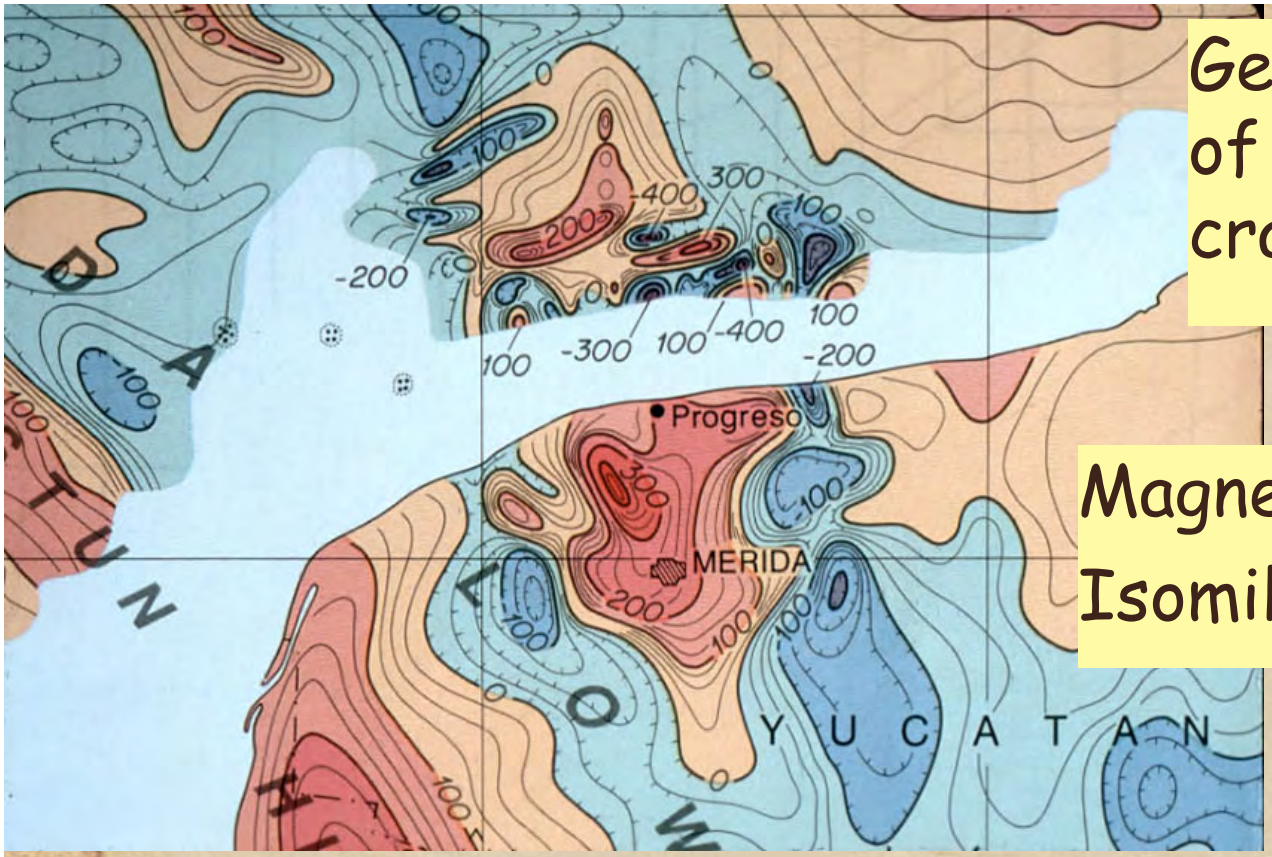






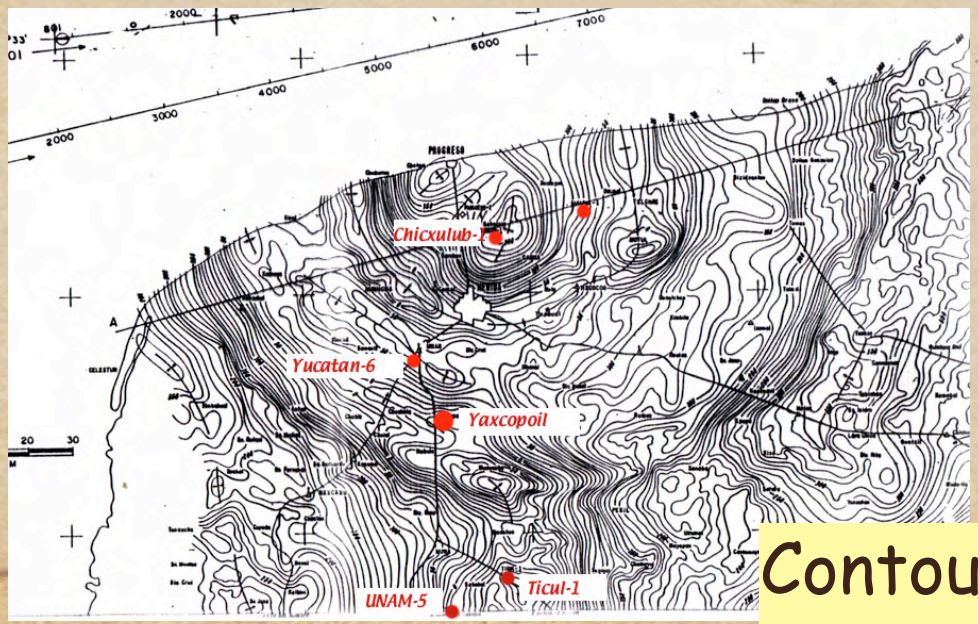


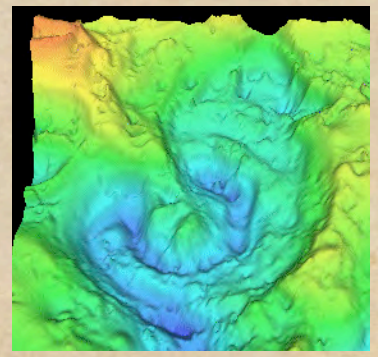
Geophysical discovery of the Chicxulub crater



Magnetic anomalies

Isomilligal contours

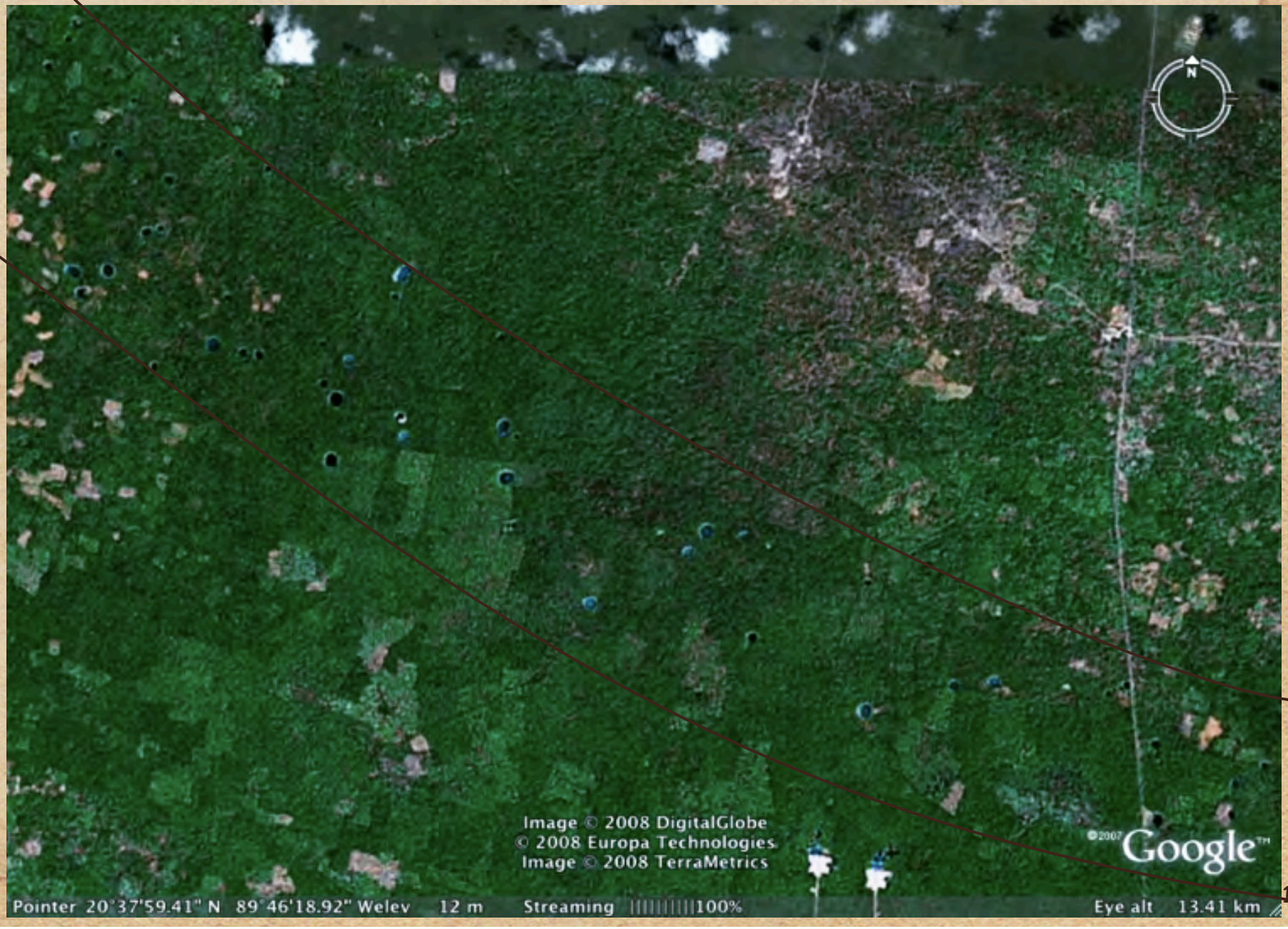




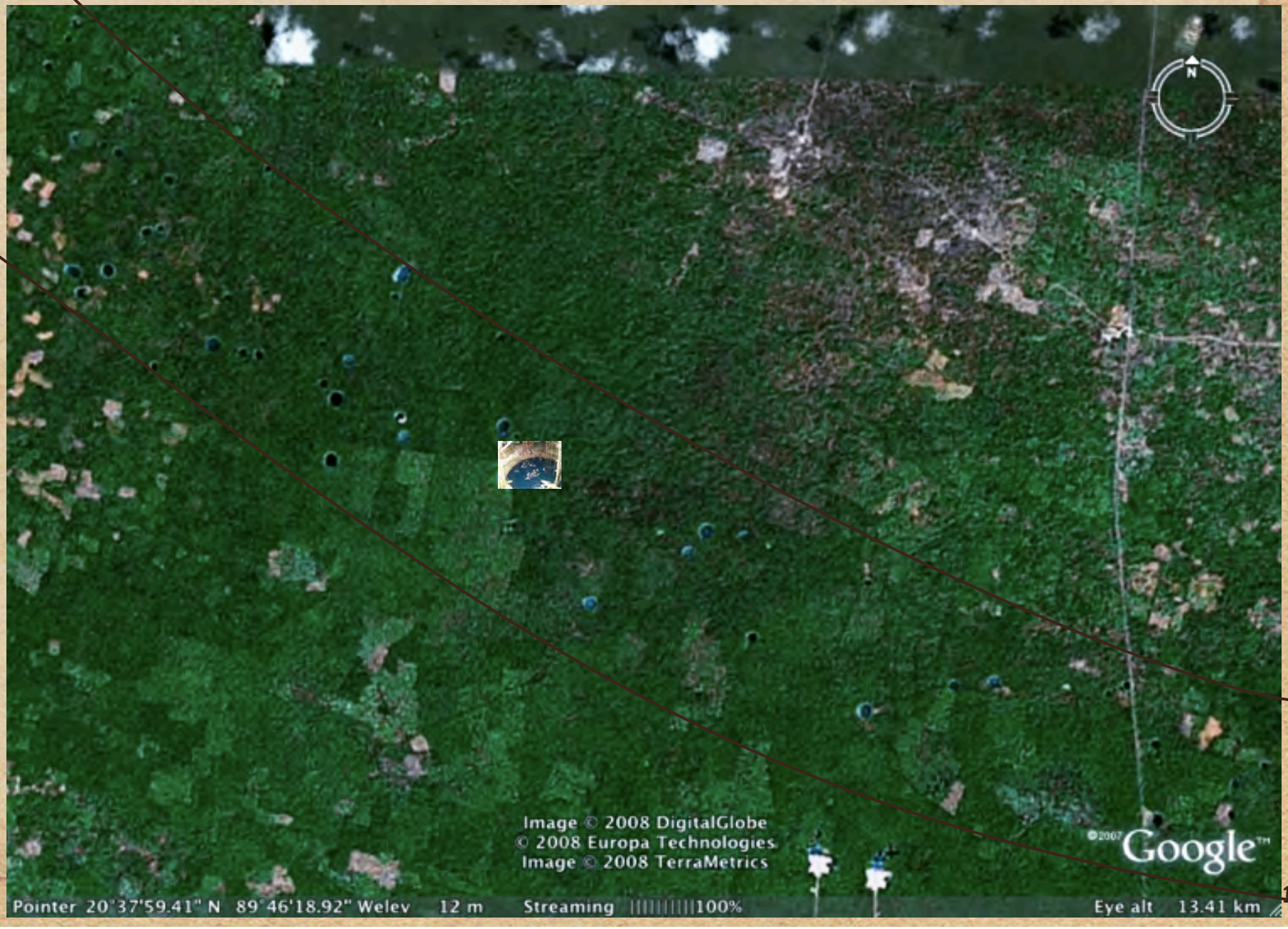
Contours of gravity anomalies

On Google Maps the Chicxulub crater is visible

The cenote ring of the Chicxulub crater is well visible on Googe Earth!

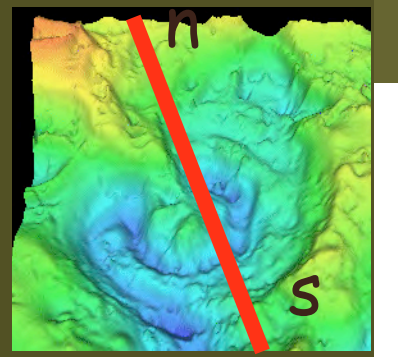


The cenote ring of the Chicxulub crater is well visible on Googe Earth!



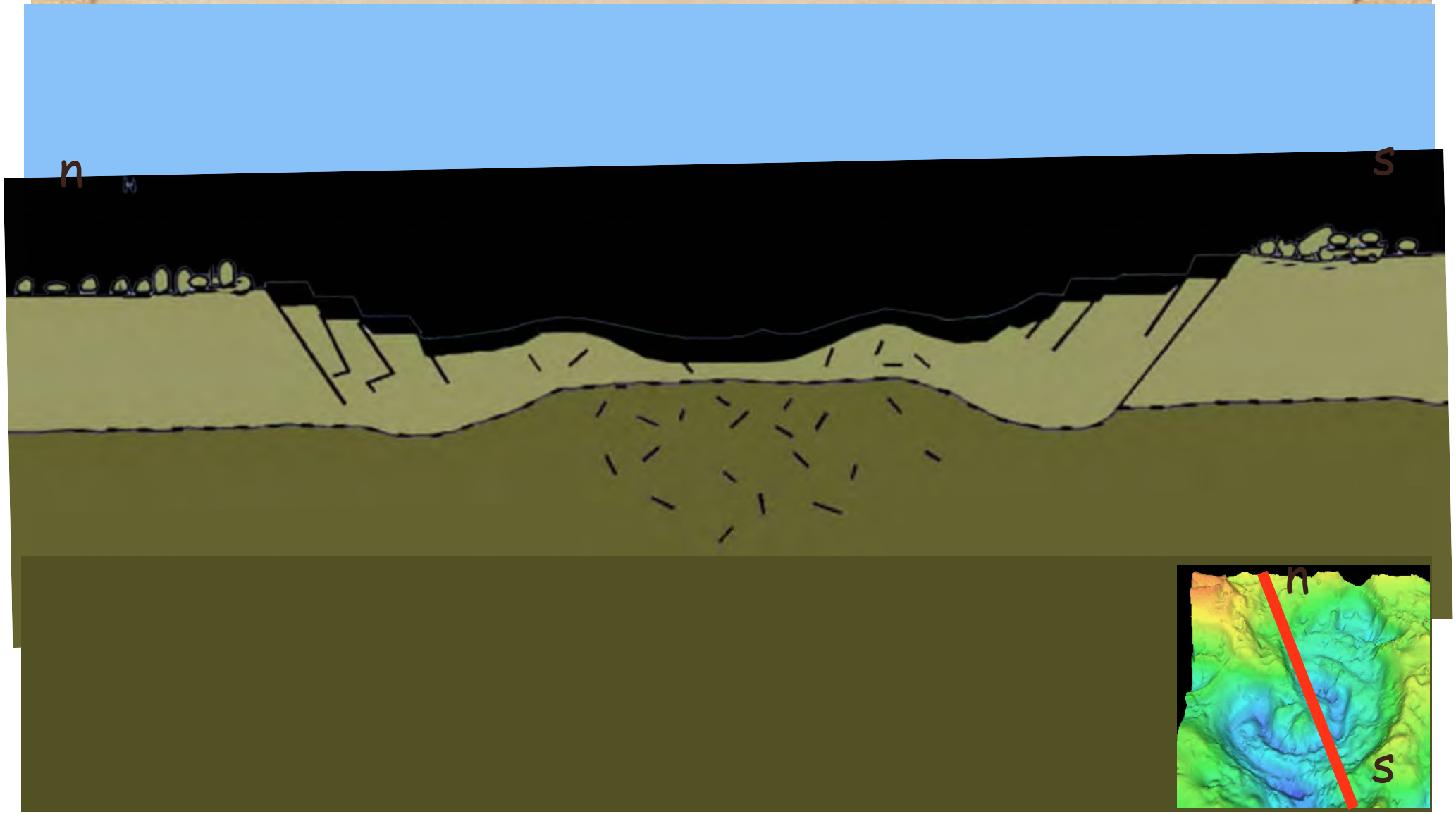
YUCATAN

Situation just after impact:



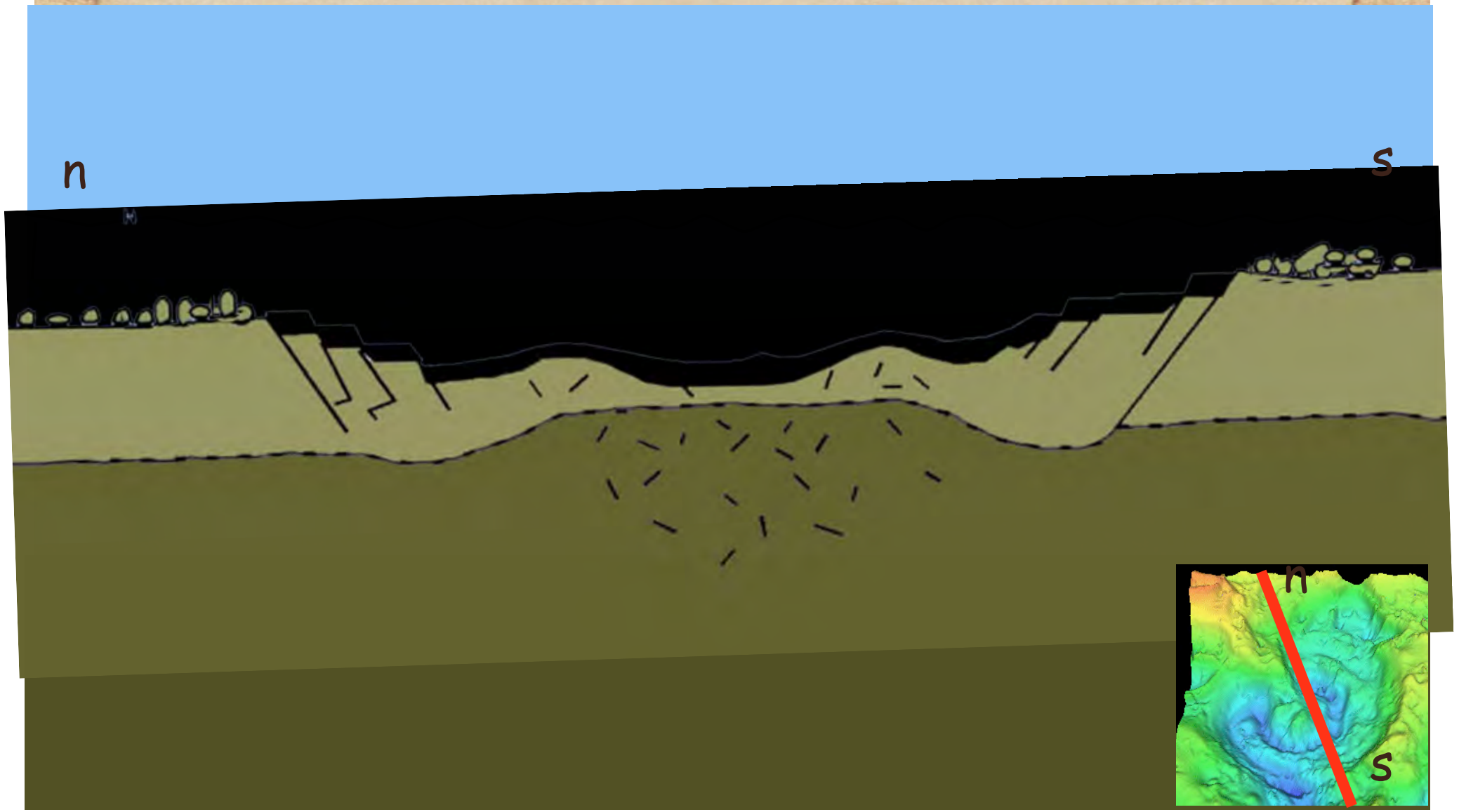
YUCATAN

The crater fills, while it subsides



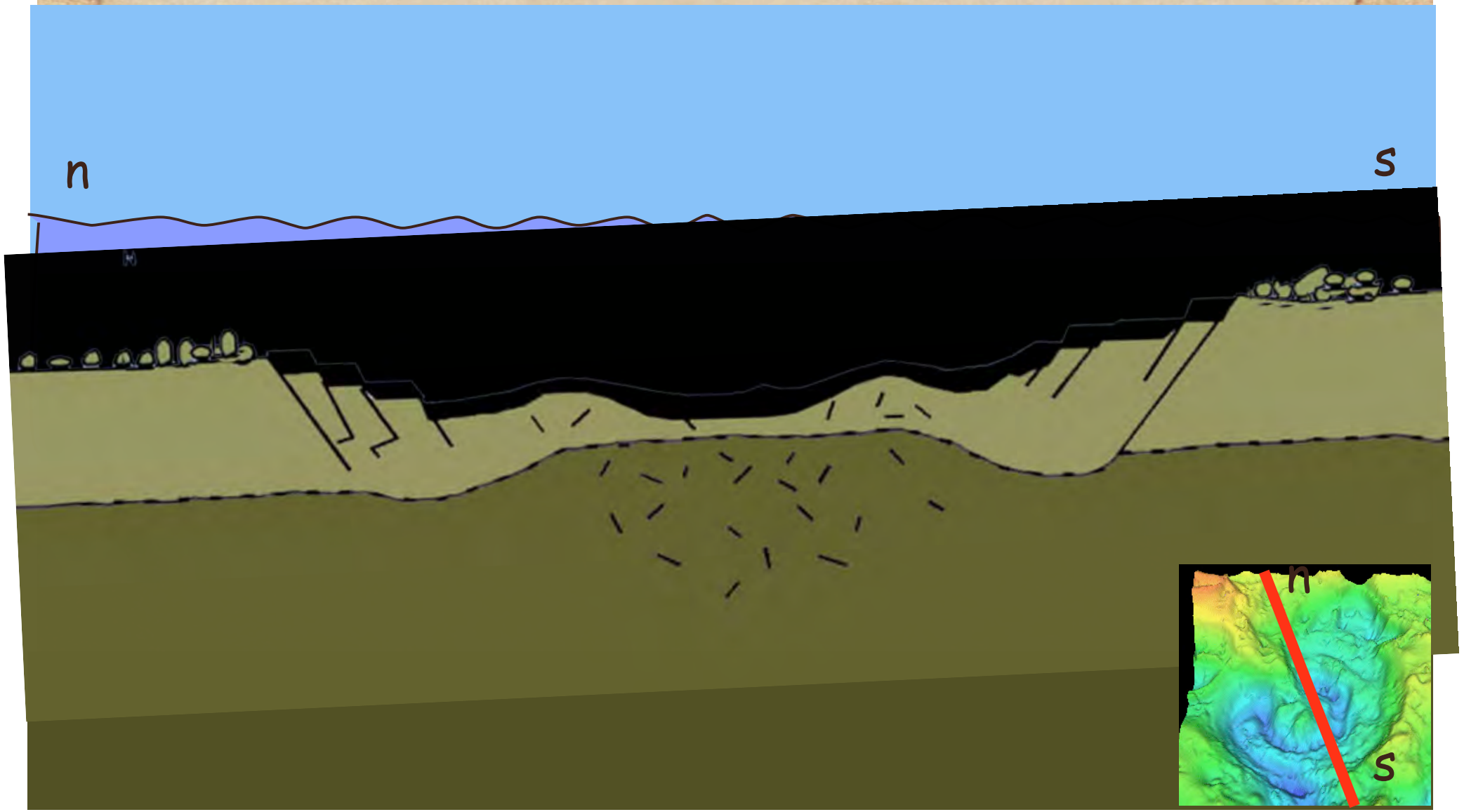
YUCATAN

The crater fills, while it subsides



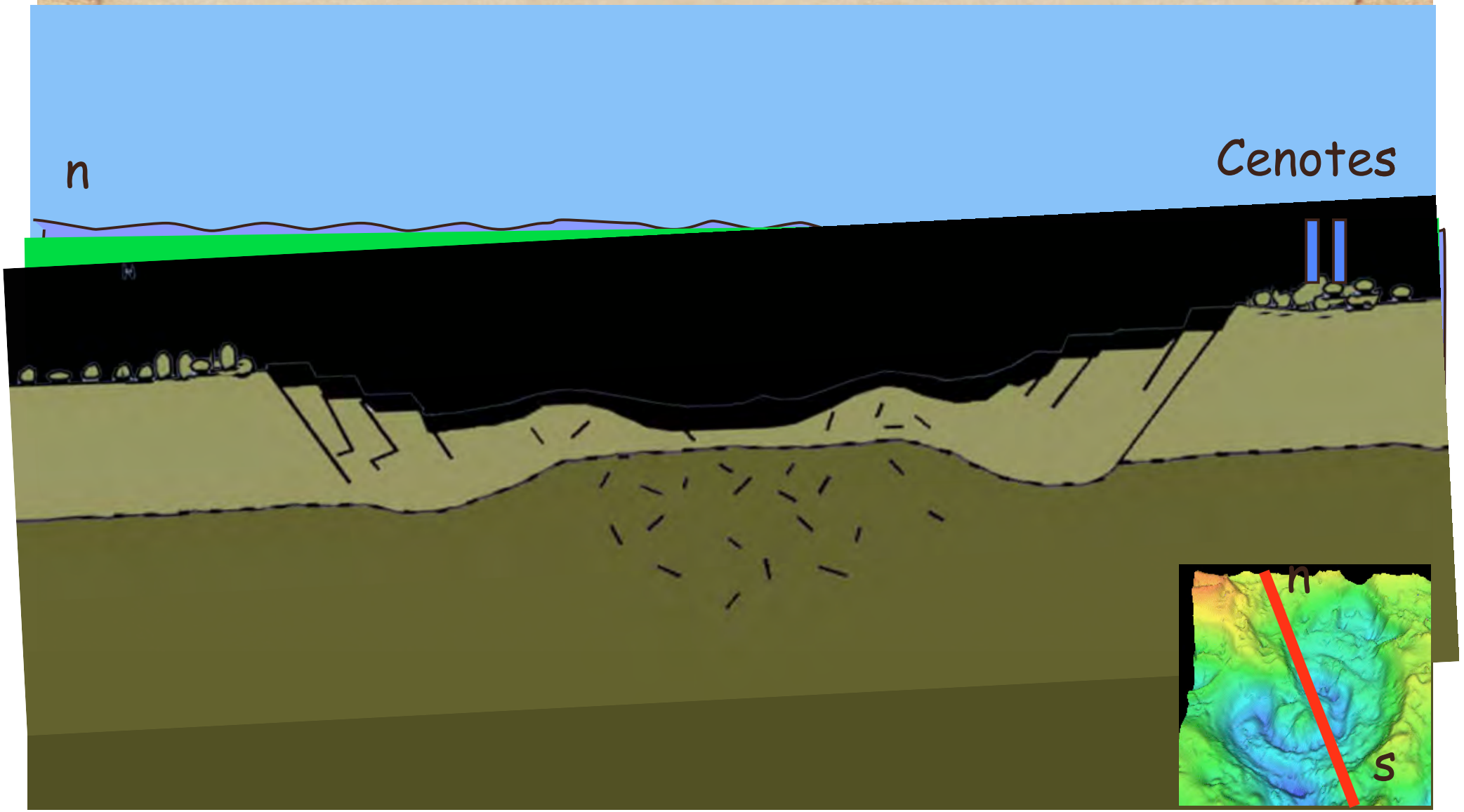
YUCATAN

The crater fills, while it subsides



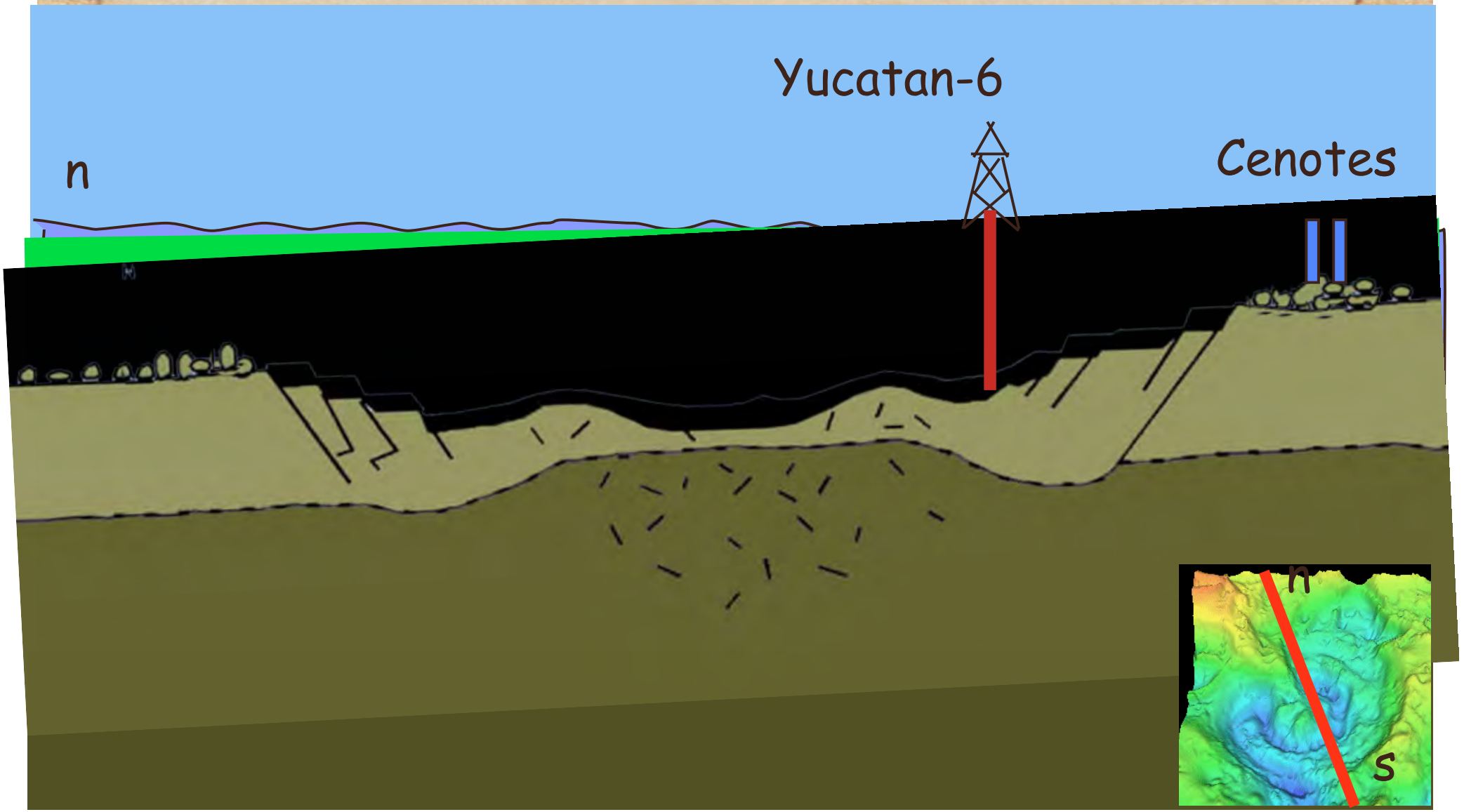
YUCATAN

The present situation, half on land, half in the sea



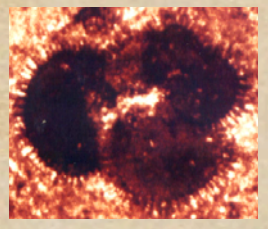
YUCATAN

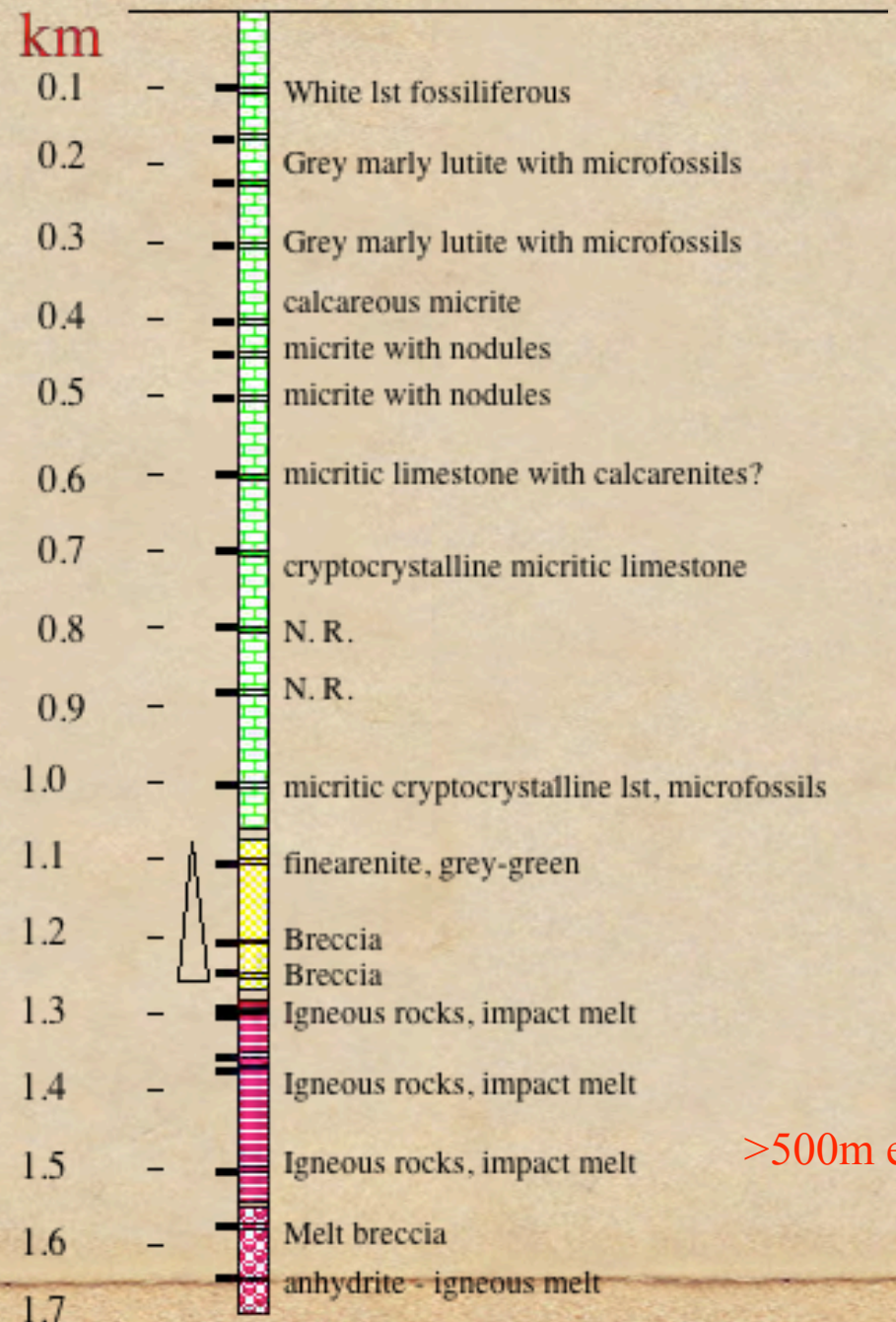
The present situation, half on land, half in the sea



Yucatan - 6

Paleocene microfossils

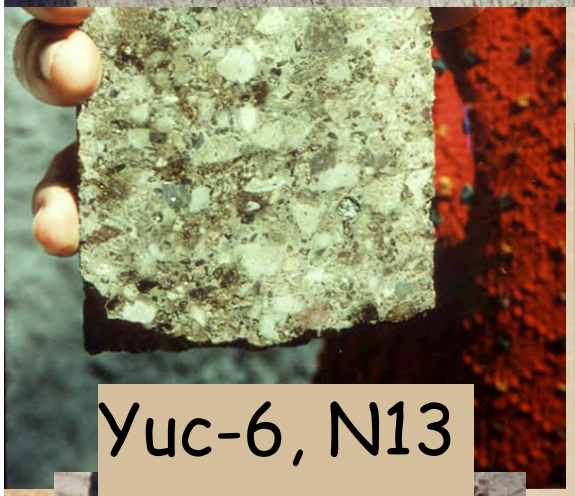




>500m ejecta

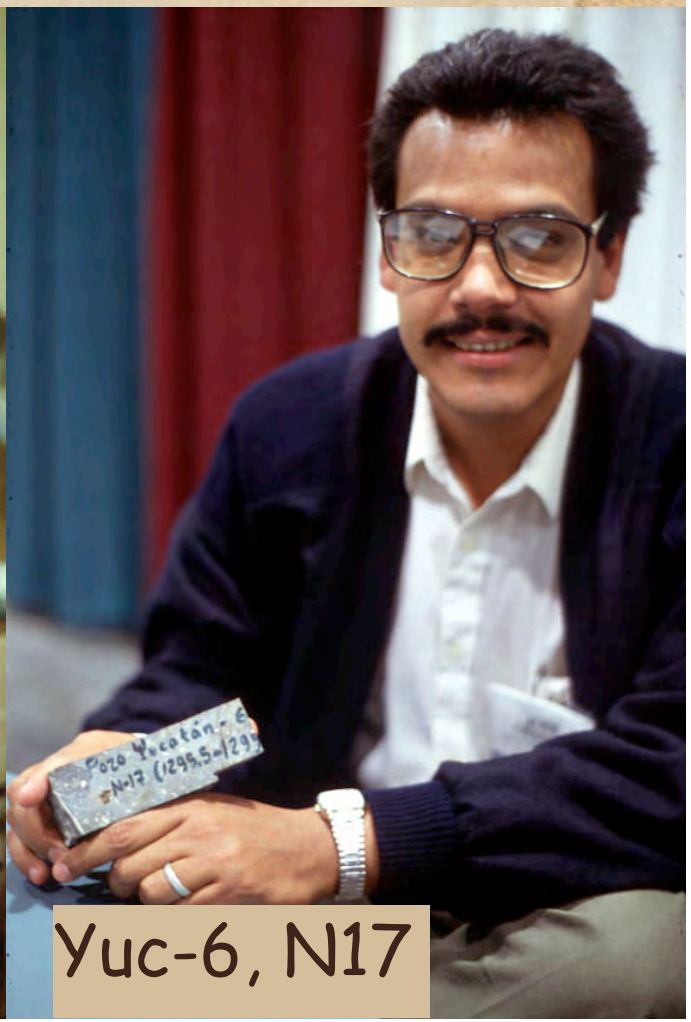
Bits and pieces of different PEMEX drill holes are still preserved

Yuc-6, N19



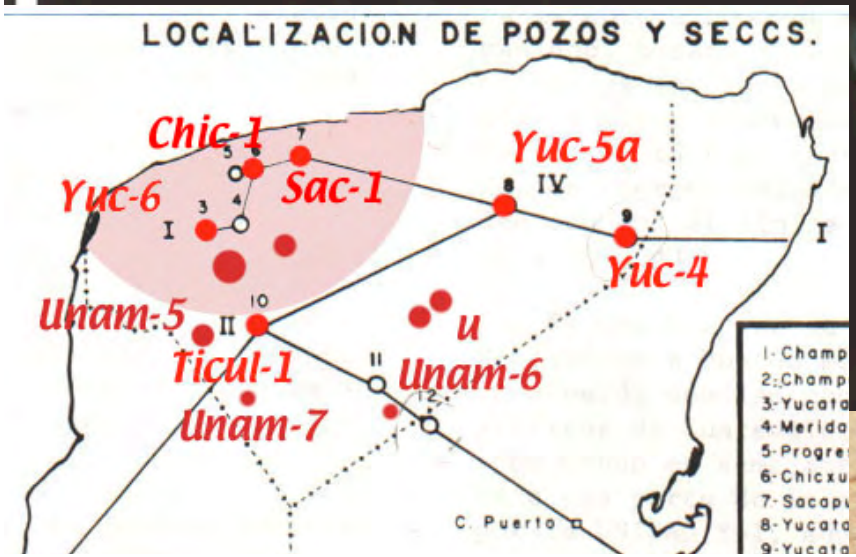
Yuc-6, N13

Chix-1-N10



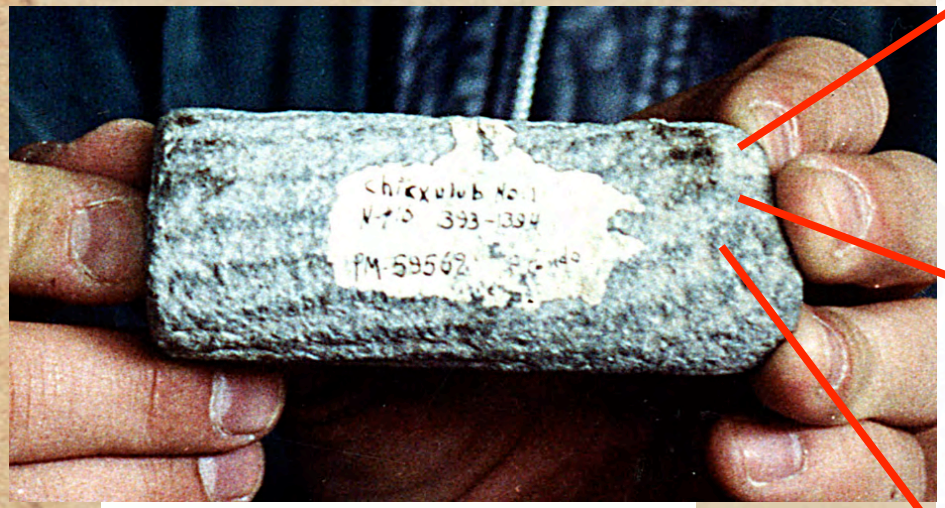
Yuc-6, N17

UNAM-5 boorkern met gesteente fragmenten net buiten de krater

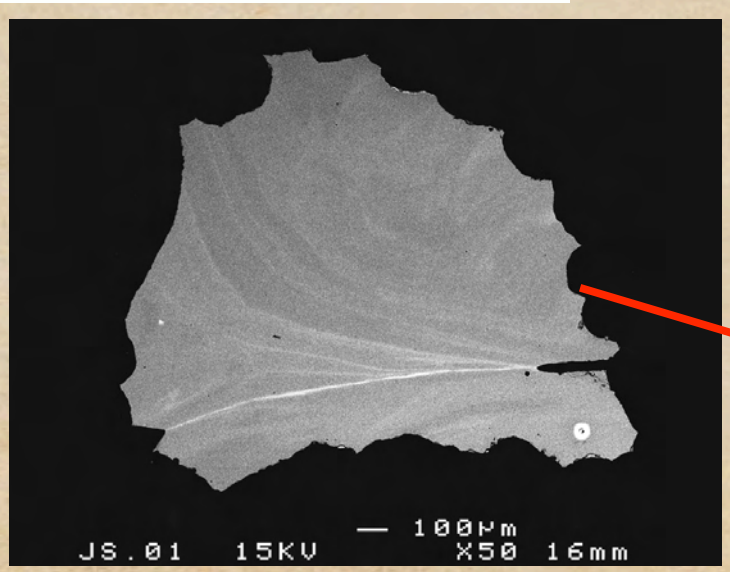


Vienna, gift-egu2011

Ar/Ar ages from the tektites are indistinguishable from impact melt inside the crater

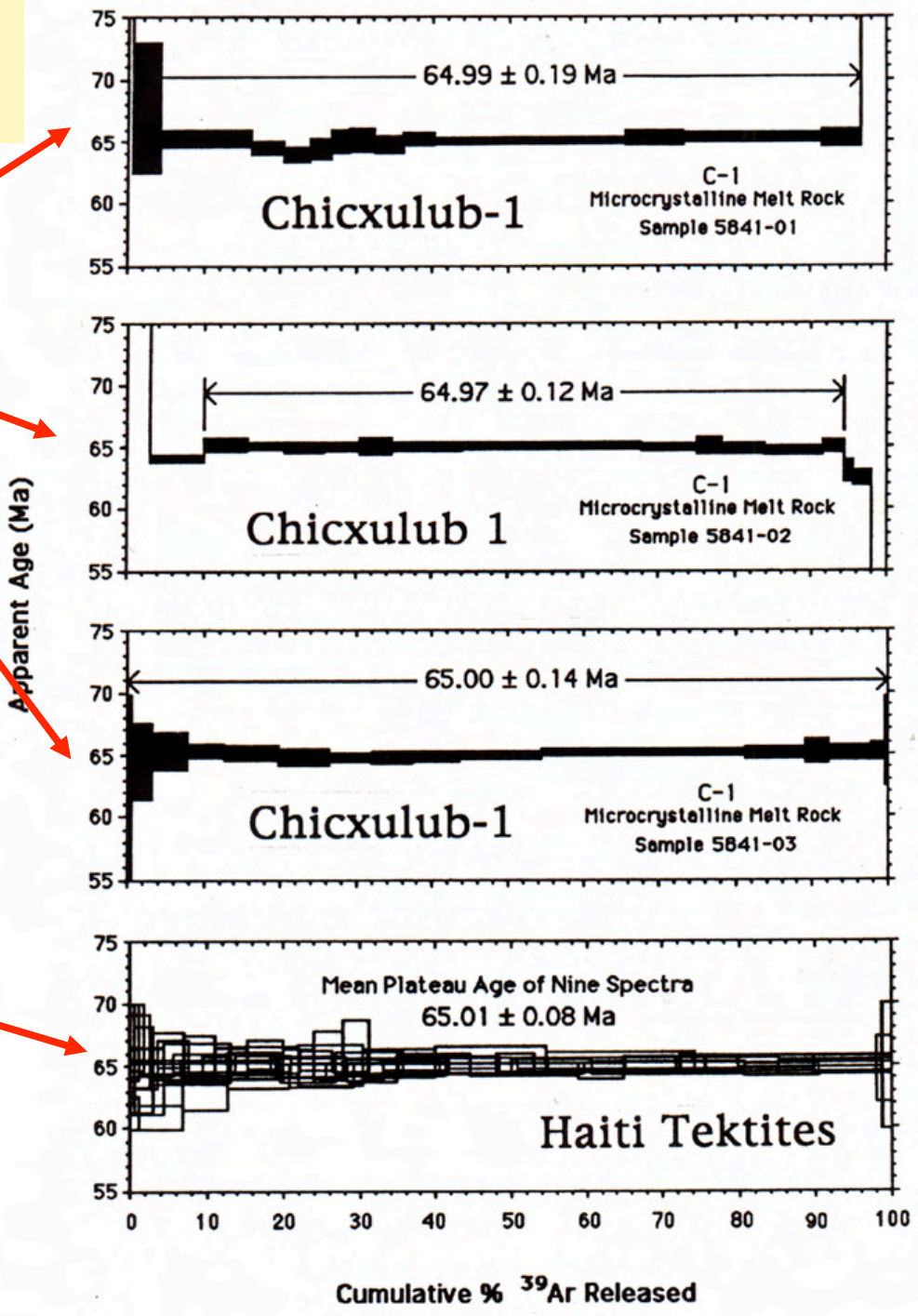


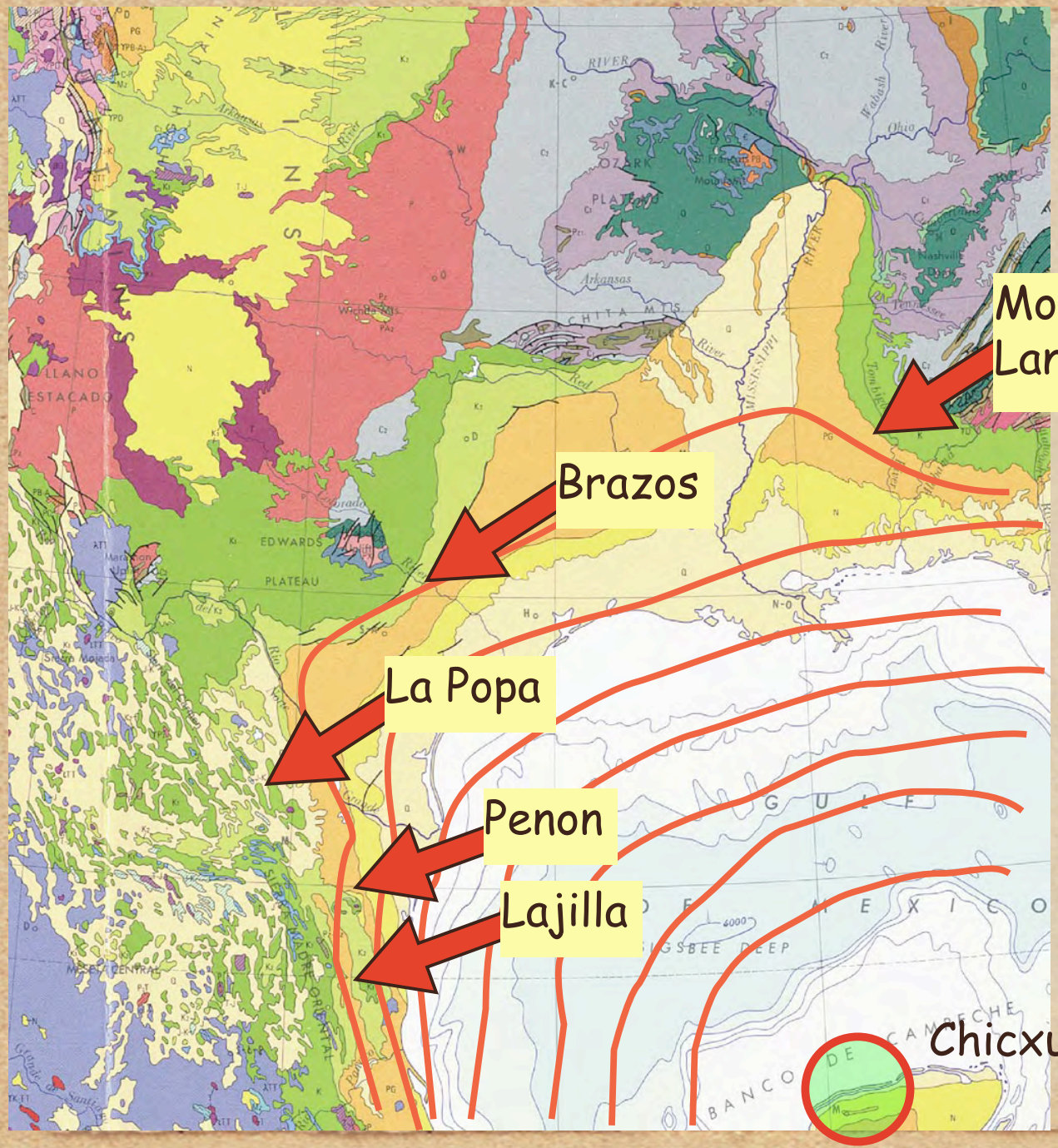
Impact melt from the crater



Haitian tektite

Figure 2. $^{40}Ar/^{39}Ar$ laser incremental heating spectra

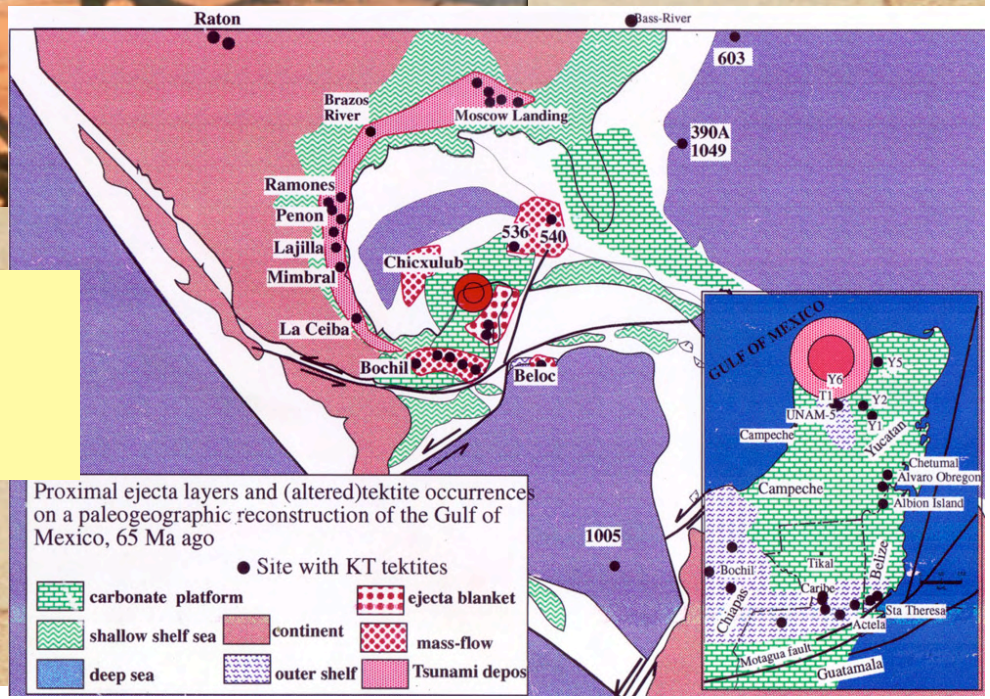




Where it gets complicated: the Gulf of Mexico

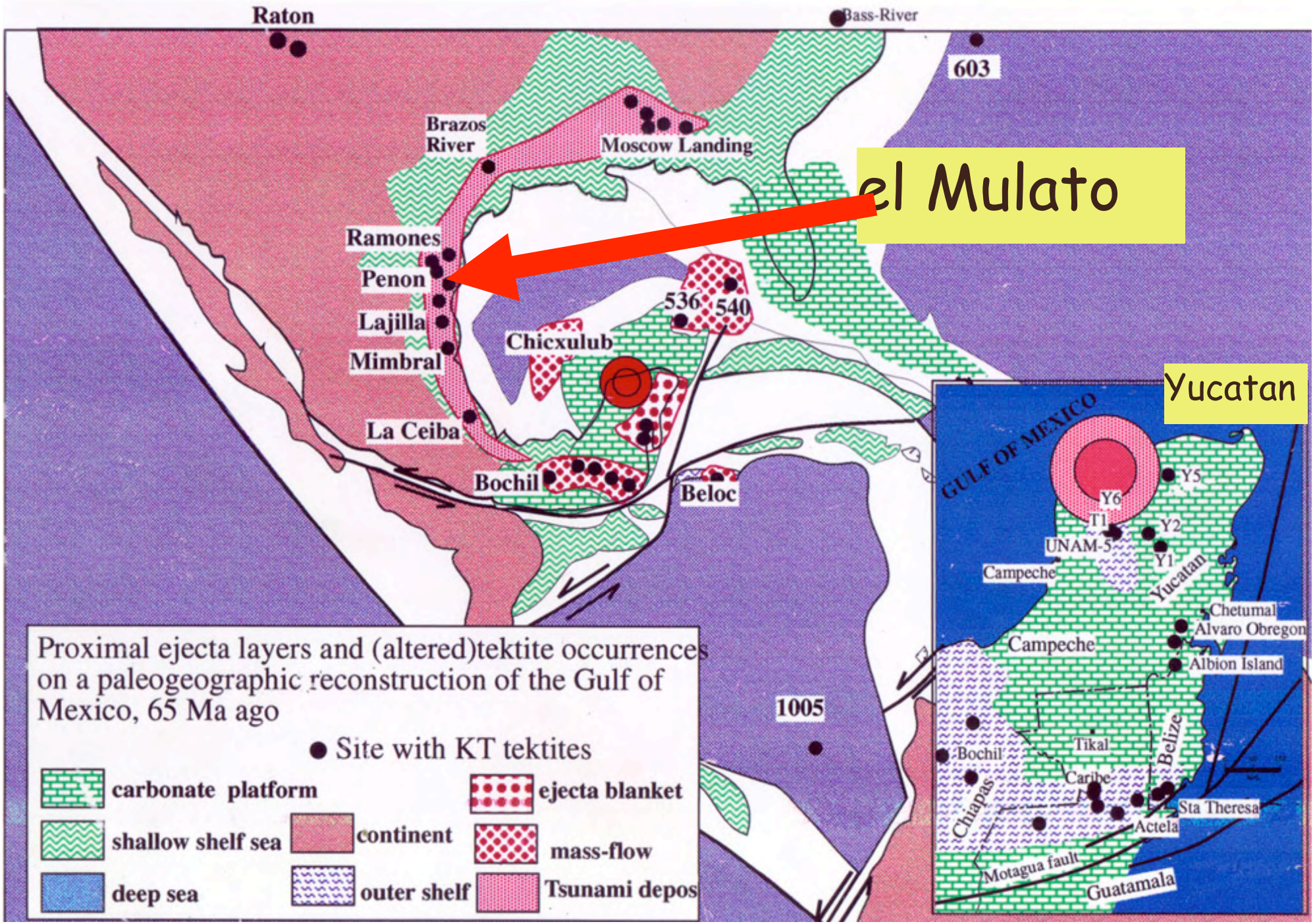
Tsunami deposits around the Gulf

Impression of Tsunami waves around the Gulf of Mexico

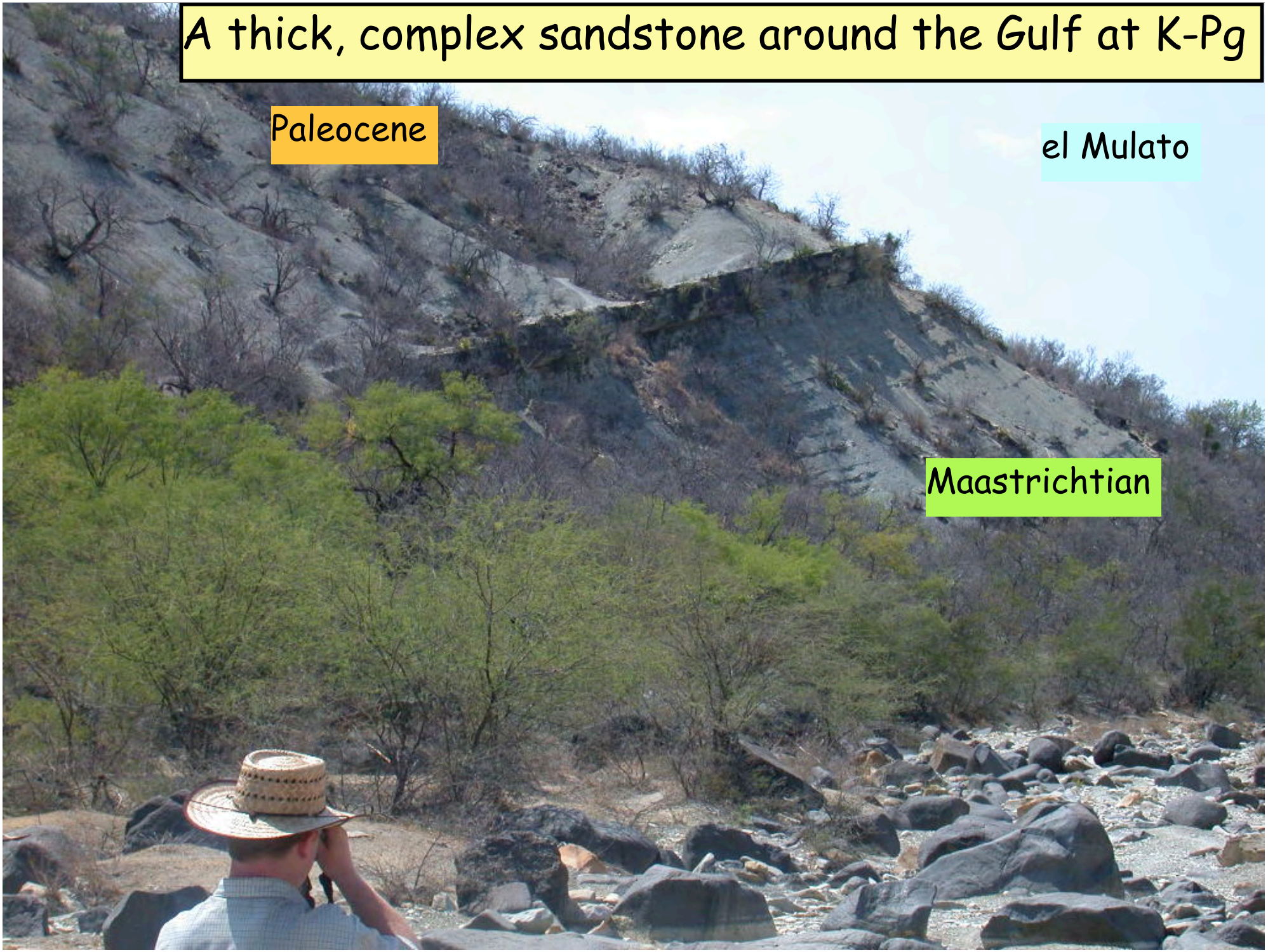


TSUNAMI: Wall of water, Resemble strong tidal surges, not waves.

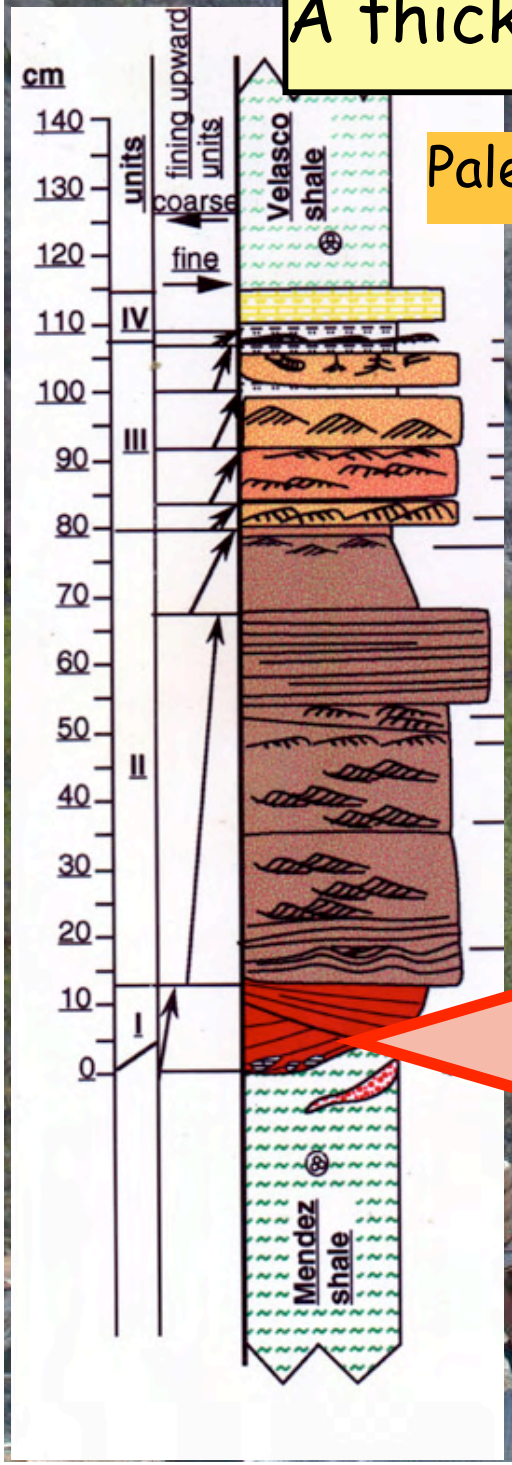
map of the Chicxulub impact region 65 Million years ago



A thick, complex sandstone around the Gulf at K-Pg



A thick, complex sandstone around the Gulf at K-Pg

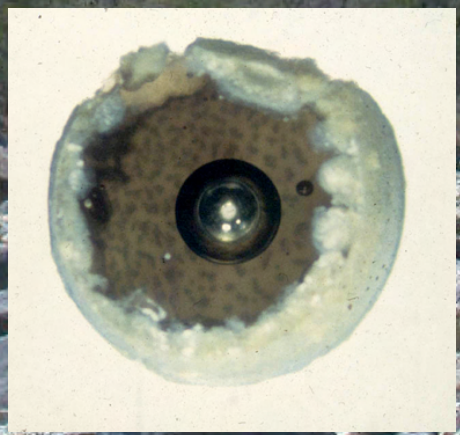


Paleocene

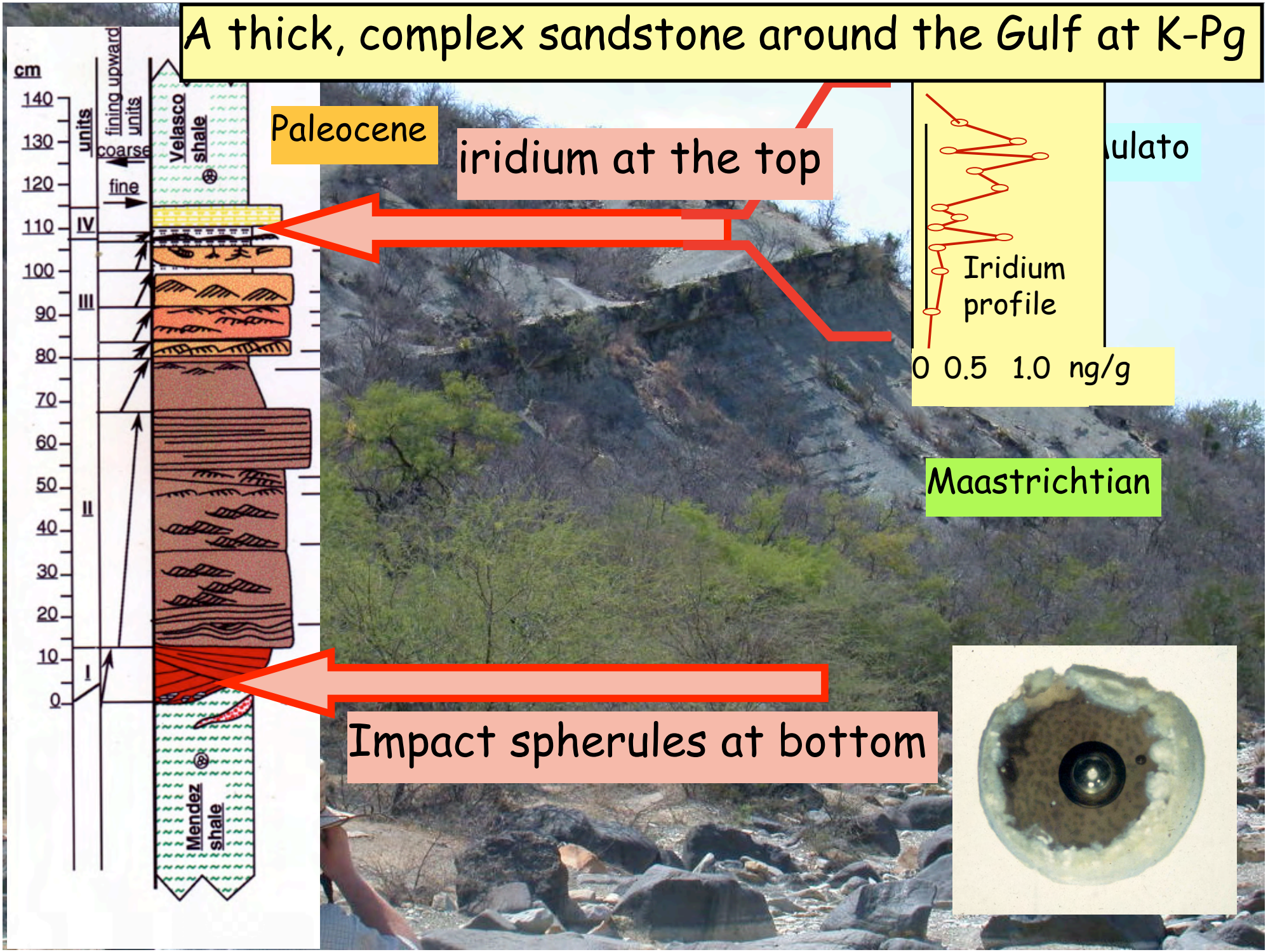
el Mulato

Maastrichtian

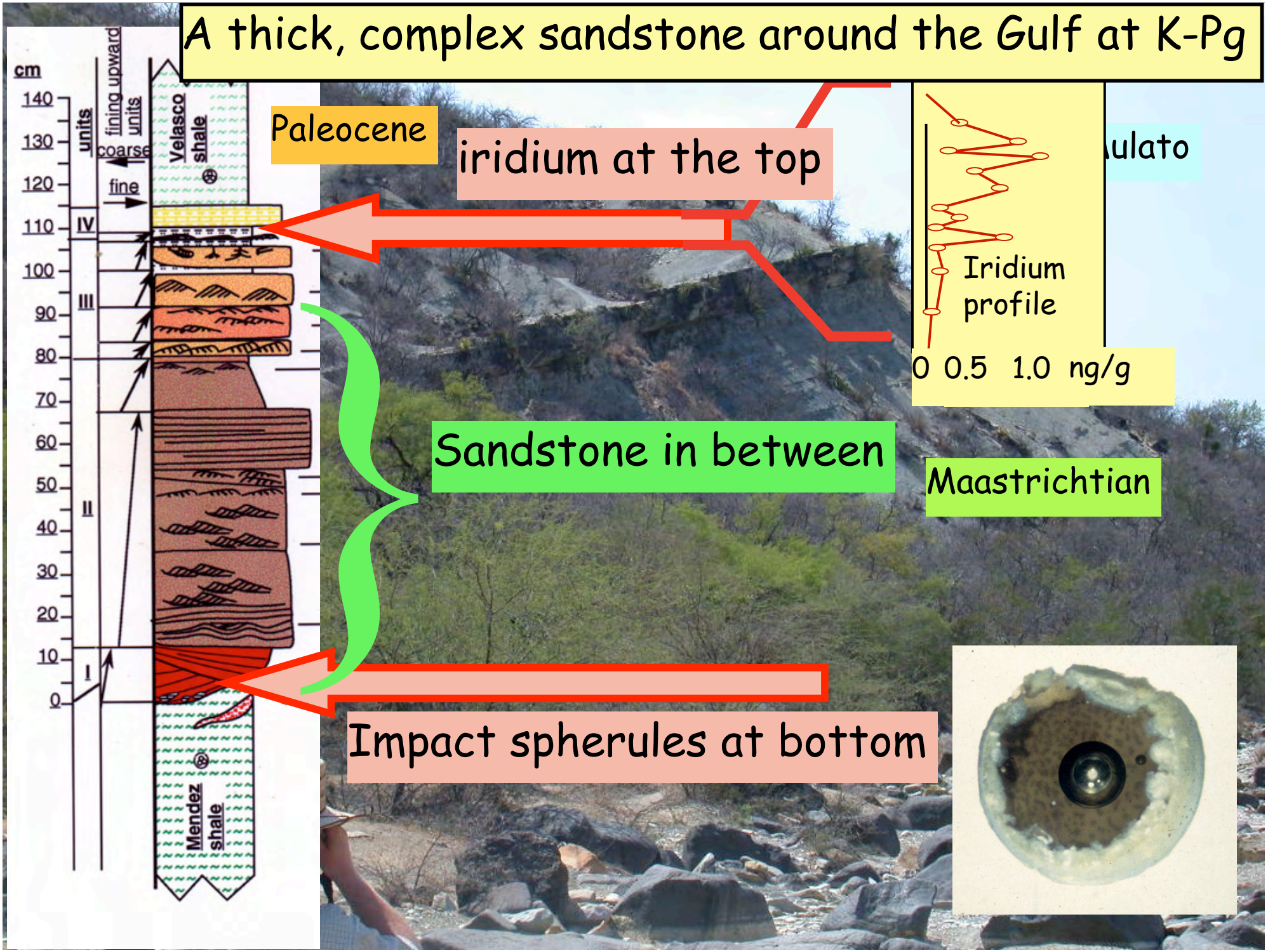
Impact spherules at bottom



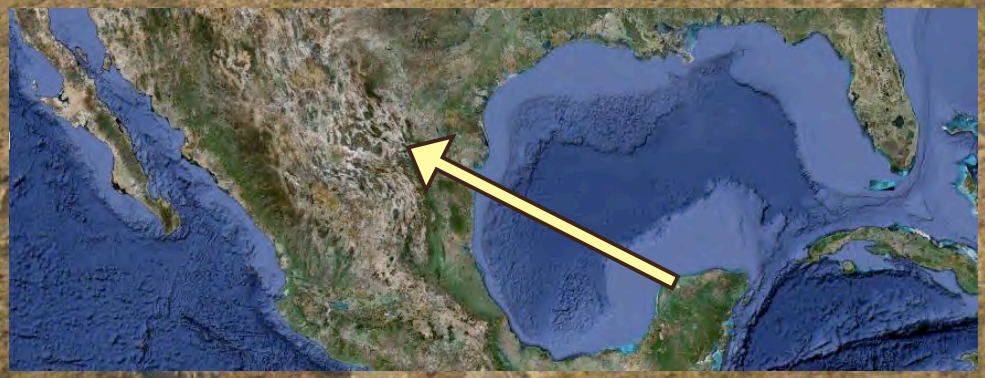
A thick, complex sandstone around the Gulf at K-Pg



A thick, complex sandstone around the Gulf at K-Pg



La Popa basin, Monterrey, Mexico tsunamiite



La Popa basin, Monterrey, Mexico tsunamiite

Mosasaur vertebra

Dinosaur (Ornithomimus) Tooth

Tektites

Vienna, gift-egu2011

What about the extinction record?

Italy

OCEAN

Spain

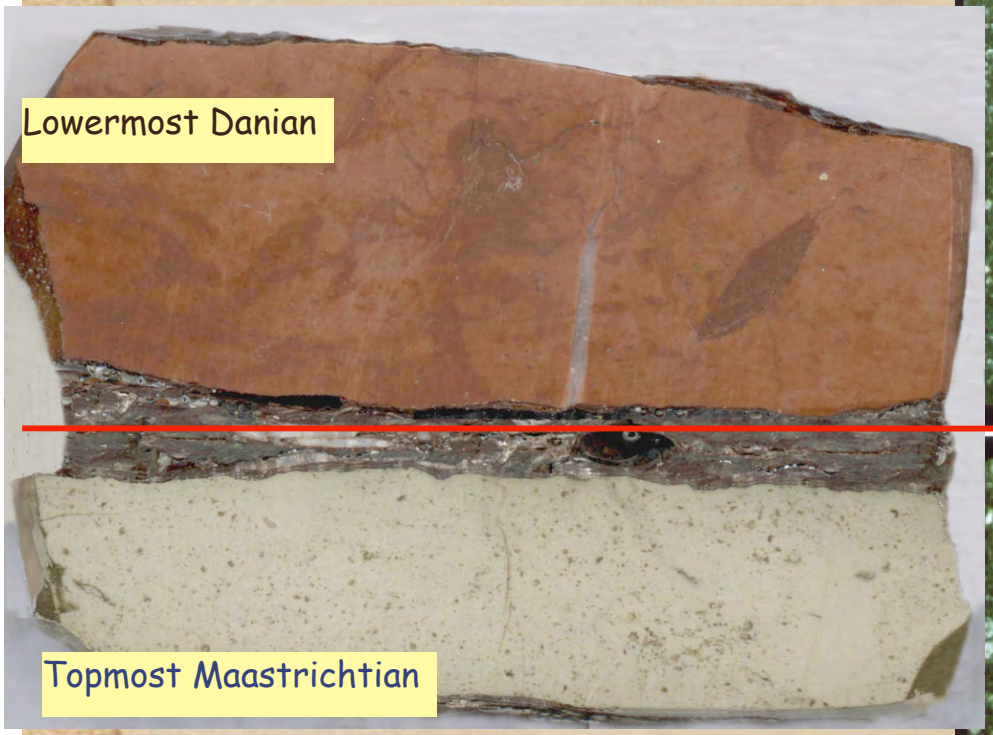
LAND

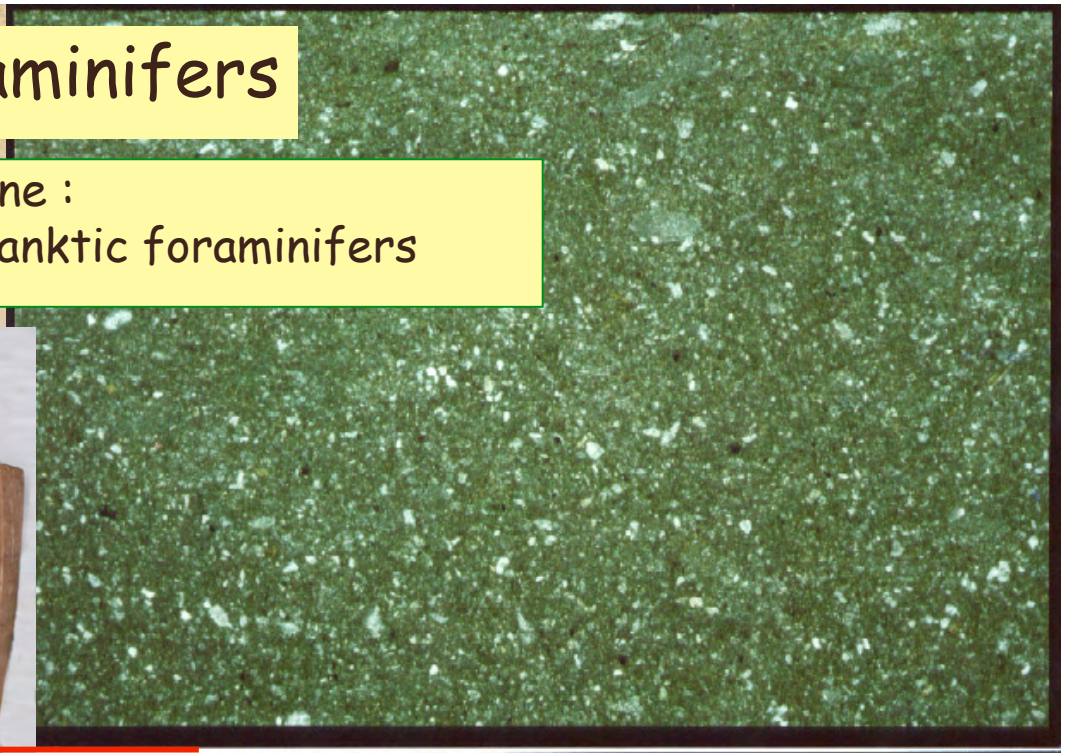
First a look in the deep sea

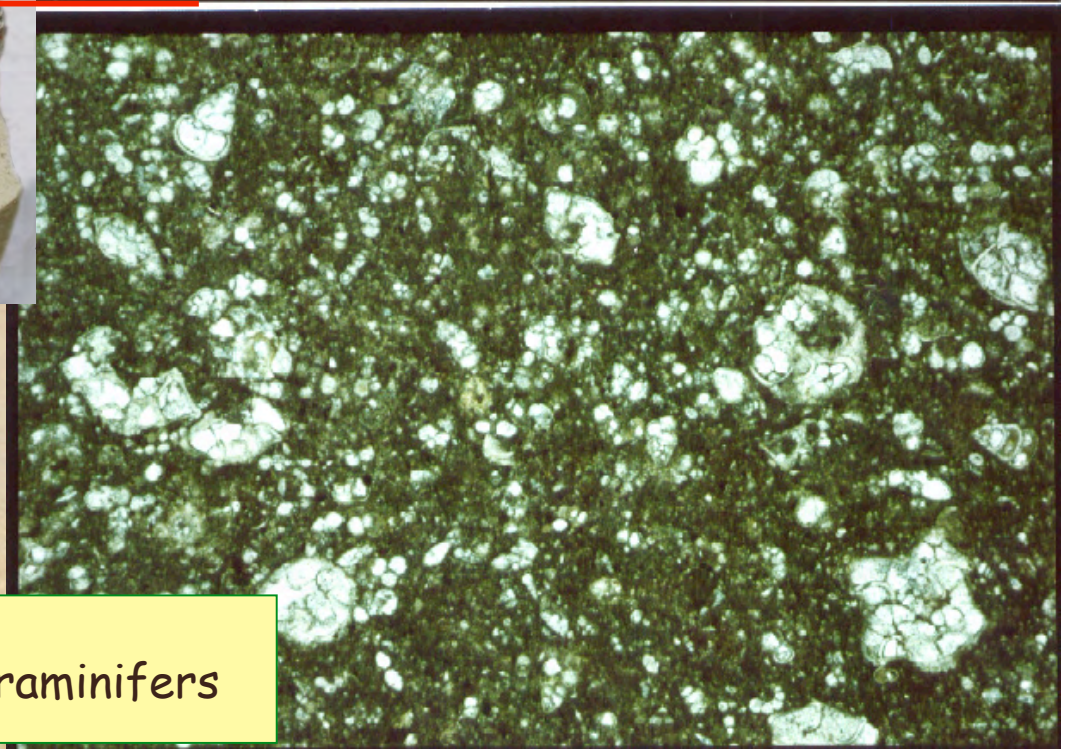
Image © 2006 TerraMetrics
Image © 2006 NASA

Mass extinctions of foraminifers

Lowermost Paleocene :
exclusively small planktic foraminifers



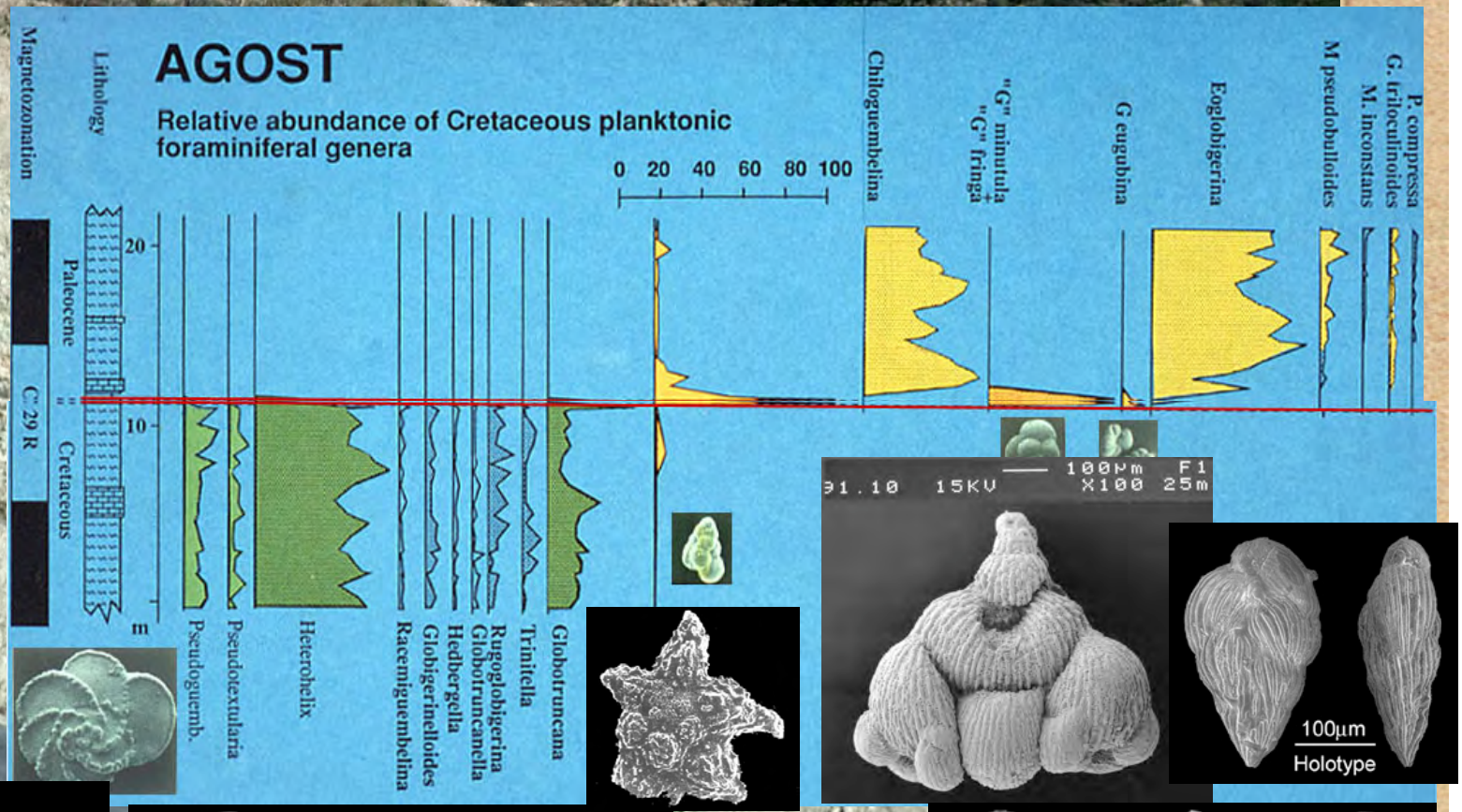


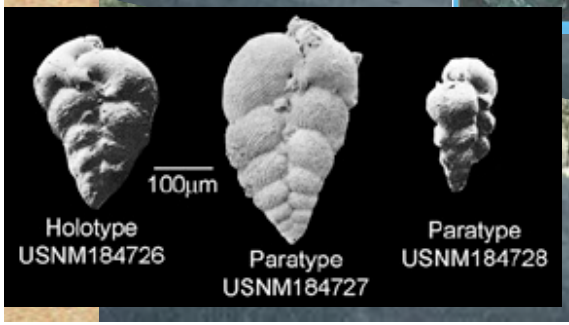


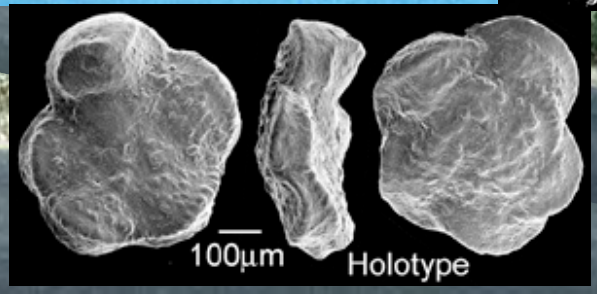
Gubbio

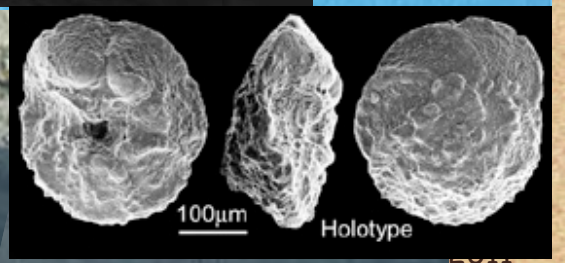
Uppermost Maastrichtian:
Abundant large, specialized planktic foraminifers

Agost Spain:
Mass-extinction and new radiation of Foraminifers





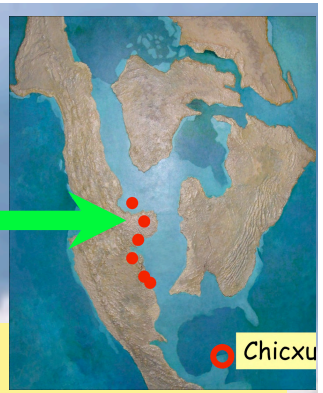




Zumaia, Bay of Biscaye ammonite and inoceramus ranges

US Western Interior Dinosaur and Mammal Turnover at Bug Creek Montana

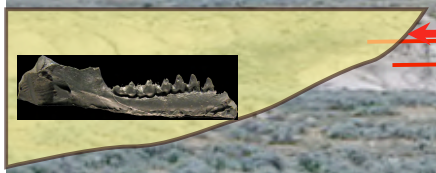
How about the dinosaurs (terrestrial record?)



There are two major problems:
A: Too many Z-coals (=K/T boundaries)
B: Cut off by rivers containing the mammalfossils

W- coal

Tertiary



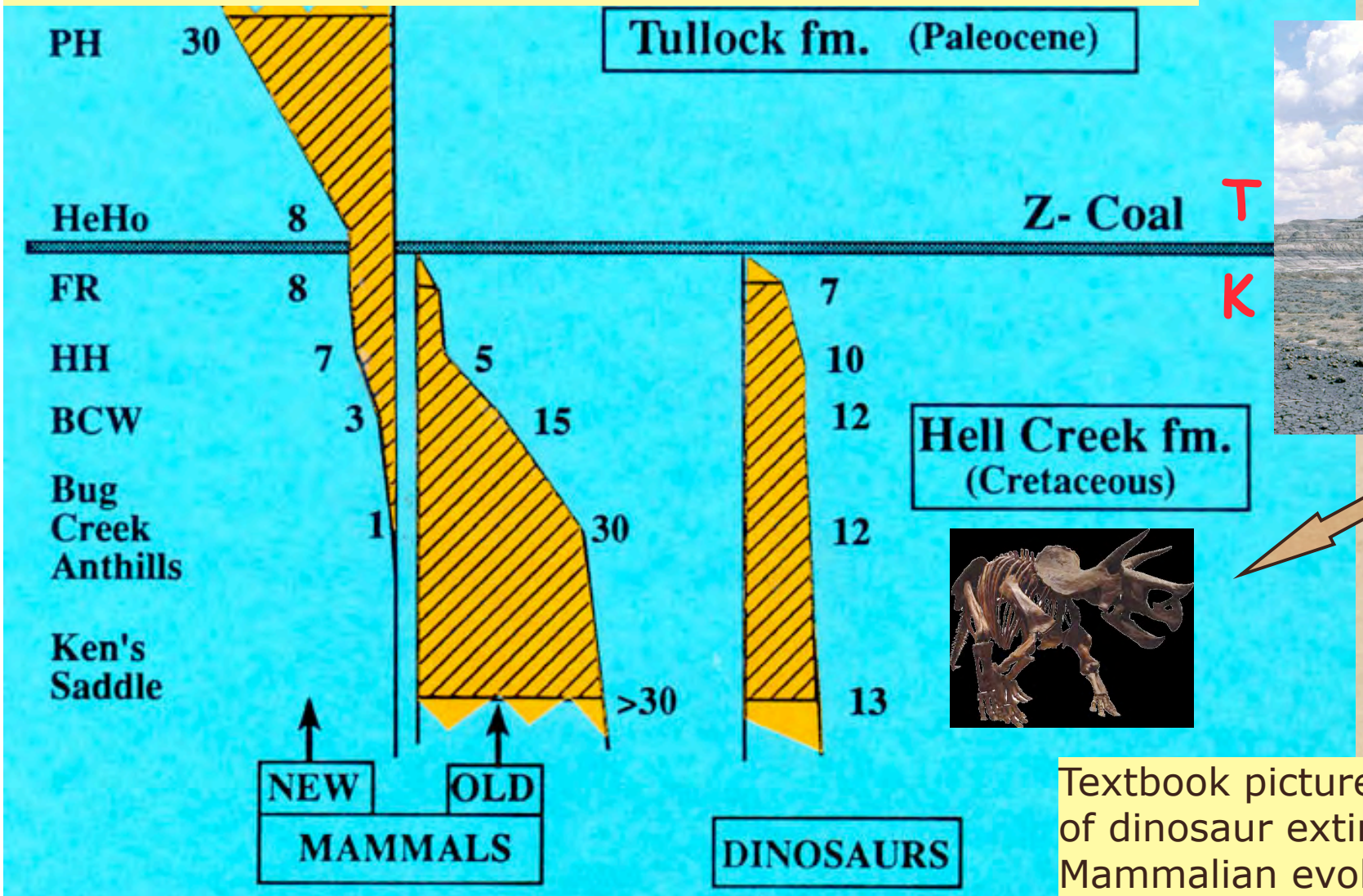
Z-coal

Cretaceous

egu2011

New (placental) mammals seemingly co-evolve with the disappearance of dinosaurs.....

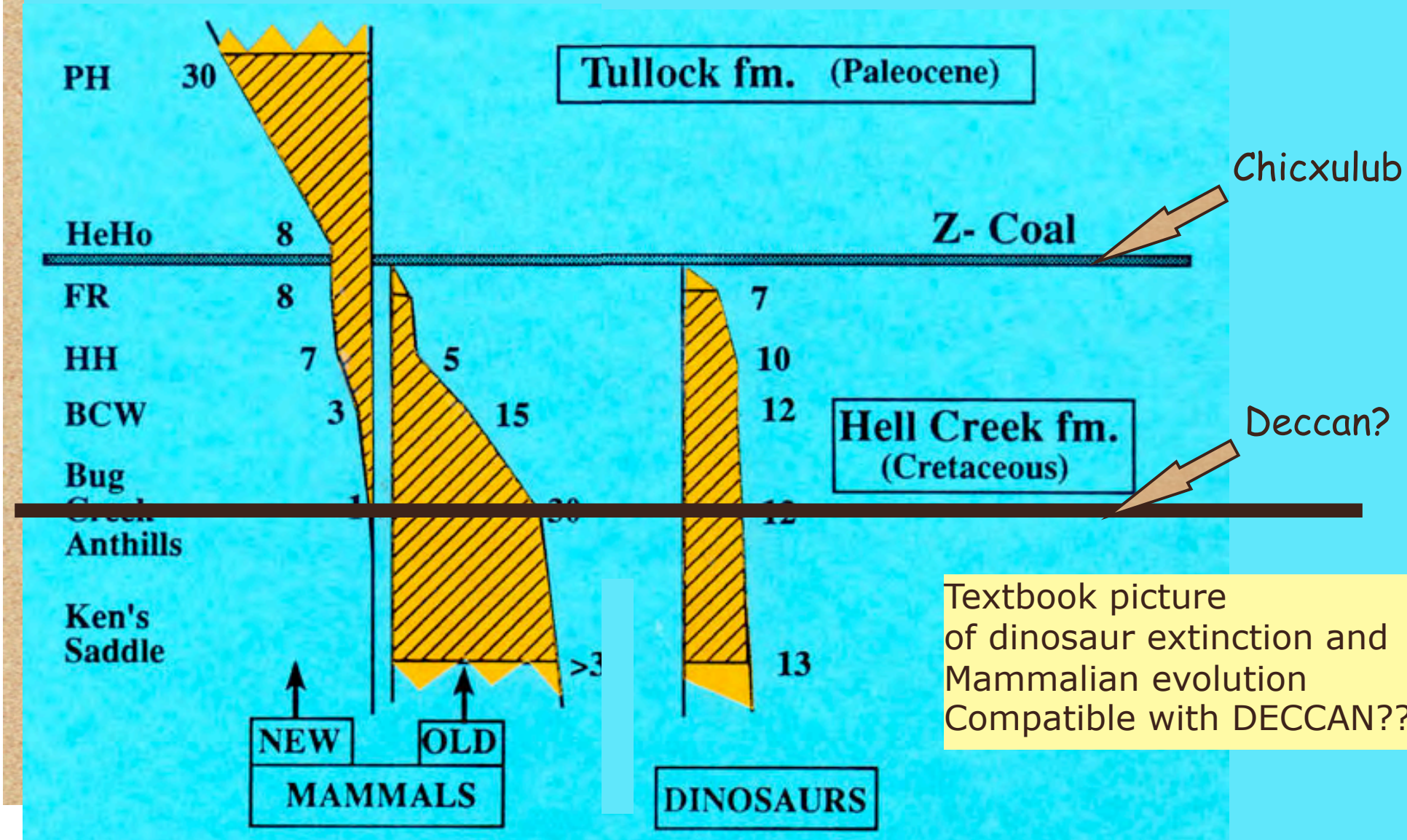
.....Below the K/T boundary (?!)

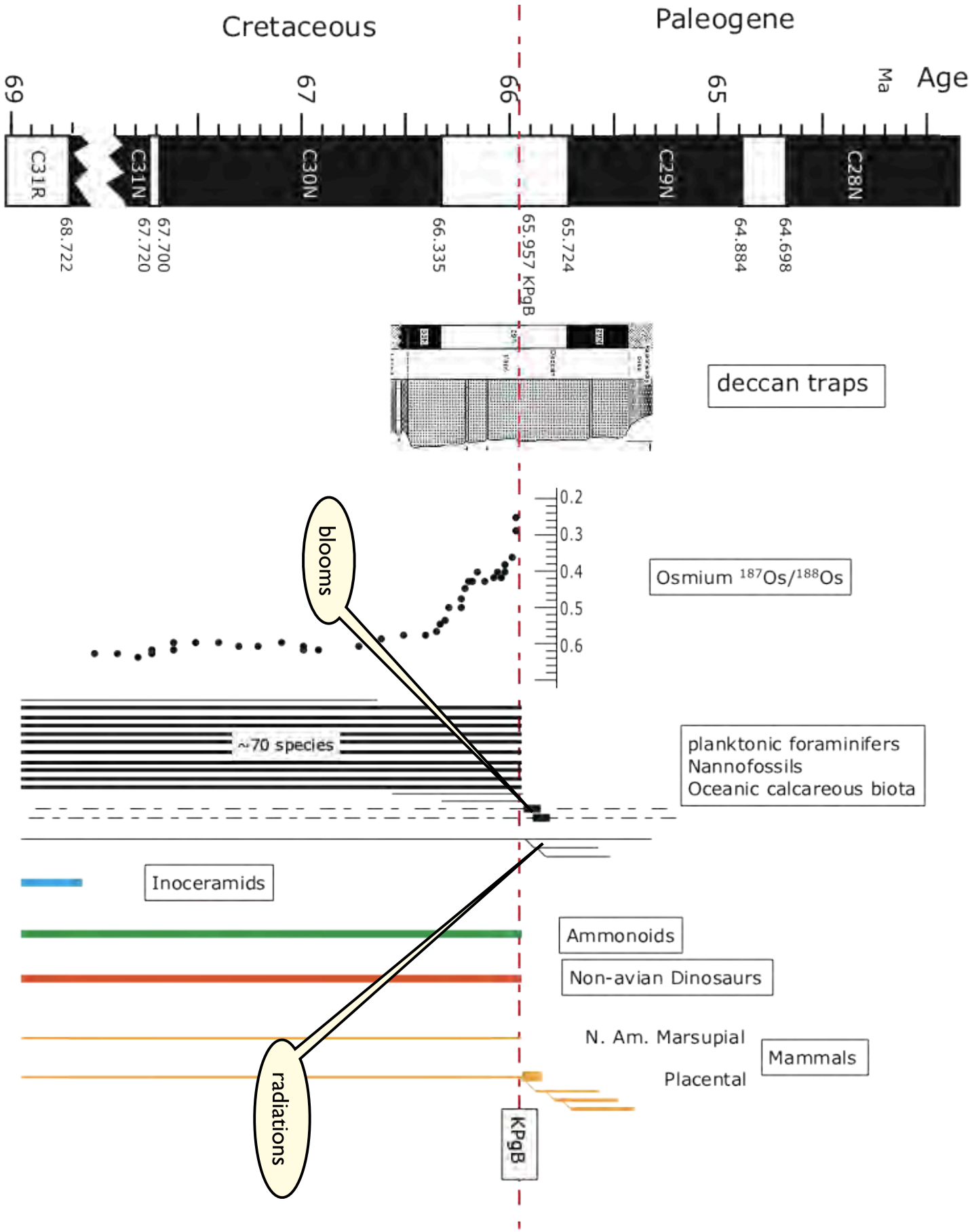


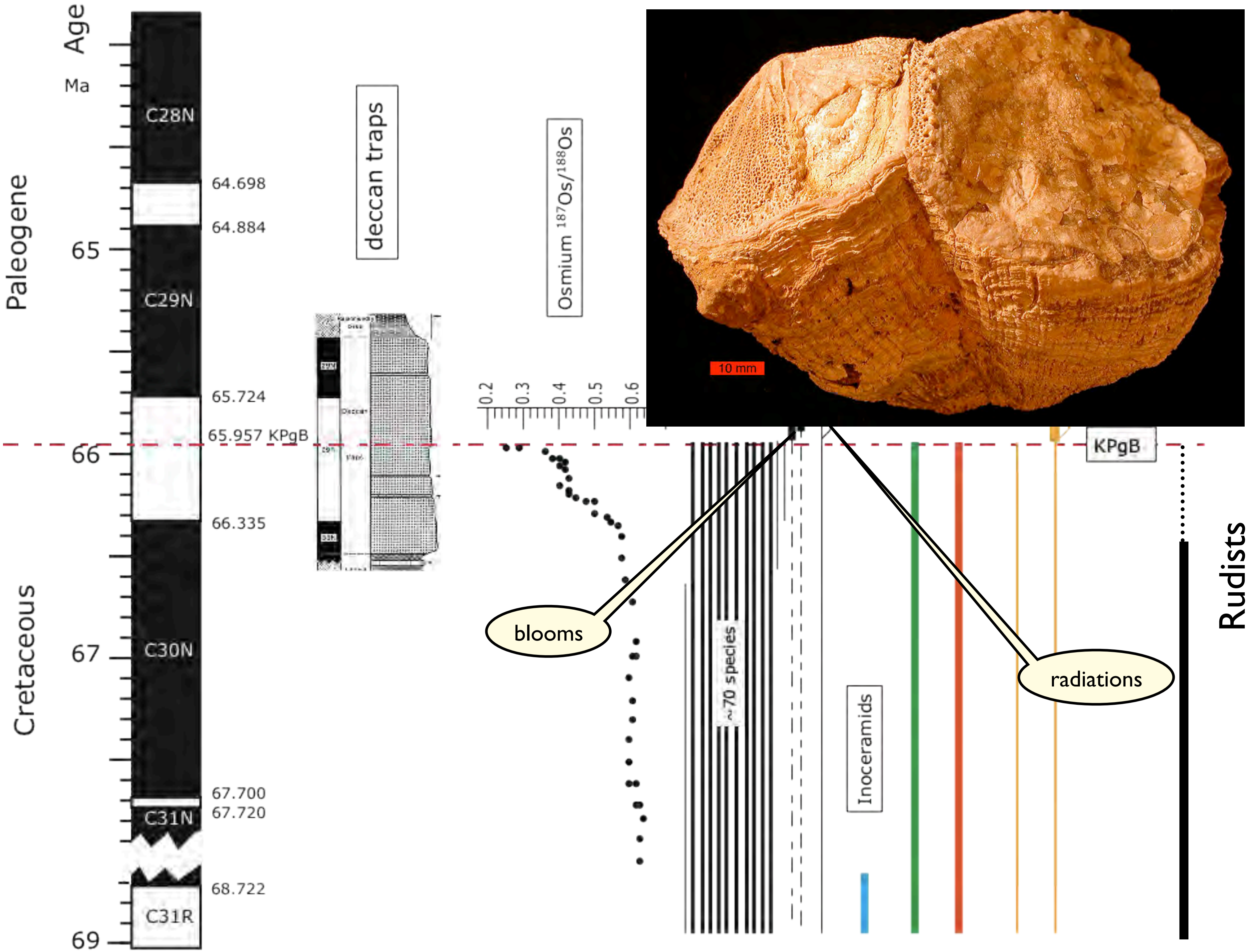
Deccan?

Textbook picture
of dinosaur extinction and
Mammalian evolution
Compatible with DECCAN??

However: Two changes had to be made:
1) Lower the KT boundary (which of the four)
2) Put the Paleocene mammals above the K/T boundary (because they are found in river channels)




Cretaceous
Paleogene
69
67
66
65
Ma
Age
C31R
C31N
C30N
C29N
C28N
68.722
67.700
67.720
66.335
65.957 KPgB
65.724
64.884
64.698
deccan traps
0.2
0.3
0.4
0.5
0.6
Osmium $^{187}Os/^{188}Os$
blooms
~70 species
planktonic foraminifers
Nannofossils
Oceanic calcareous biota
Inoceramids
Ammonoids
Non-avian Dinosaurs
N. Am. Marsupial
Placental
Mammals
radiations
KPgB



Age
Ma
Paleogene
Cretaceous
C28N
C29N
C30N
C31N
C31R
64.698
64.884
65.724
65.957 KPgB
66.335
67.700
67.720
68.722
65
66
67
69
deccan traps
Osmium $^{187}Os/^{188}Os$
0.2
0.3
0.4
0.5
0.6
10 mm
KPgB
~70 species
Inoceramids
Rudists
blooms
radiations

What really happened after Chicxulub

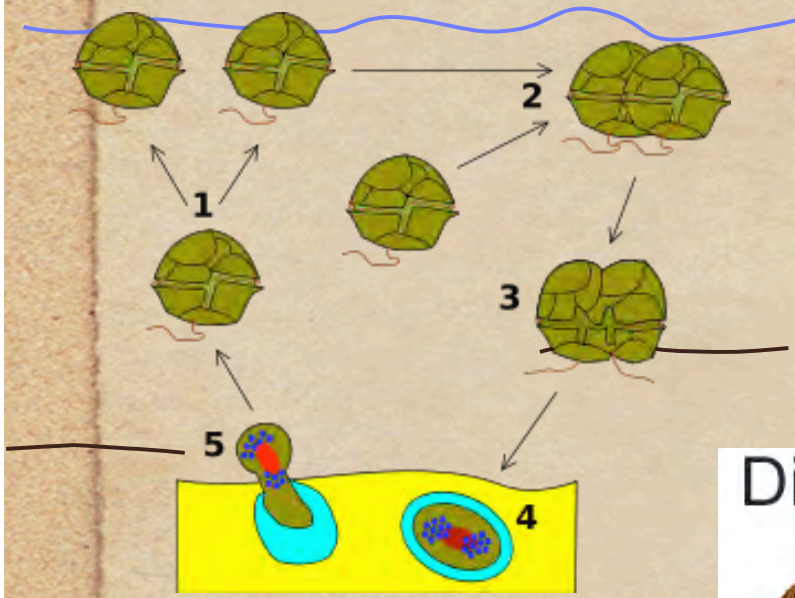
AGOST SPAIN

High Temperatures !

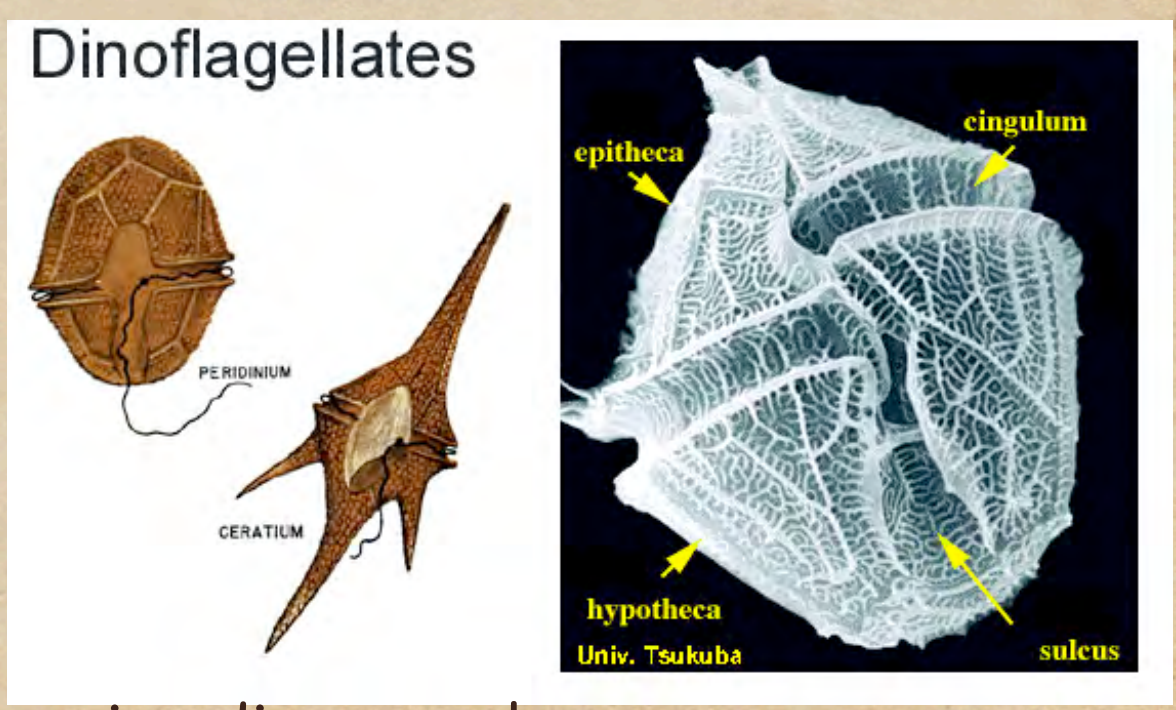
No photosynthesis

Room for sudden cooling here!

Also, Dinoflagellates provide a clue:

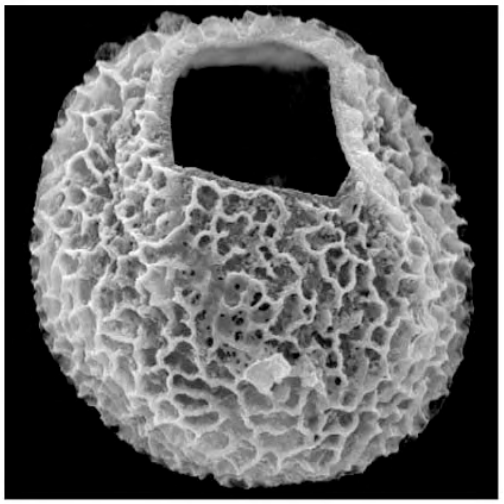


In contrast to forminifers, who become extinct, dinoflagellates can react to the changing circumstances after the Chicxulub impact



Dinoflagellates: NO species disappear!

DINOFLAGELLATE CYST MIGRATIONS ACROSS THE K/T BOUNDARY



Equator
Nigeria

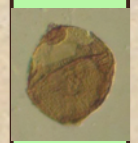
El Kef
Tunisia

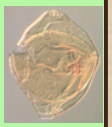
Agost
Spain

Geulhem
Holland

Denmark

TERTIARY

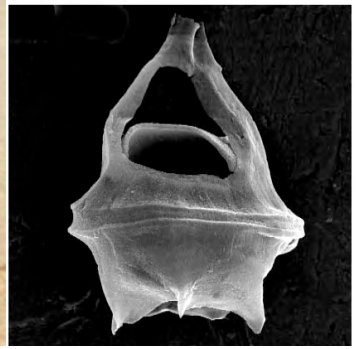




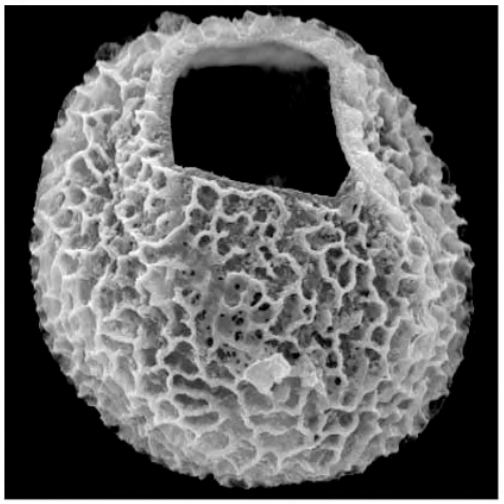
CRETACEOUS

Warm
>1Ma

(Brinkhuis et al 1998 Paleo3x)



DINOFLAGELLATE CYST MIGRATIONS ACROSS THE K/T BOUNDARY



Equator
Nigeria

El Kef
Tunisia

Agost
Spain

Geulhem
Holland

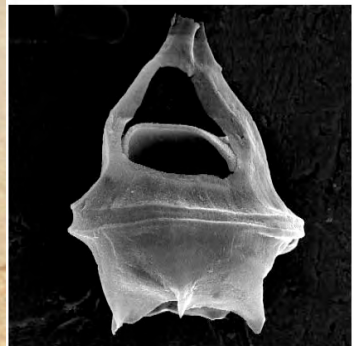
Denmark

TERTIARY

Cooling (?<50yr)

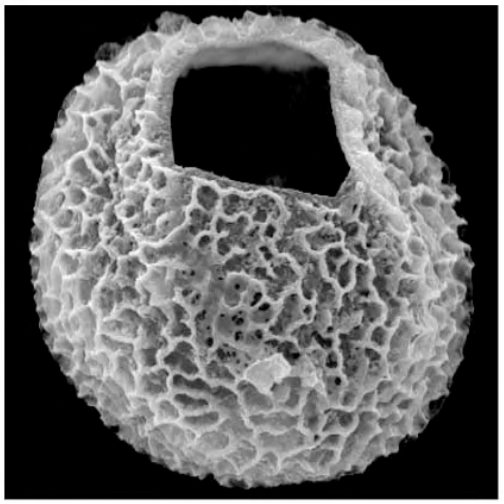
Warm
>1Ma

CRETACEOUS



(Brinkhuis et al 1998 Paleo3x)

DINOFLAGELLATE CYST MIGRATIONS ACROSS THE K/T BOUNDARY



Equator
Nigeria

El Kef
Tunisia

Agost
Spain

Geulhem
Holland

Denmark

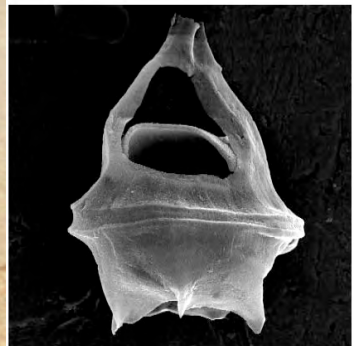
TERTIARY

Warming 2500yr

Cooling (?<50yr)

Warm
>1Ma

CRETACEOUS

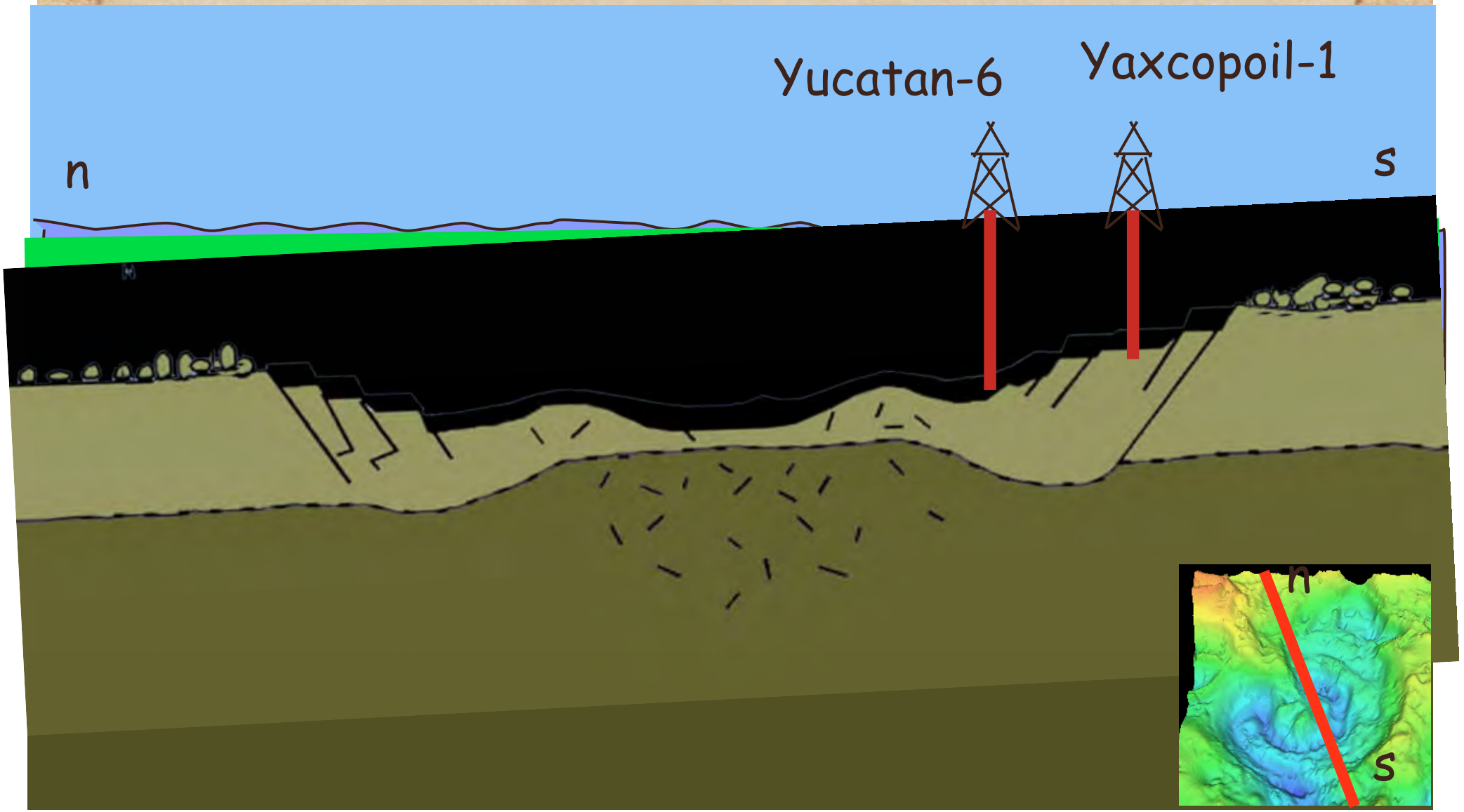


(Brinkhuis et al 1998 Paleo3x)

A 'Solution' comes from the Chicxulub data:

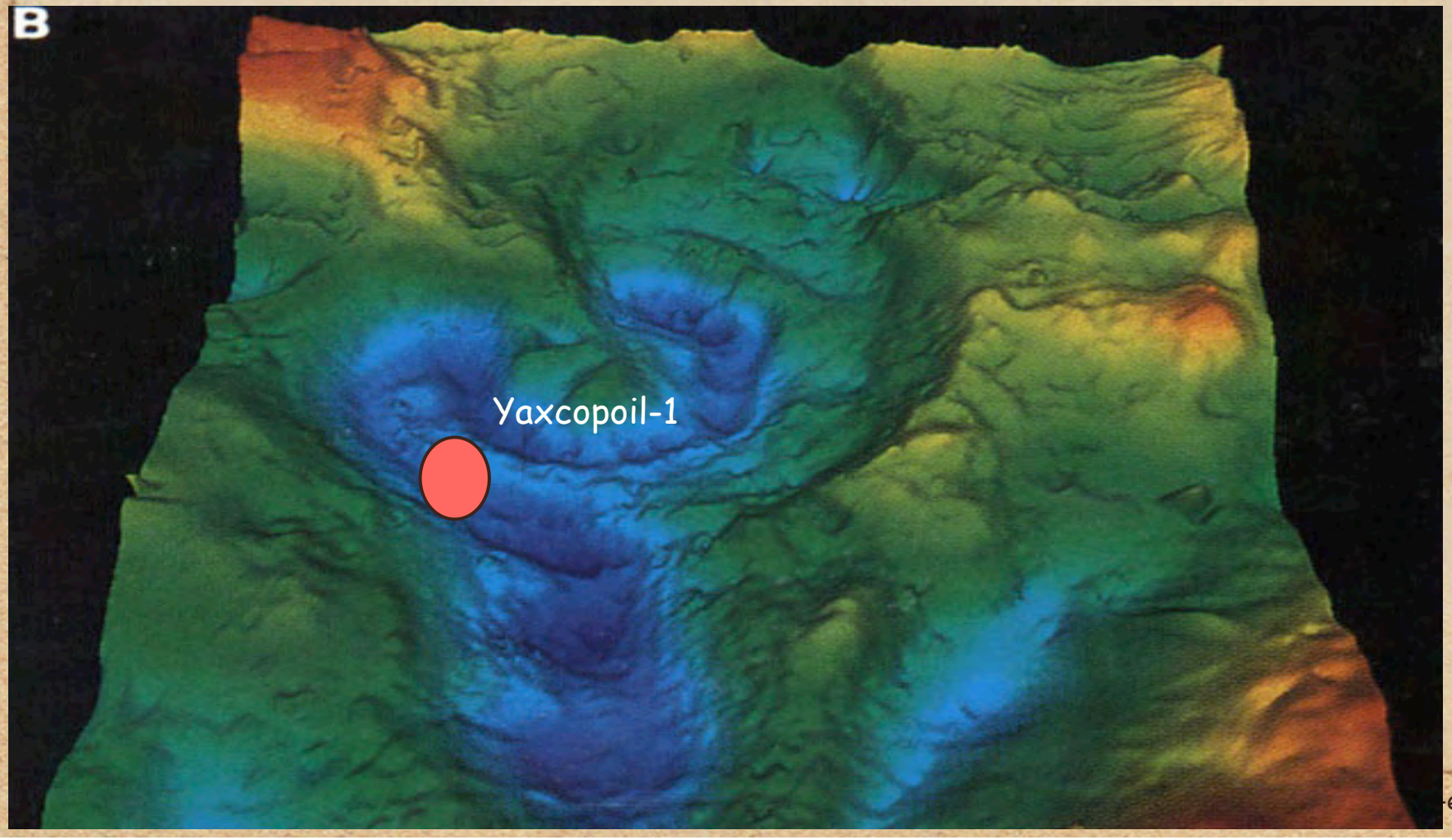
Chicxulub drilling project, CSDP initiated in 1995, excecuted 2001

N



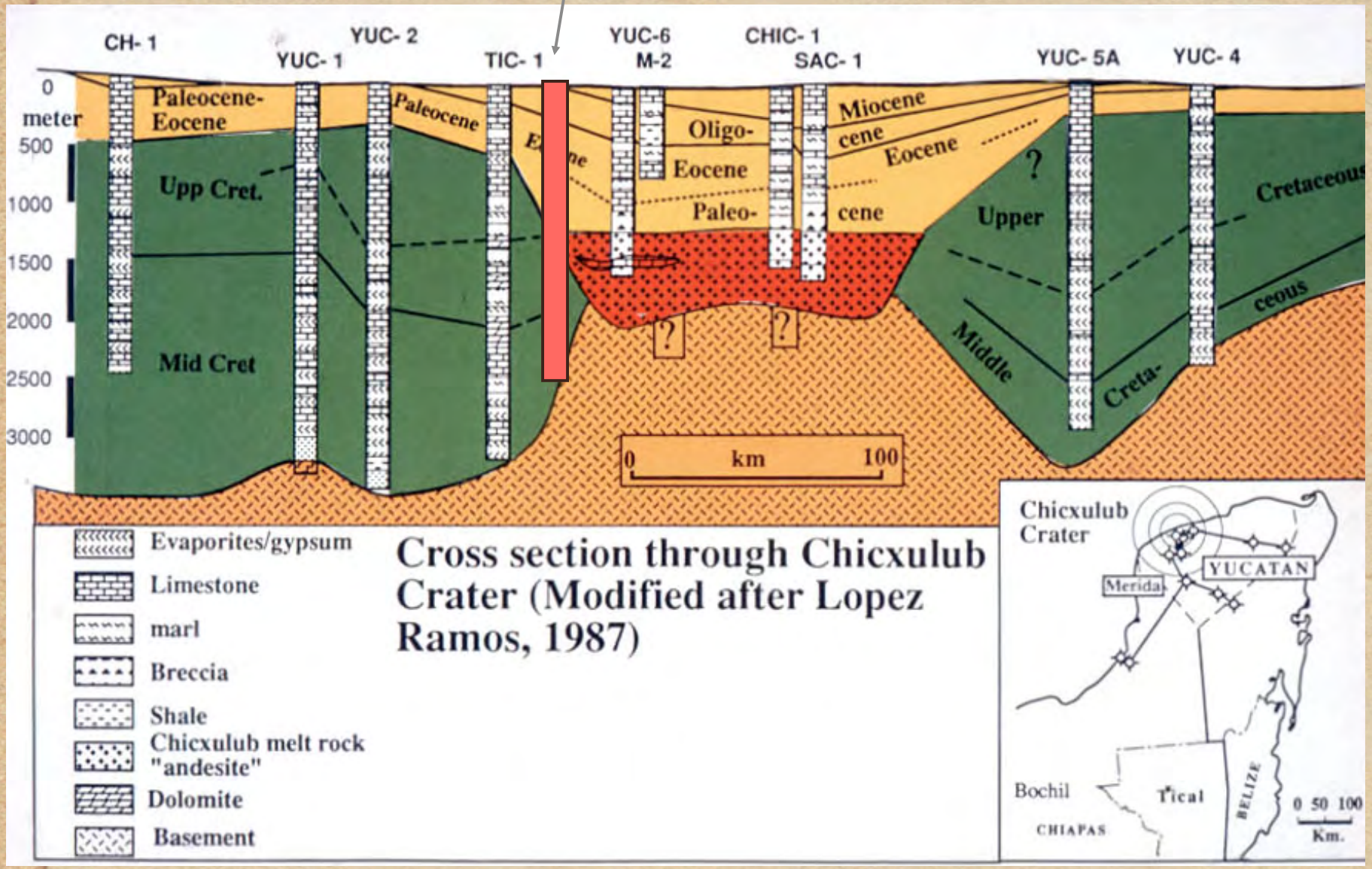
The Chicxulub Scientific Drilling Project (CSDP)

Yaxcopoil-1 drill hole



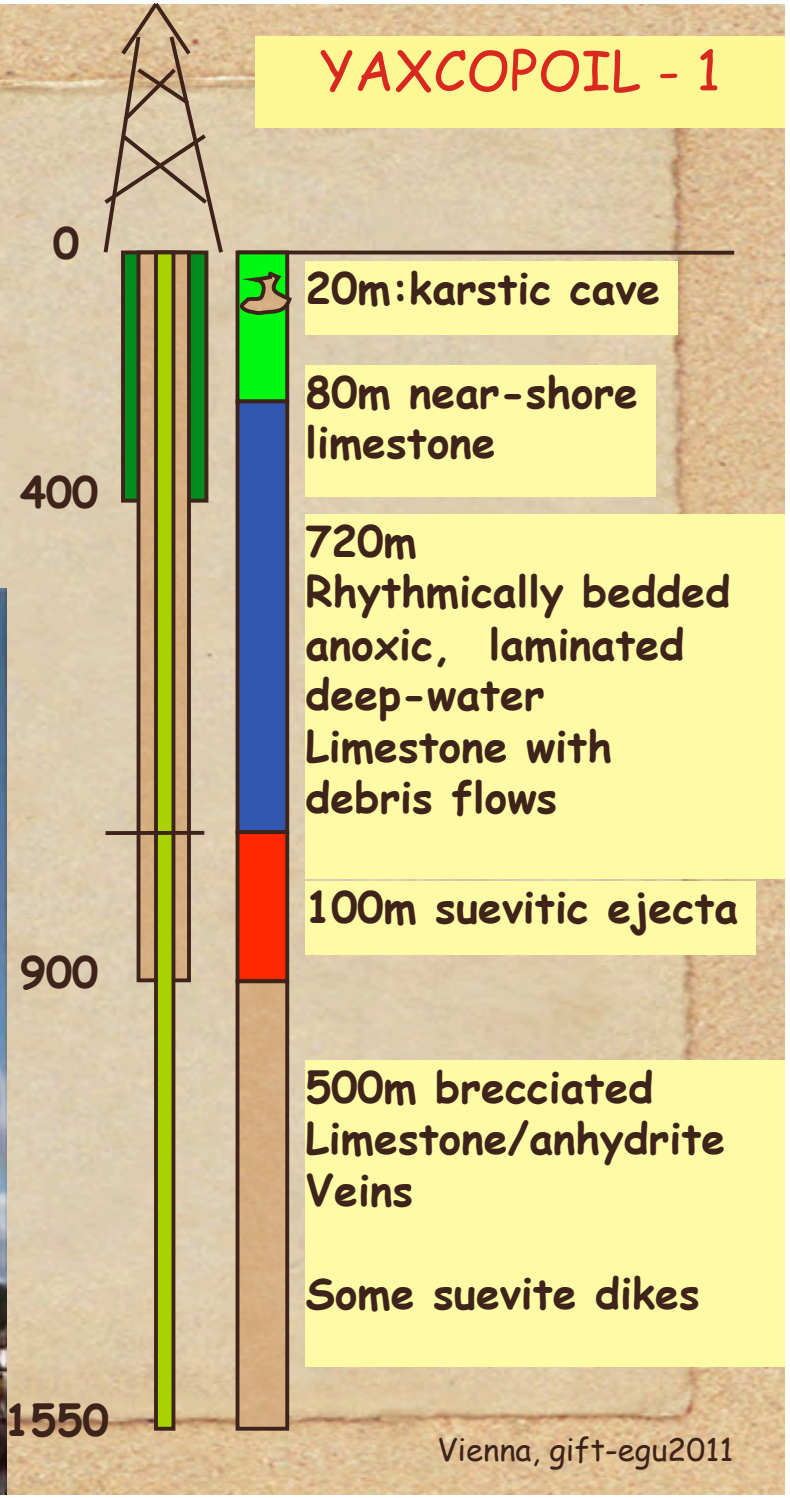
egu2011

Yaxcopoil drillhole



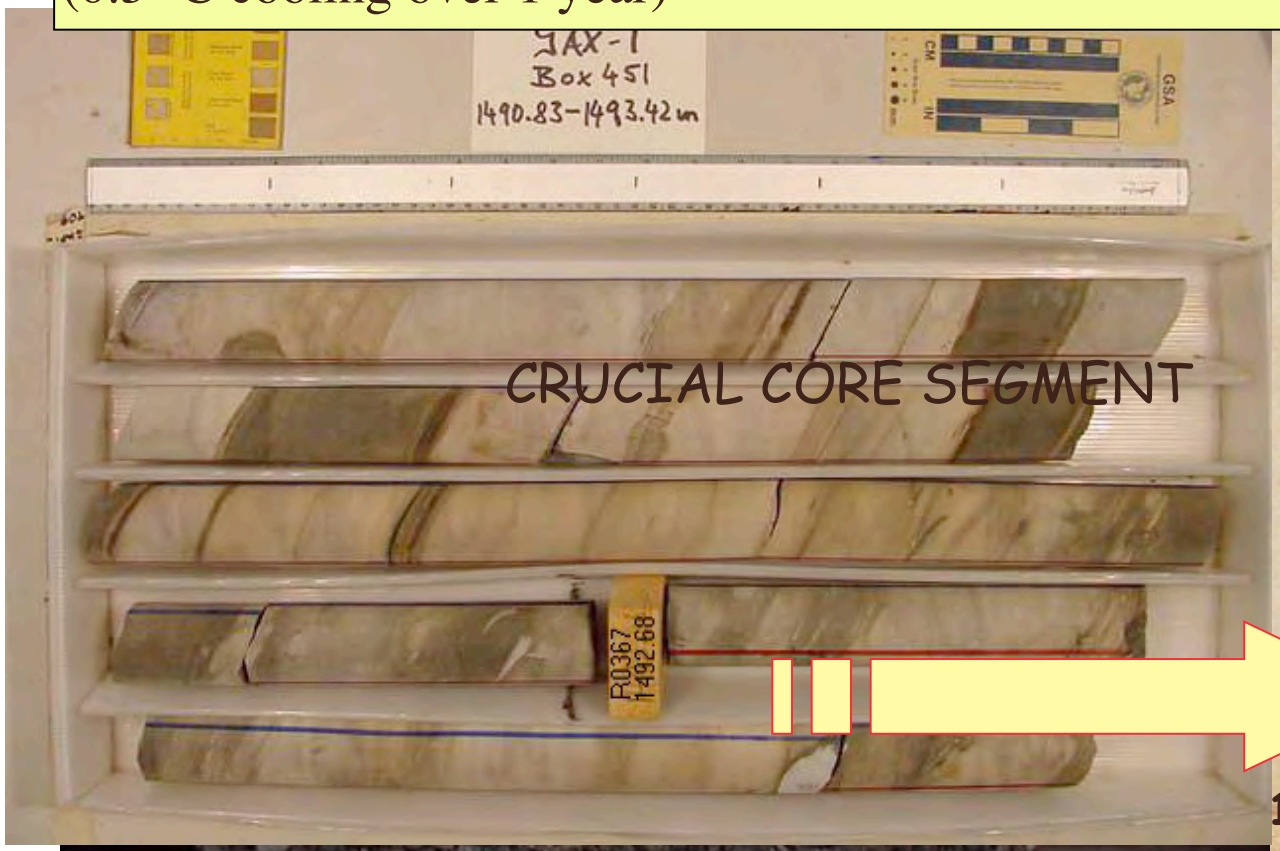
cross section of the Chicxulub crater

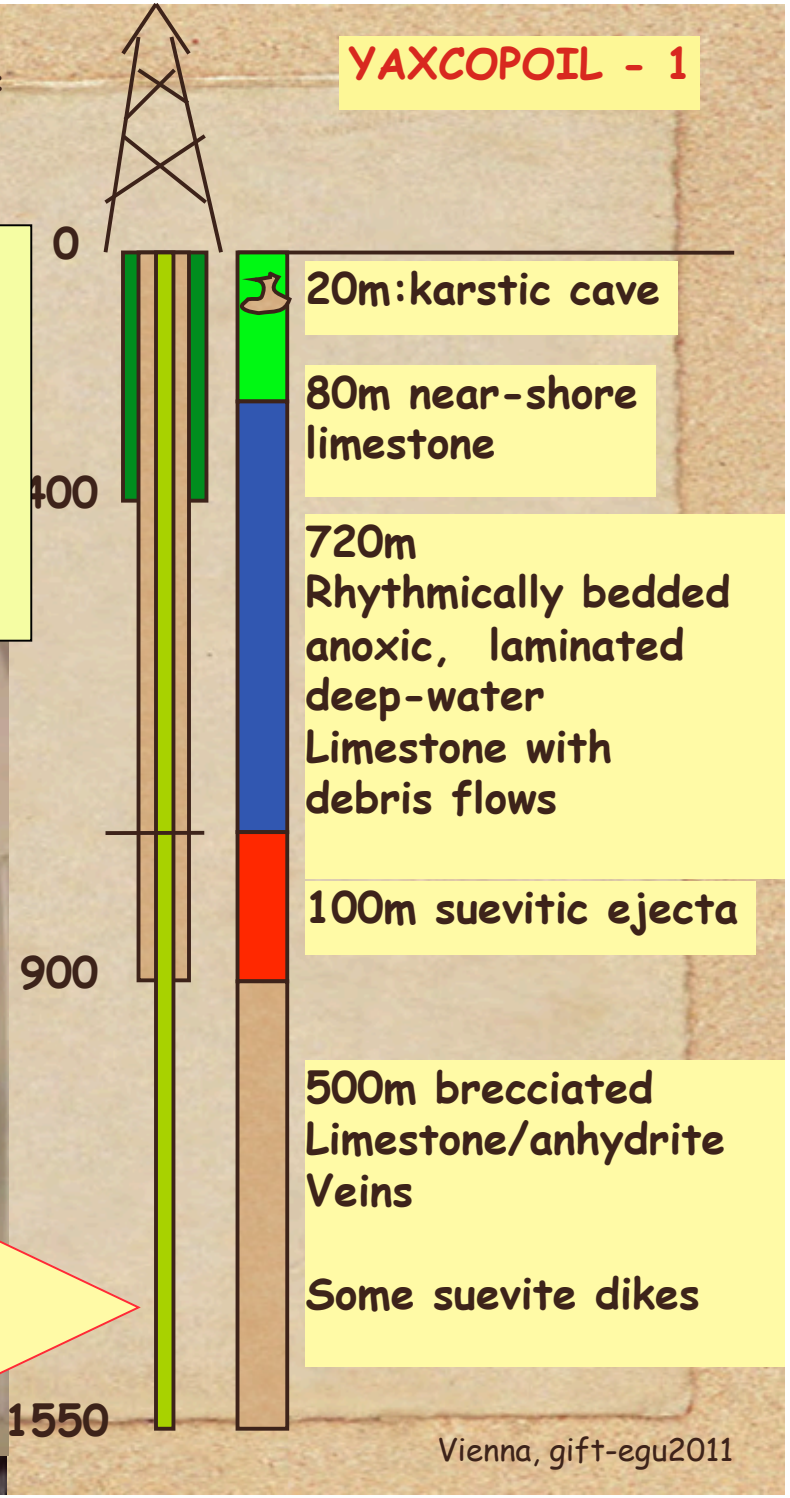
Chicxulub drilling project, CSDP initiated in 1995, excecuted 2001

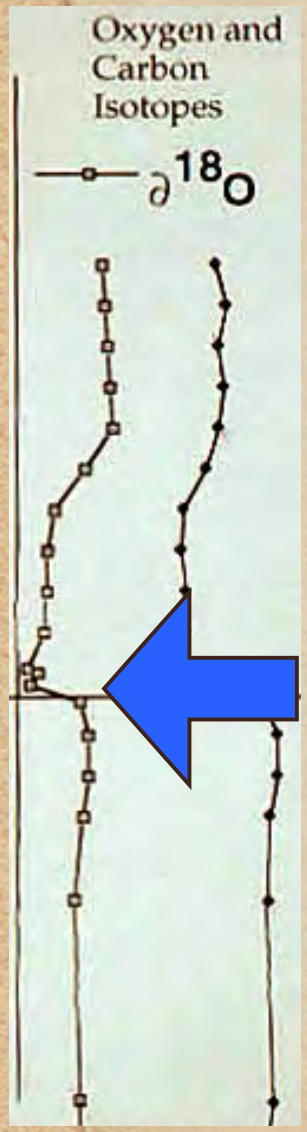


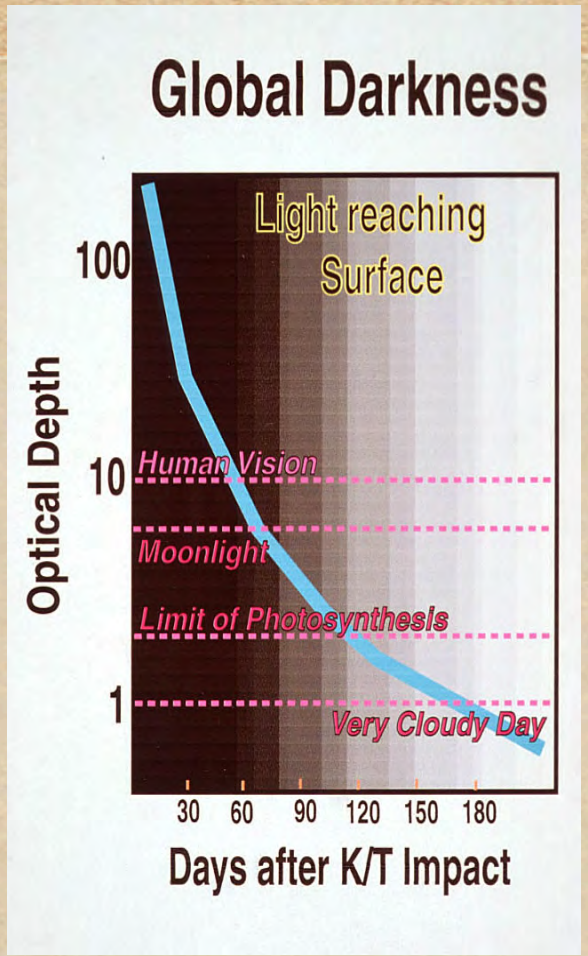
Shocked target rocks: Mega-Block zone.
Mixture Anhydrite (27%) and Carbonate (63%)

Anhydrite ($CaSO_4$):
approximately 250000mt SOx is "degassed" as aerosol (Pierazzo and Melosh, 2002)
By comparison: the Pinatubo eruption ejected 20mt sulphur
(0.5° C cooling over 1 year)



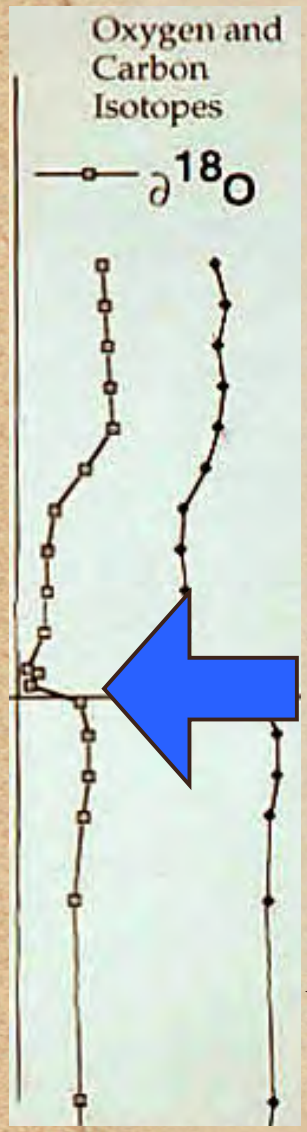


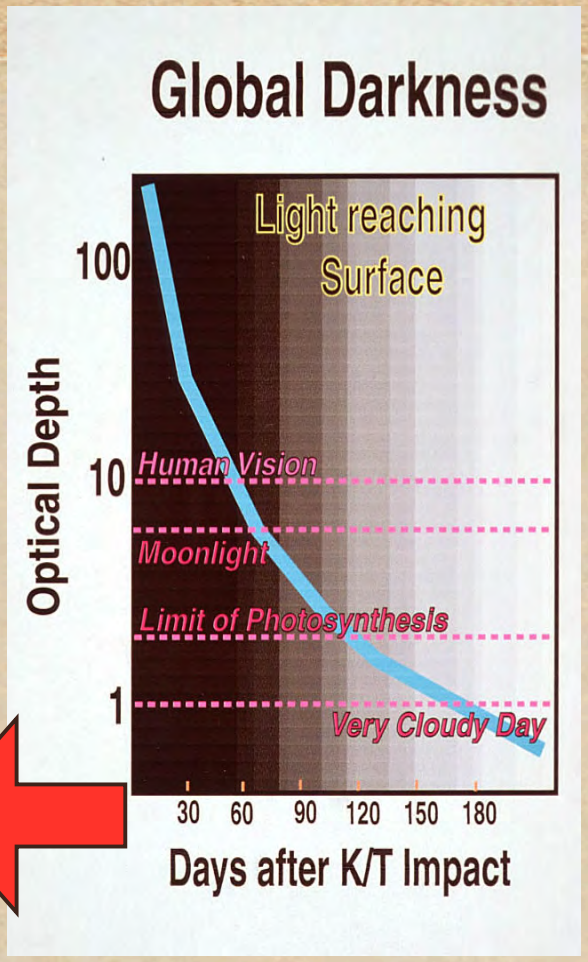




Why did the Chicxulub impact lead to mass-extinctions?

Probably because large amounts of dust and SOx aerosols reflected sunlight, and it became suddenly cold





May be a little warming by the Deccan traps

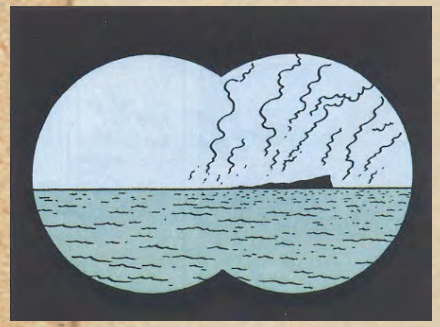
Why did the Chicxulub impact lead to mass-extinctions?

Probably because large amounts of dust and SOx aerosols reflected sunlight, and it became suddenly cold

But due to the release of CO2 and other greenhouse gases it then became

warm

meteorite



meteorite

tsunami

FIN