The Cretaceous-Paleogene Crisis and its Aftermath: Tectonic, Magmatic, Biotic, Climatic, and Evolutionary Upheavals of Indian Plate

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MAJOR EVENTS DURING THE CRETACEOUS/ PALEOGENE TRANSITION

- Rifting of Madagascar from India (~88 Ma)
- Collision of India with the Kohistan-Ladakh Arc (~80 Ma)
- Shiva Impact and Deccan Volcanism at the K/Pg boundary (~65 Ma)
- Dinosaur extinction
- Acceleration of the Indian plate (~67-52 Ma)
- Separation of Seychelles from India (~64 Ma)
- India-Asia collision at PETM (~55 Ma)
- Explosive evolution of Placental Mammals

INDIA-MADAGASCAR RIFT (~88 Ma)

Two intracratonic Subductions of the Neotethys:

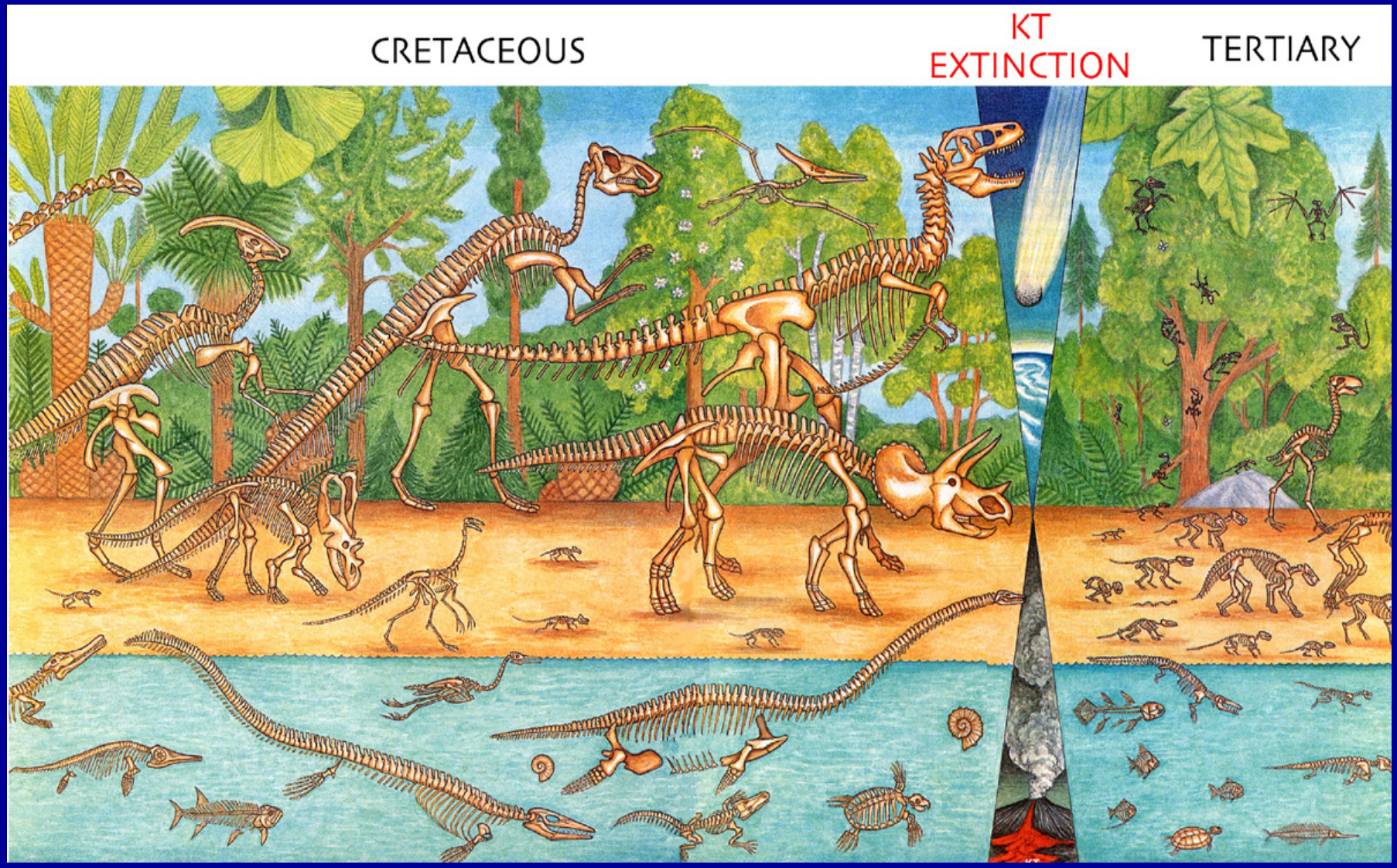
- Collision of India with the K-L Arc (~80 Ma)
- India-Eurasia Collison around PETM (~50 Ma)

COLLISION OF INDIA WITH THE KOHISTAN-LADAKH ARC (~80Ma)

K/Pg Boundary Events

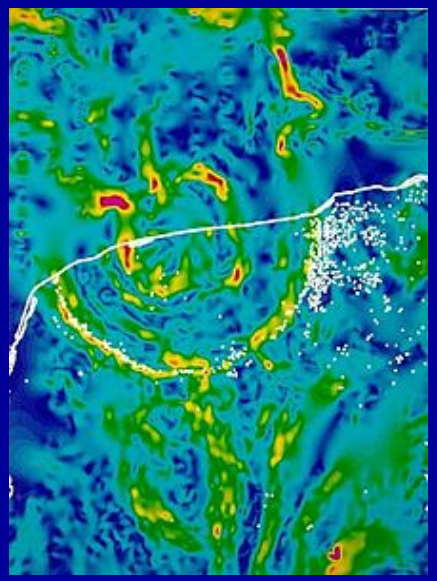
What killed the dinosaurs?

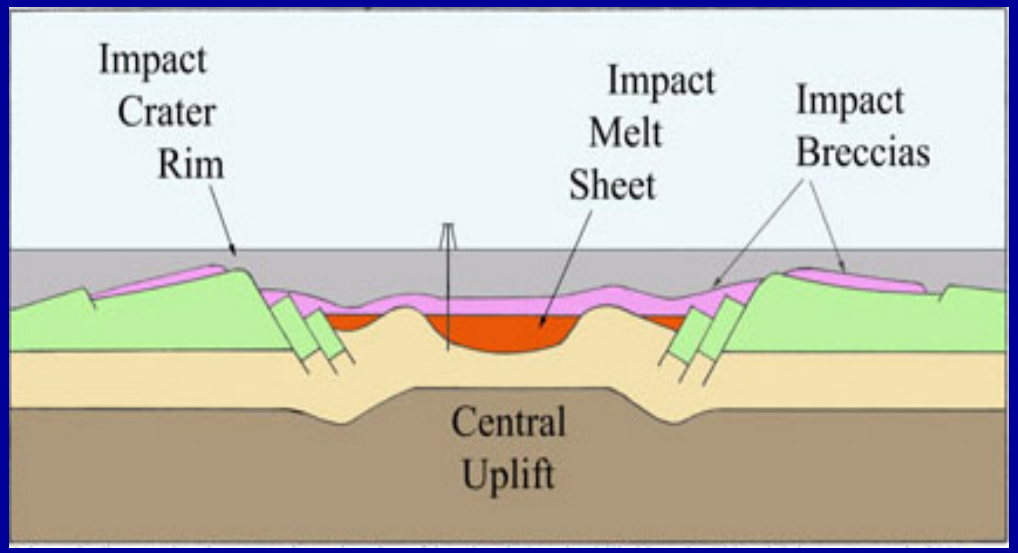
METEORITES OR DECCAN VOLCANISMS?



Chicxulub Crater, Yucatan Peninsula, Mexico

Estimated crater size ~ 180 km diameter
Estimated bolide size ~10 km diameter
NEO asteroid ~ Sisyphus





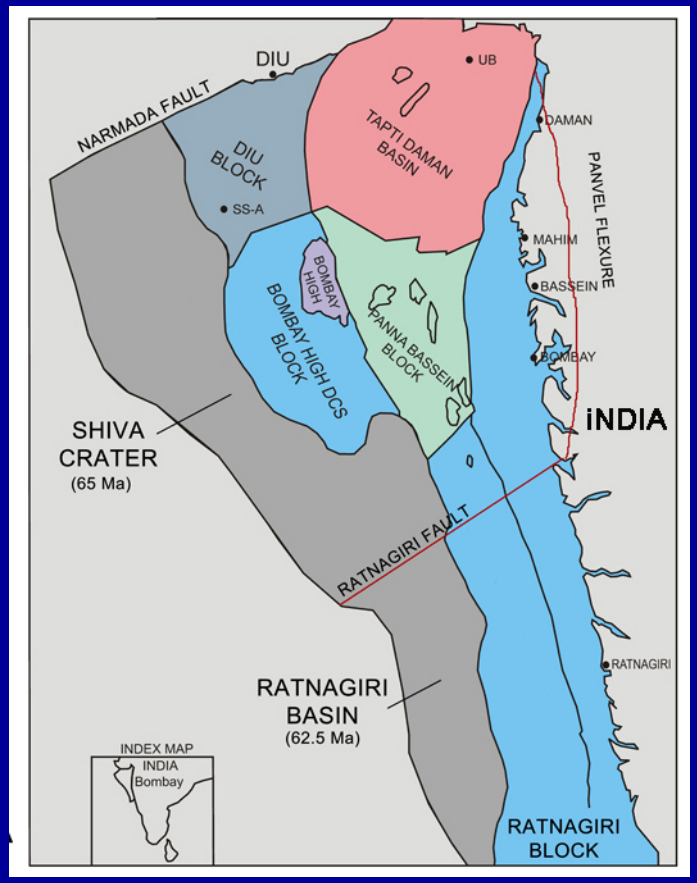
K/T Boundary Events in India

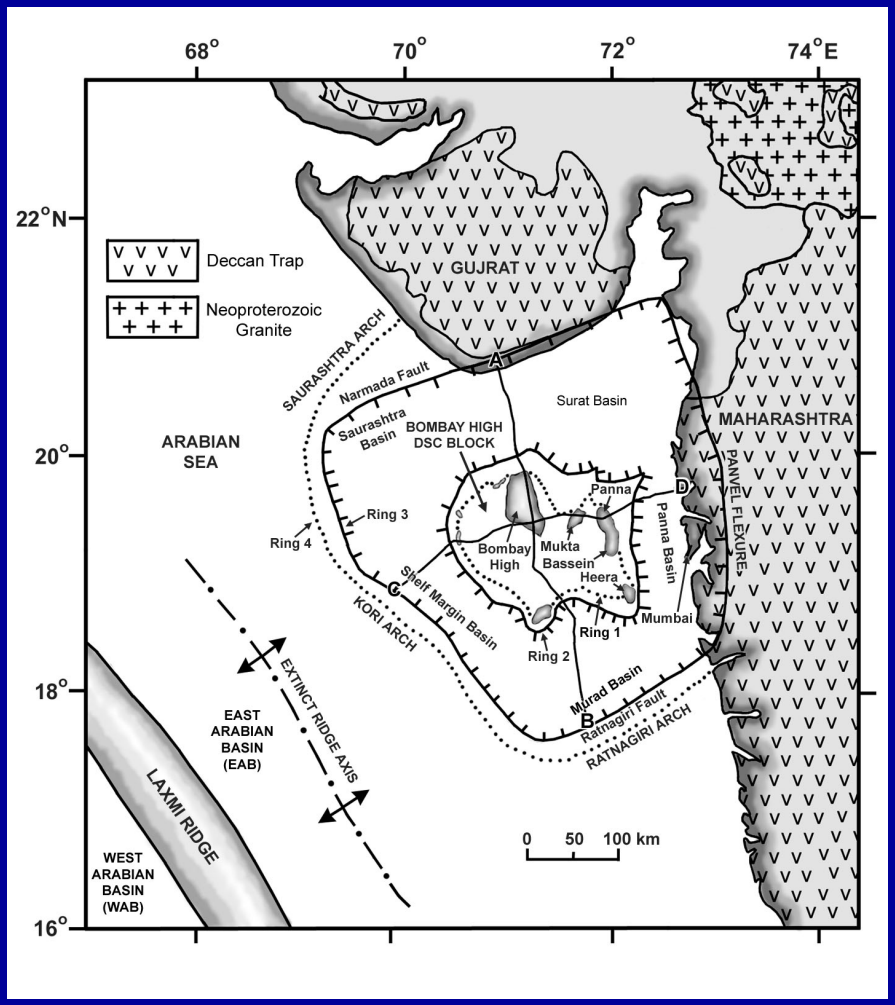
INDIA WAS GROUND ZERO FOR TWO CATASTROPHIC EVENTS AT THE K/T BOUNDARY

- SHIVA IMPACT
- DECCAN VOLCANISM

BOTH EVENTS LINKED TO DINOSAUR EXTINCTION AND MEGA TECTONICS

Shiva Crater at the Mumbai Offshore Basin, western Shelf of India



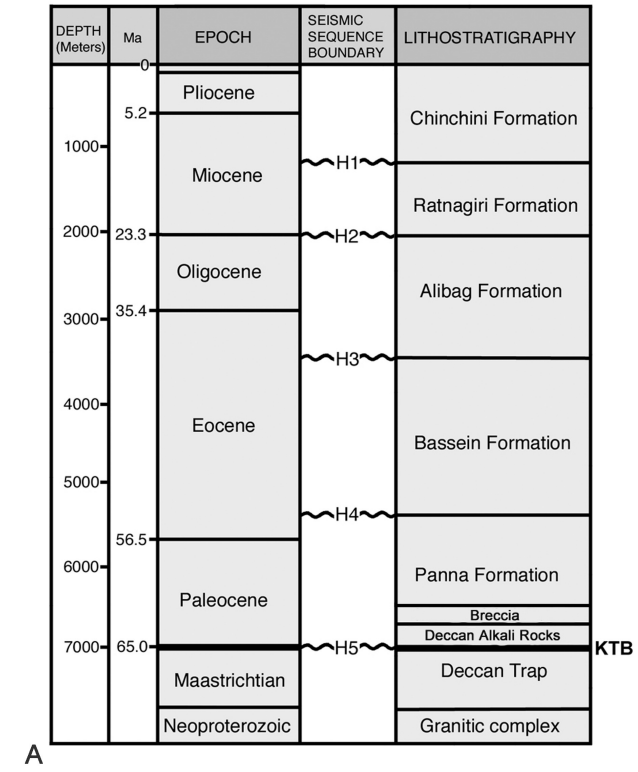


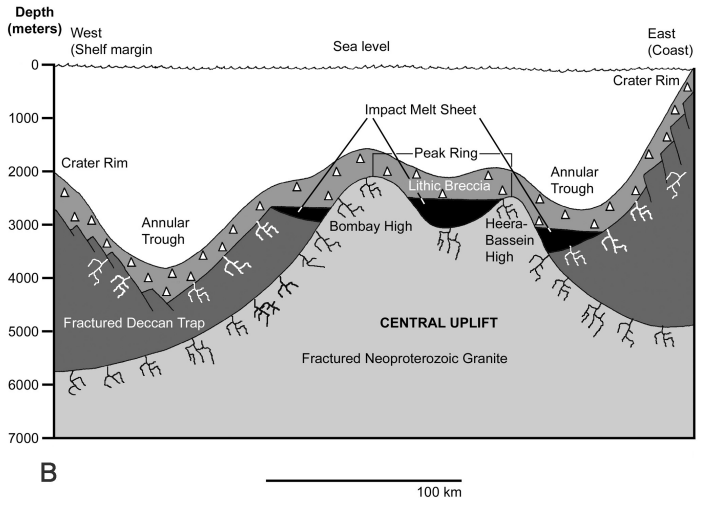
Estimated crater size ~ 500 km diameter

Estimated bolide size ~40 km diameter

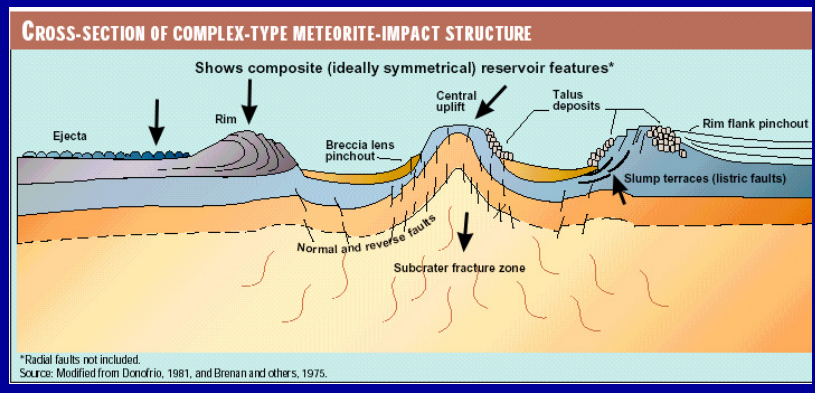
NEO asteroid ~ Ganymed

SHIVA CRATER



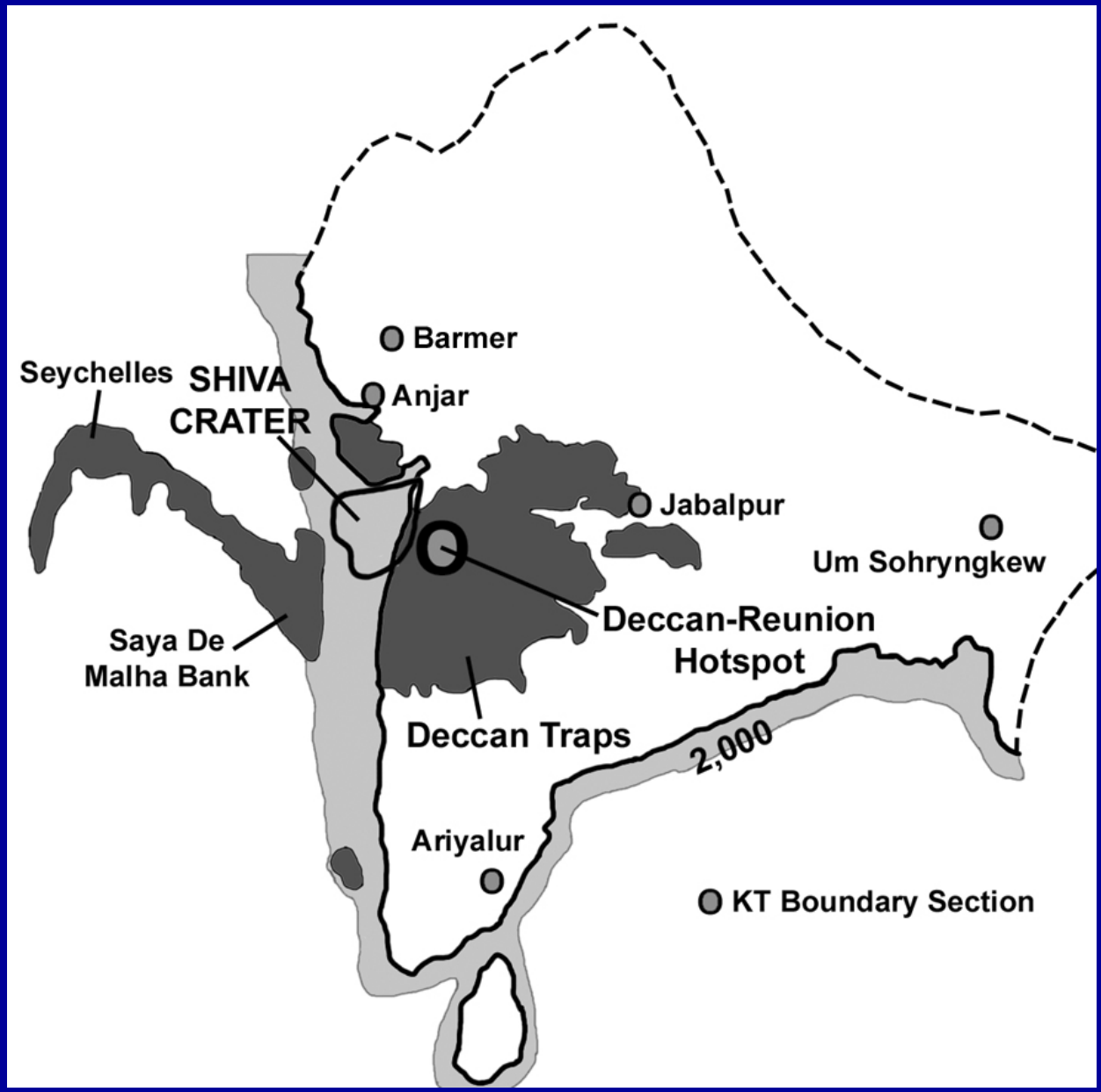


Bombay High is the central peak of the Shiva crater: the largest Oilfield in India



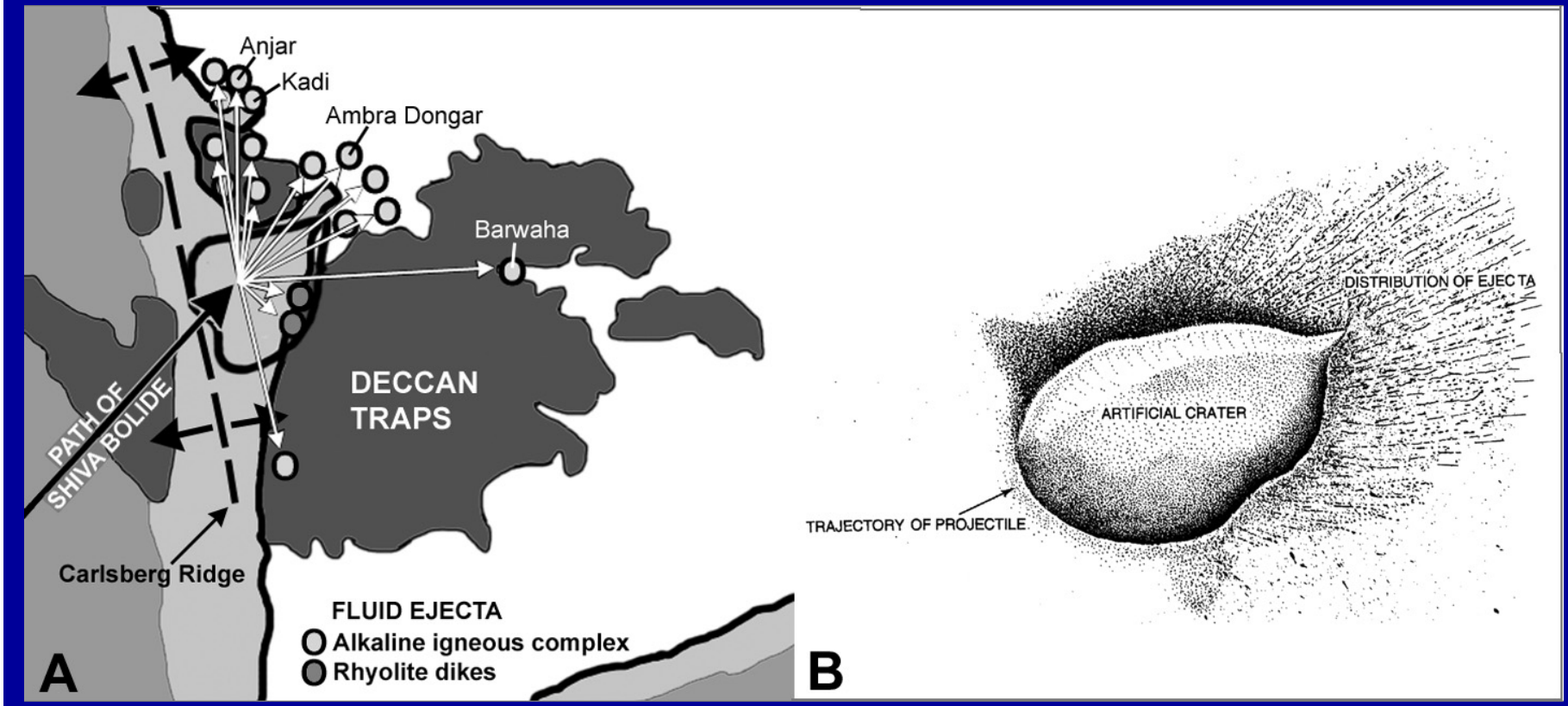
K/T Boundary impact signatures in India

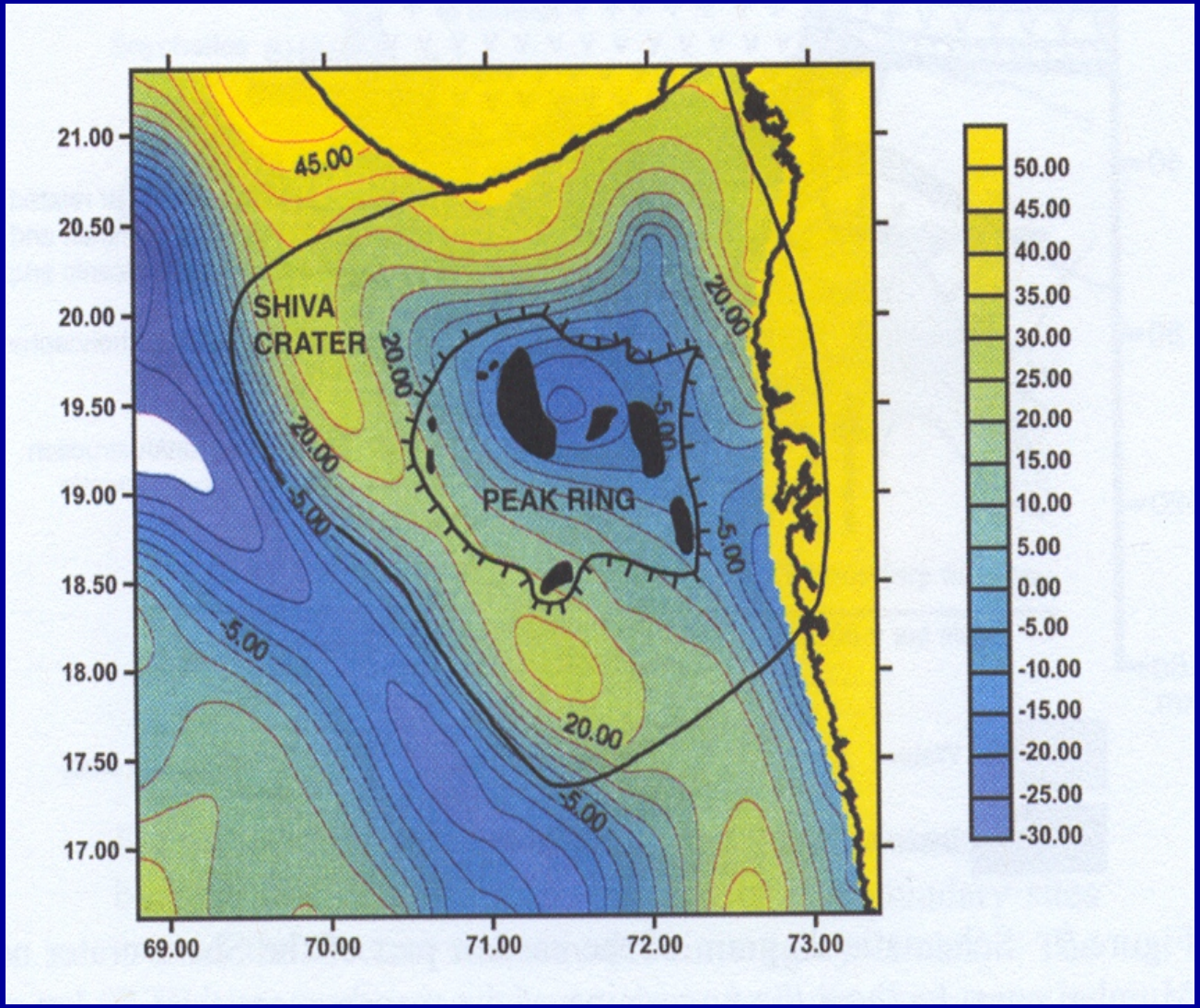
Iridium anomaly, shocked quartz, iridium-rich alkaline melt rocks, metallic spherules, fullerenes, nickel-rich spinels



SHIVA IMPACT TECTONICS

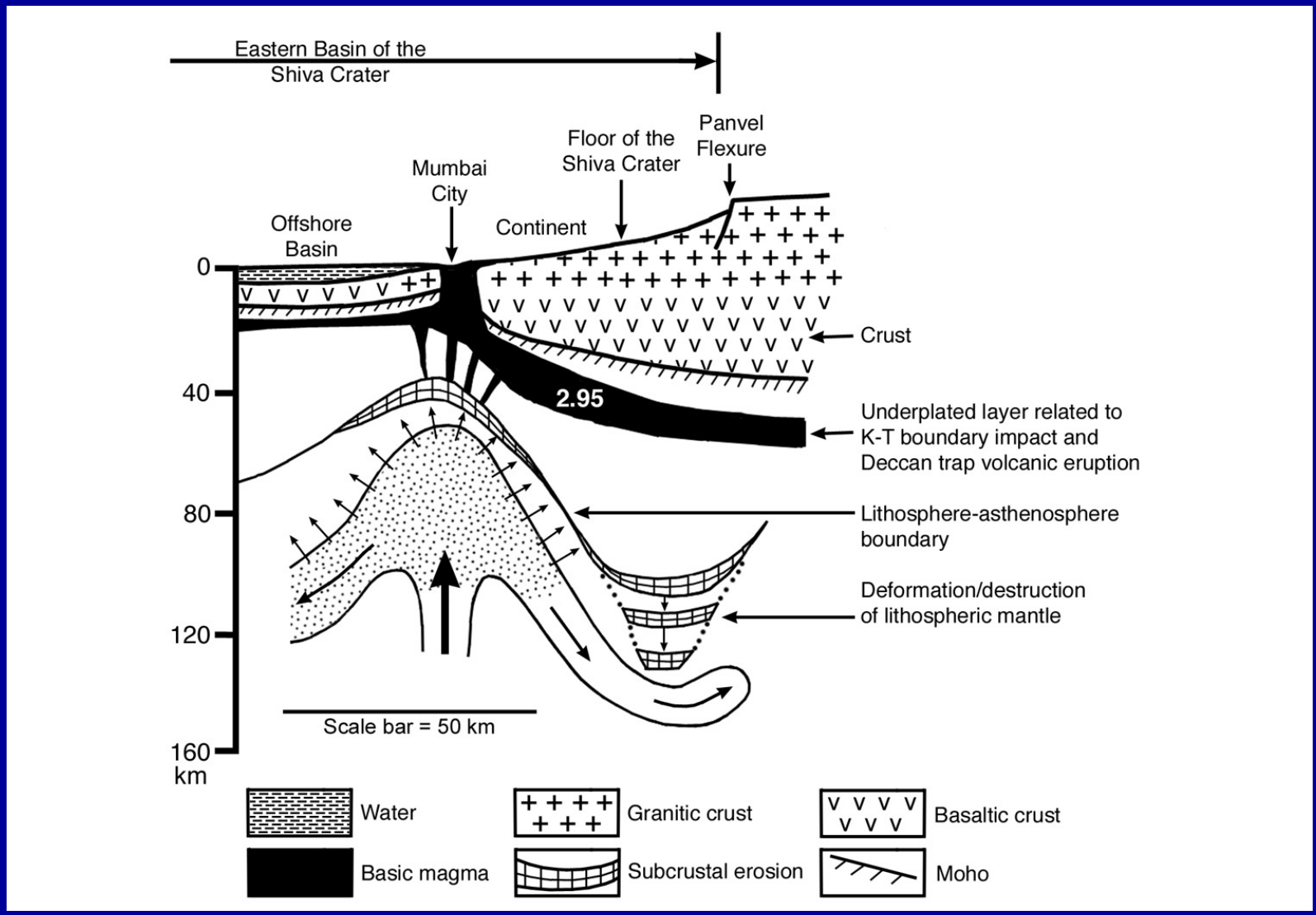
Radial, asymmetric distributions of alkaline igneous complexes: impact melt rocks
(~65 Ma; iridium anomaly)





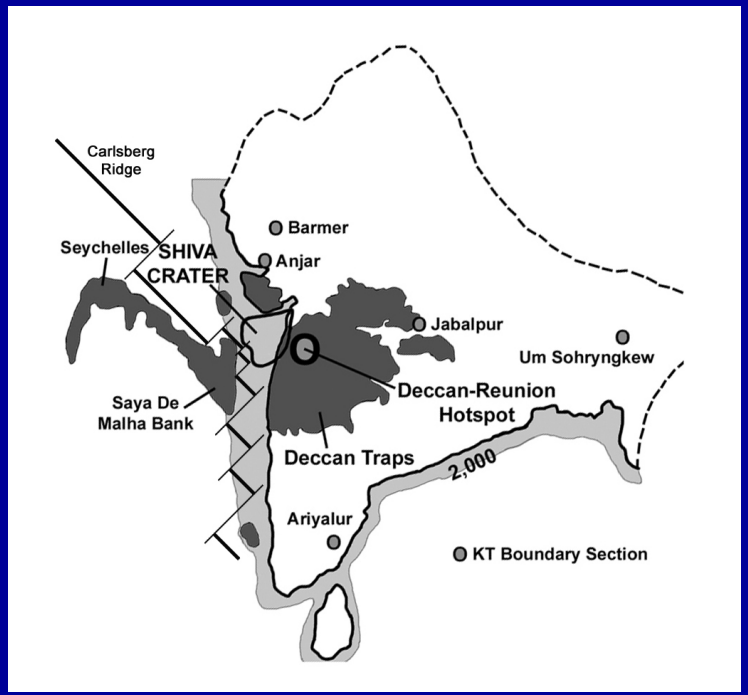
Negative gravity anomaly around the central peak (ONGC data)

REBOUND OF MOHO BY 50 KM; DESTRUCTION OF LITHOSPHERE

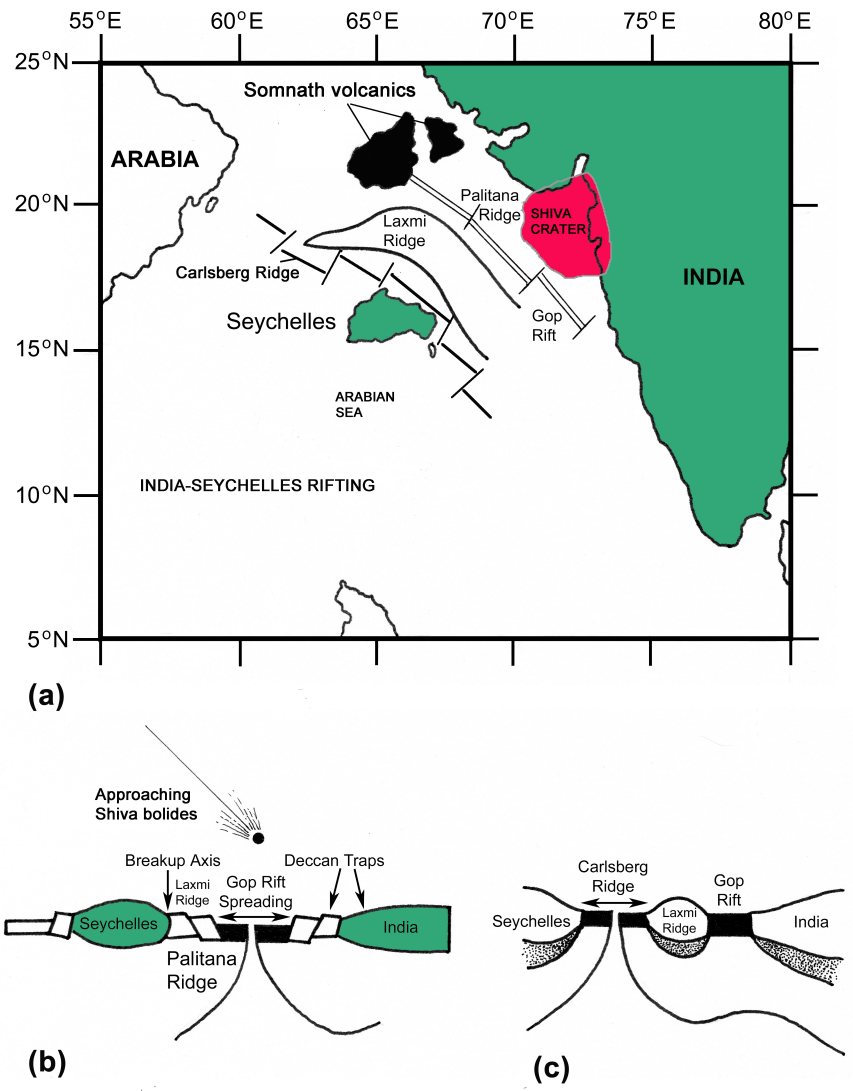


(after Pandey and Agarwal, 2001)

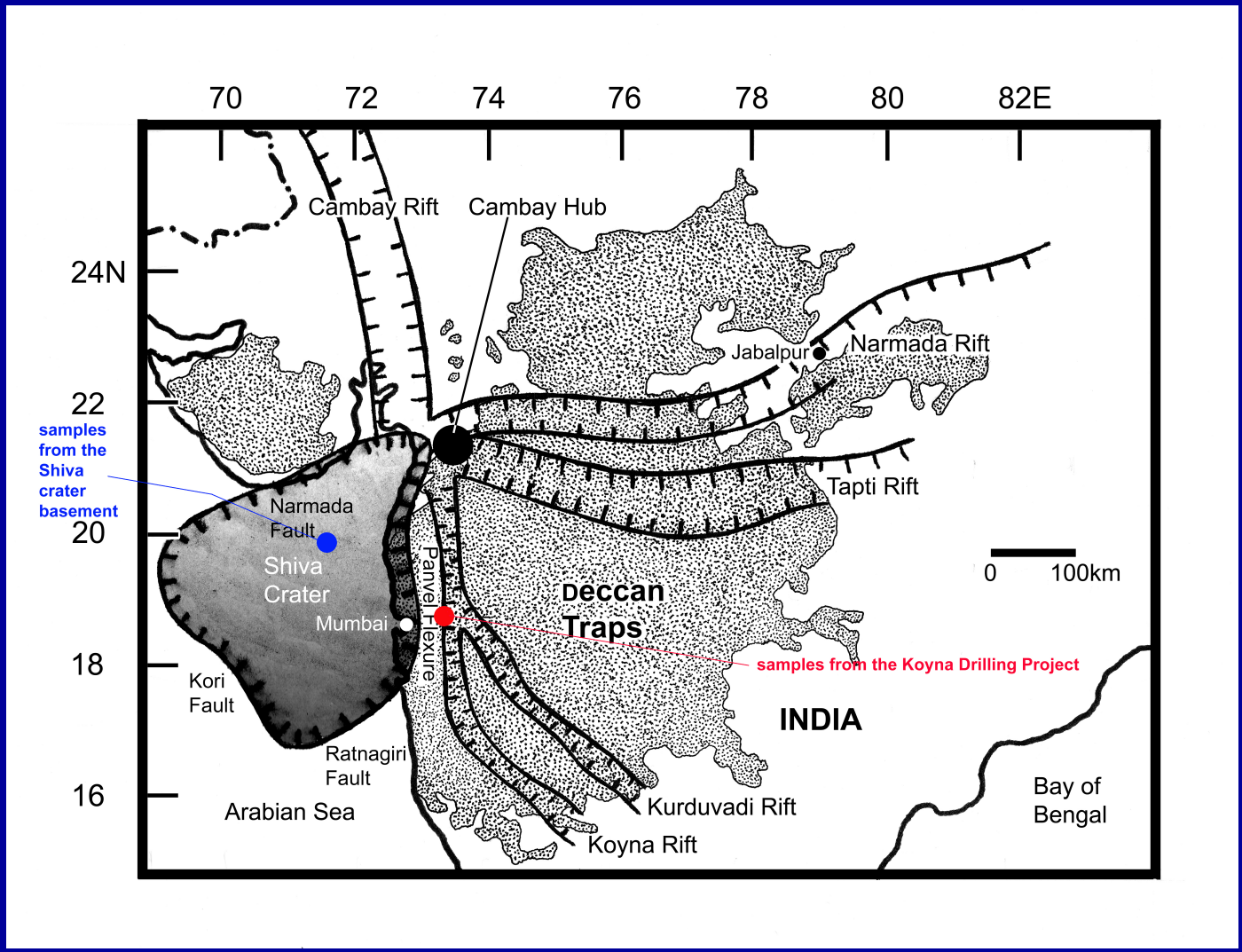
Seychelles was rifted from India during the Shiva Impact



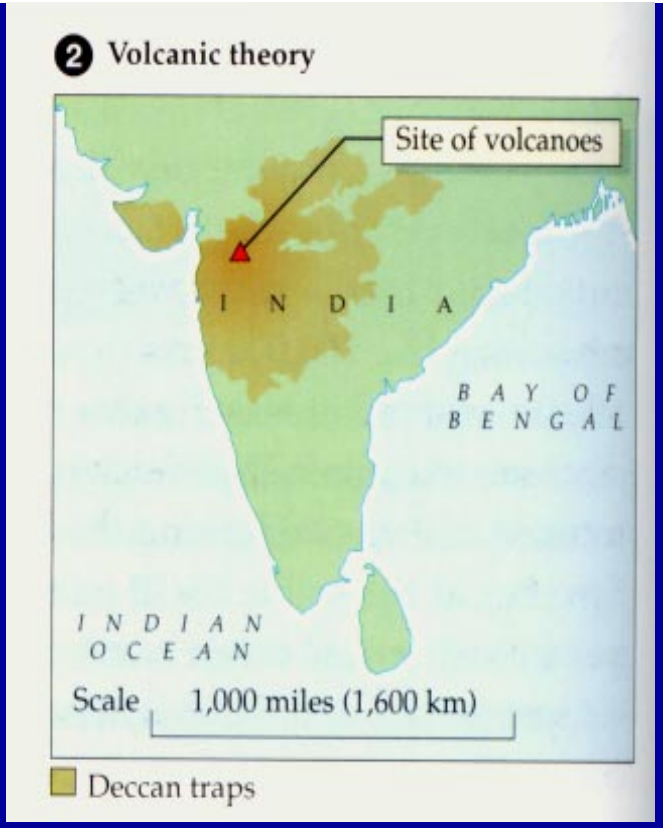
Vicki Hansen (2007) hypothesized how bolide impact might have triggered plate tectonics



SHATTERING OF WEST-CENTRAL INDIA BY SHIVA IMPACT: REACTIVATION OF OLD RIFT BASINS



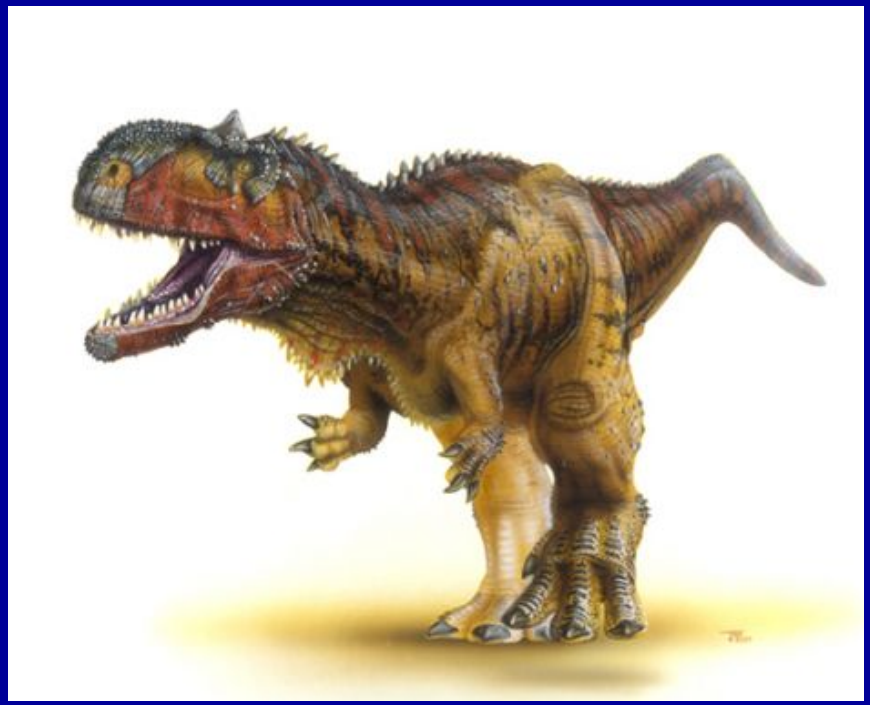
DECCAN VOLCANISM



Some scientists believe that the Deccan volcanism in India was the cause for dinosaur extinction

THE LAST DINOSAURS FROM INDIA: CARNIVOROUS ABELISAURS AND HERBIVOROUS TITANOSAURS

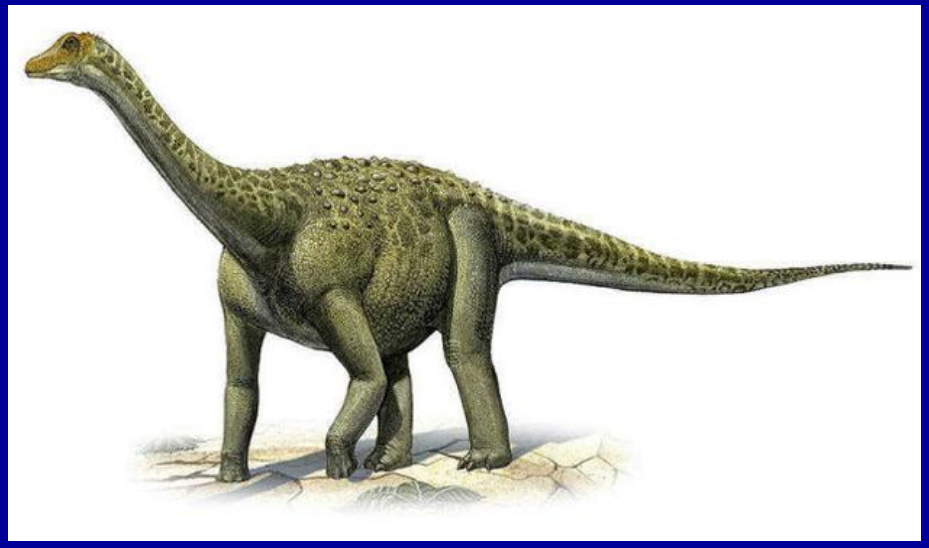
Abelisaurs, theropod dinosaurs from the Lameta Formation



Rajasaurus

Rahiolisaurus

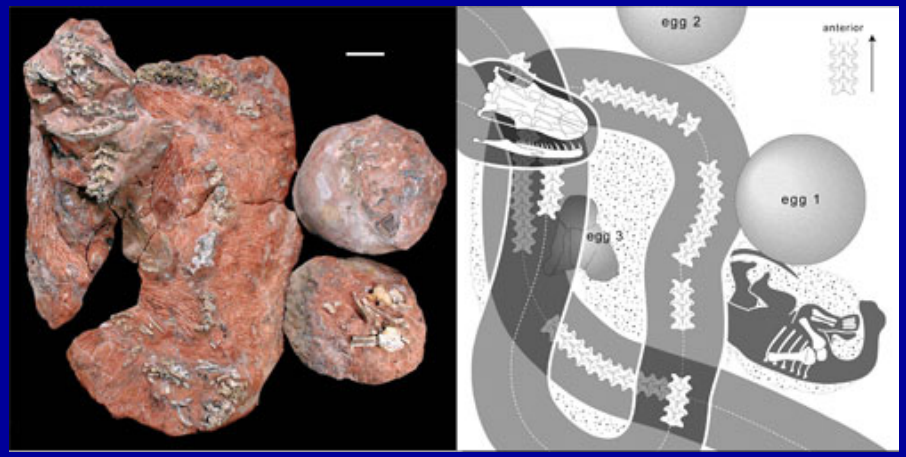
TITANOSAURS AND THEIR EGGS FROM RAIHOLI, GUJARAT



Jainosaurus

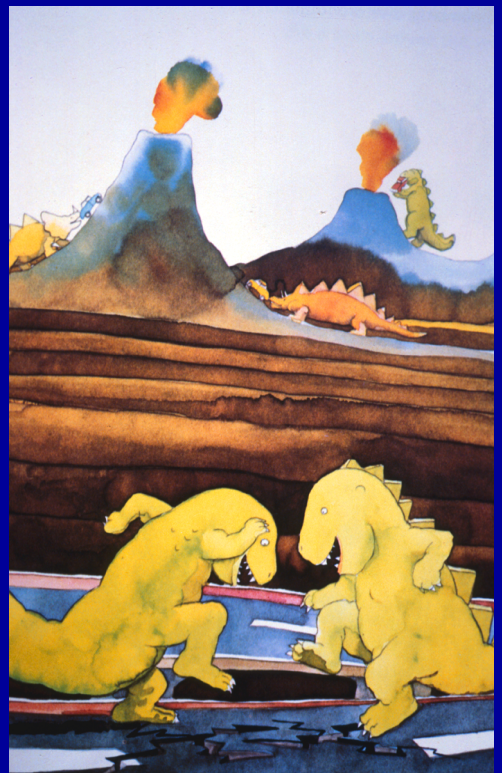
Isisaurus

Titanosaur eggs



Sanajeh, the snake that ate baby titanosaurs

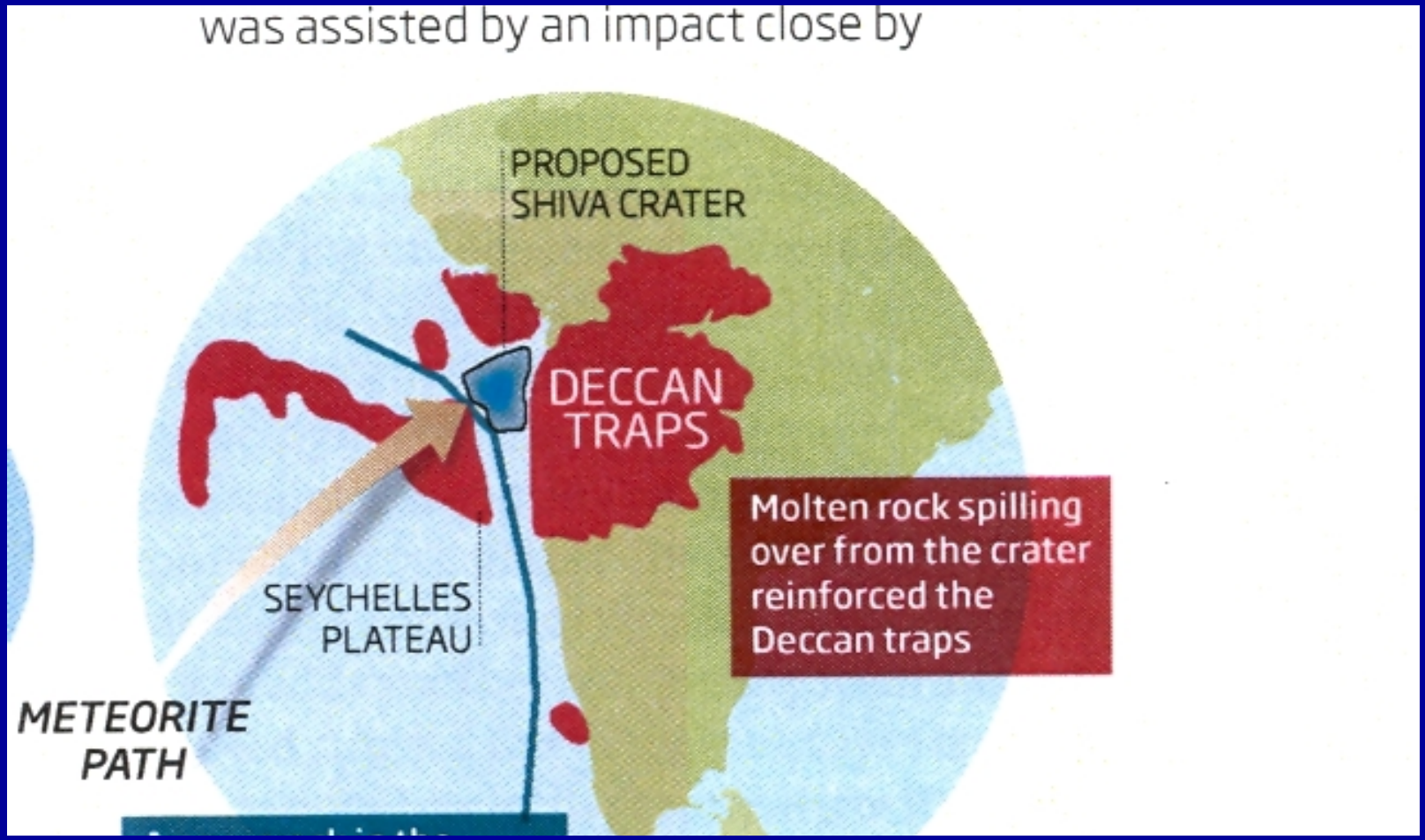
Late Cretaceous Dinosaurs survived during the Deccan eruptions but died out suddenly above the Iridium anomaly at the Anjar section, Gujarat

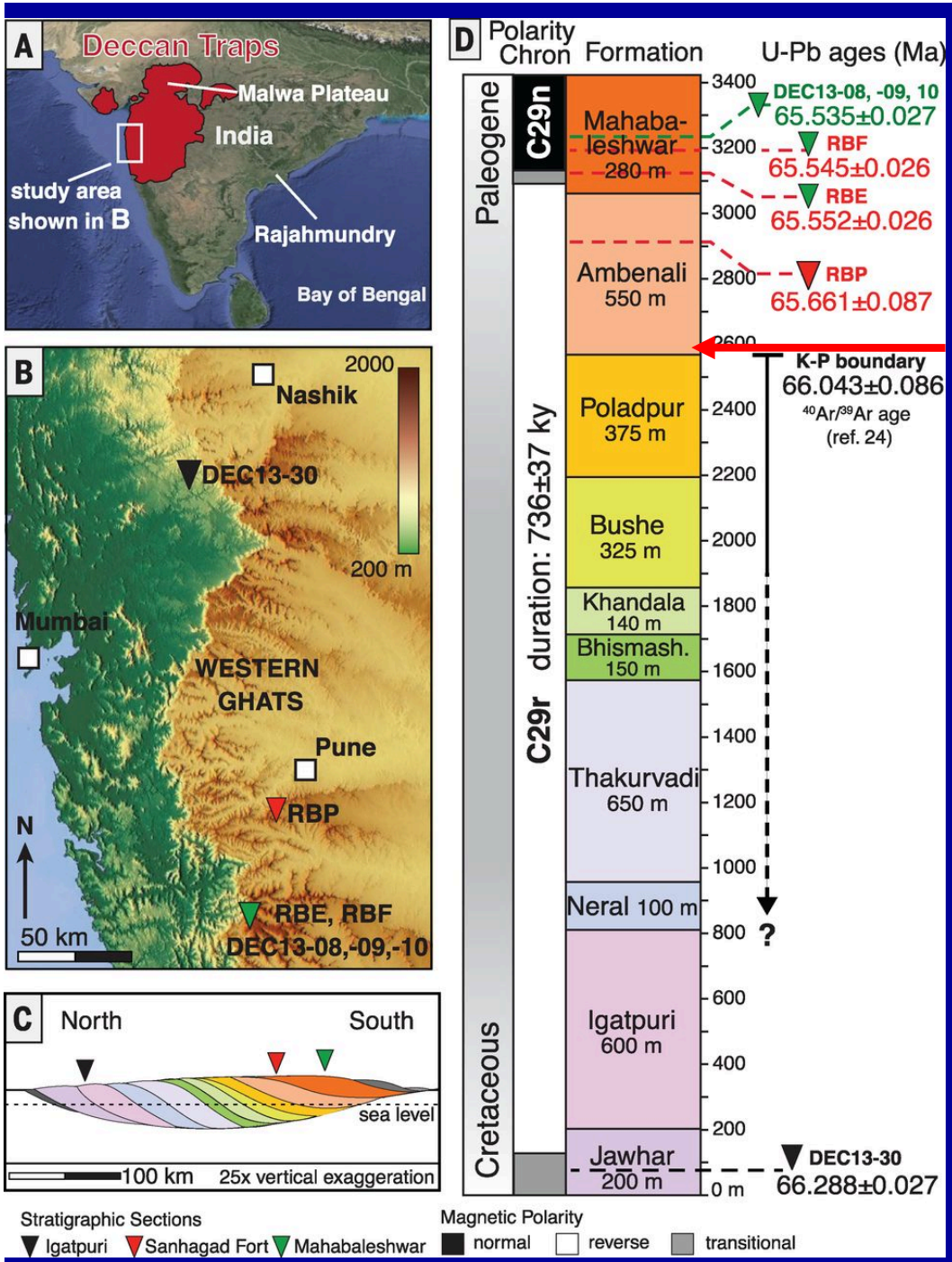


Abelisaur

Titanosaur

Did Shiva impact trigger Deccan Volcanism?





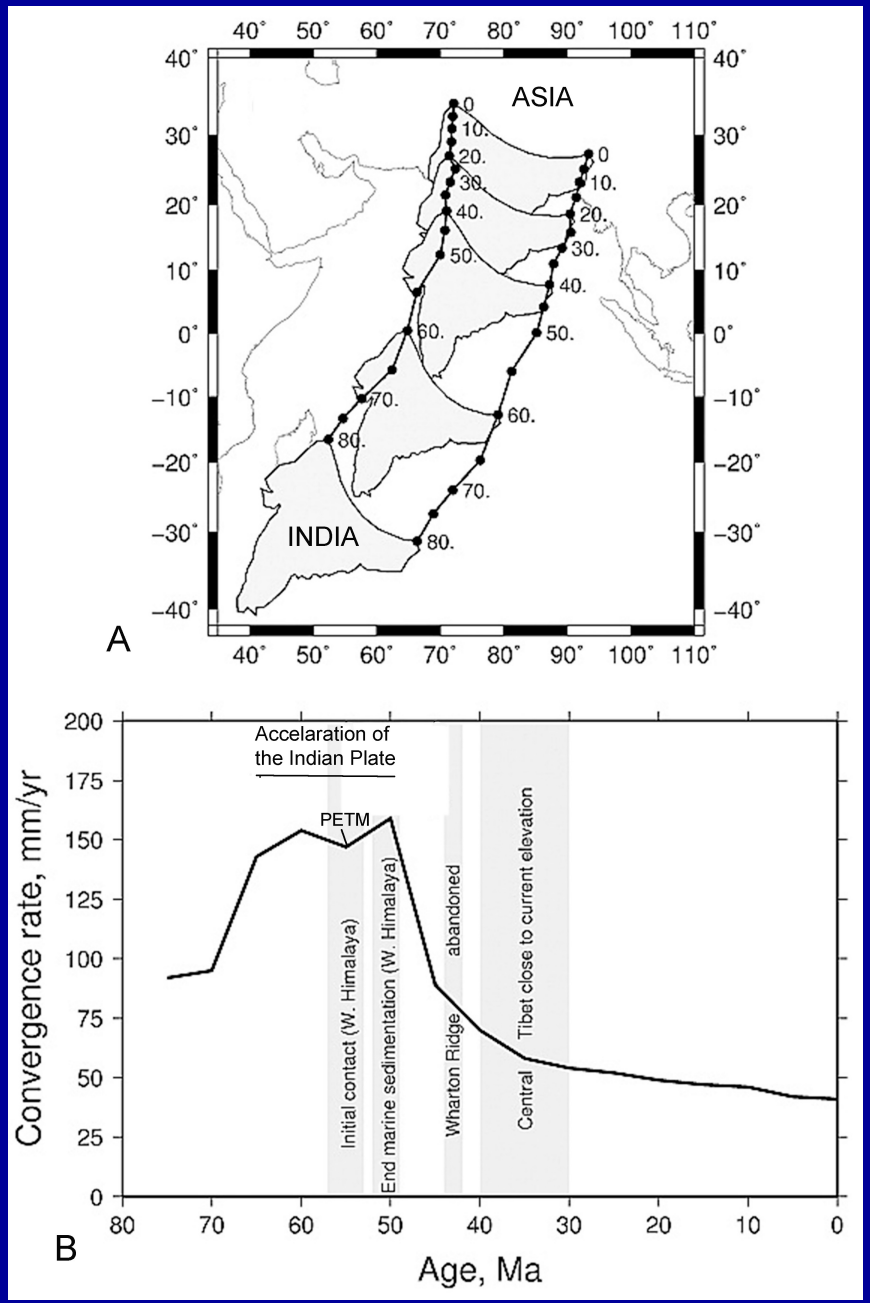
Blair Schoene et al. Science 2015

Impact-triggered volcanism

Shiva Impact event

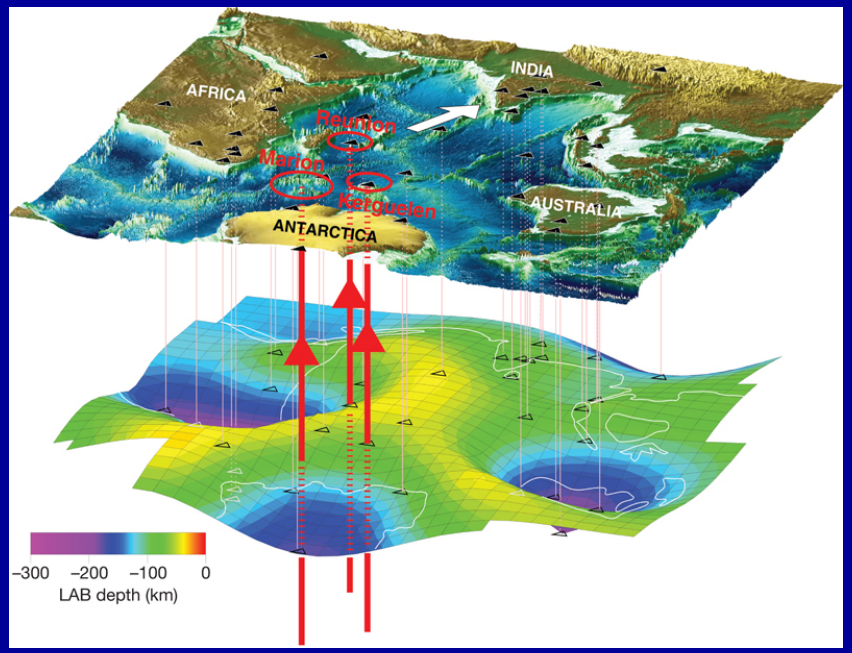
At the K/T boundary, the main pulse of the Deccan volcanism (80% of the Traps total volume) was extruded within a short time. Shiva impact might have shaken the magma chamber and triggered the main phase of the volcanism. A trickle became a torrent.

Acceleration of the Indian plate during the Paleocene (~67-52 Ma): ~15- 20 cm/year; sudden decrease in the velocity at ~50 Ma, indicating initial collision



Copley et al. (2010)

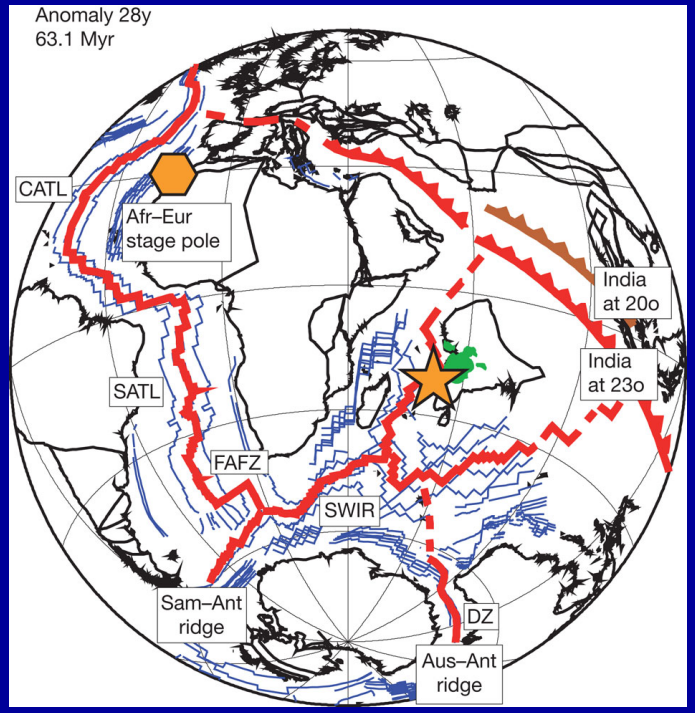
Acceleration of the Indian plate



Kumar et al (2007) suggested that Indian plate became thinned (~ 100 km) by recurrent plume activities such as:

- Kerguelen (~130 Ma)
- Marion (~90 Ma)
- Reunion (~65 Ma)

The Indian plate decoupled from the asthenosphere, and moved fast by ridge push or slab pull.



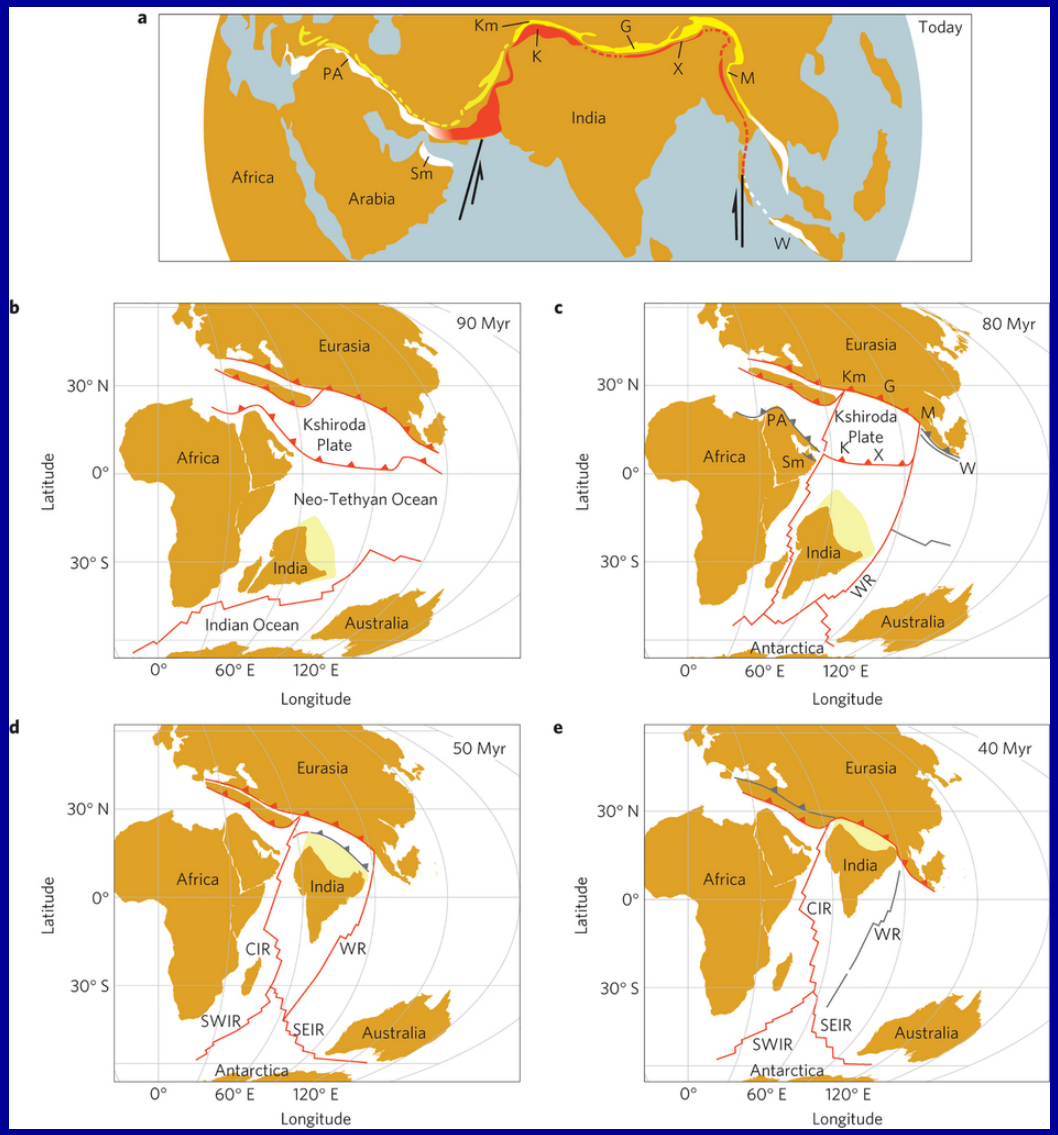
India's acceleration was driven by the push force of the Reunion plume that lubricated the lower surface of the Indian plate. India surfed over the asthenosphere (Cande & Stegman, 2011)

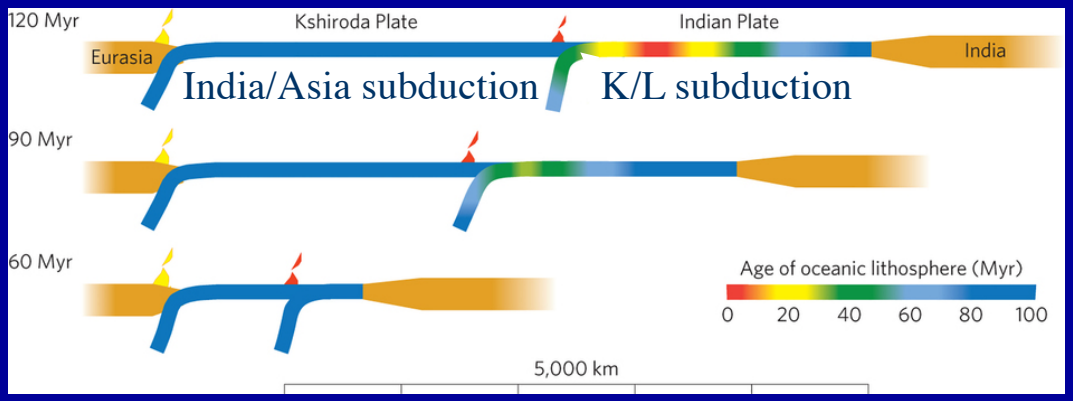
Acceleration of the Indian plate

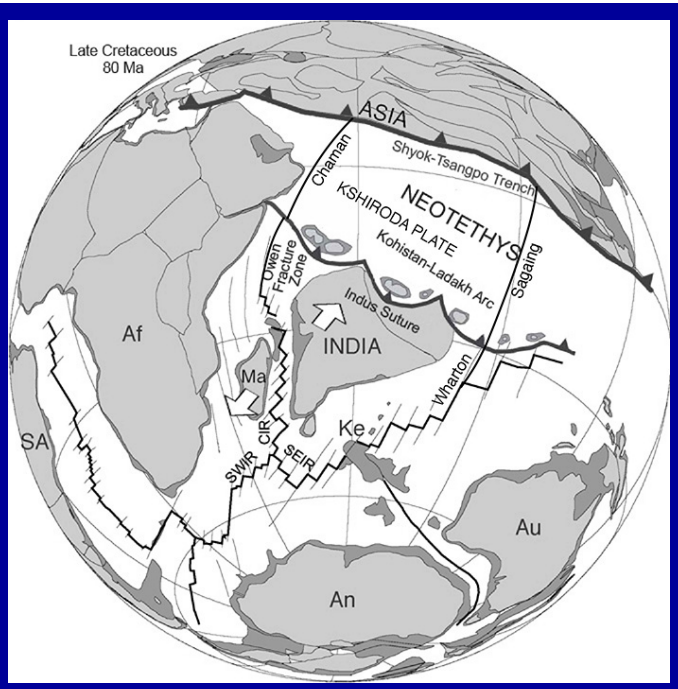
Jagoutz et al. (2015)

- Double subduction

However, early subduction at the K/L Arc occurred ~ 80 Ma and India/Asia ~ 55 Ma. More like a relay race one after another







(~80 Ma)

(~65 Ma)

(~60 Ma)

(~55 Ma)

Acceleration

- 2 parallel transform faults facilitated northward move
- Subduction along Shyok-Tsangpo Suture
- Indian plate became thinned by the Marion and Kerguelen plumes; it decoupled from deeper interior;

The Reunion plume created volcanic lubricant under India; India 'surfed' over asthenosphere, with a push from the plume and pull from the Shyok Trench

Aftermath of Dinosaur Extinction

Radiation of Placental Mammals

Ecological Replacement

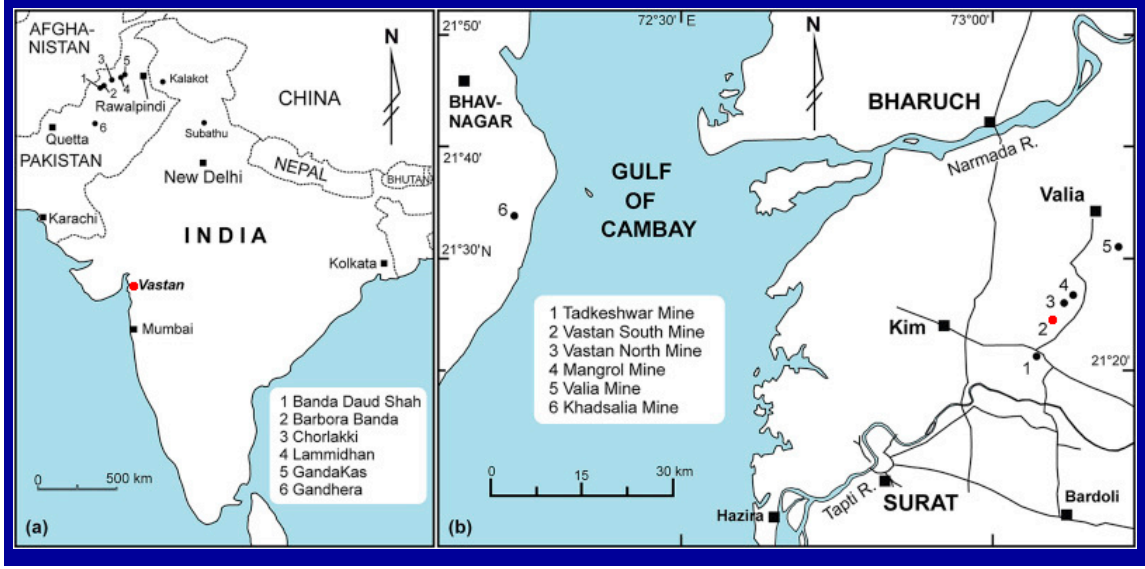
Mass extinction is a game changer in evolution. Dinosaur extinction helped adaptive radiation of placental mammals in vacant niches.

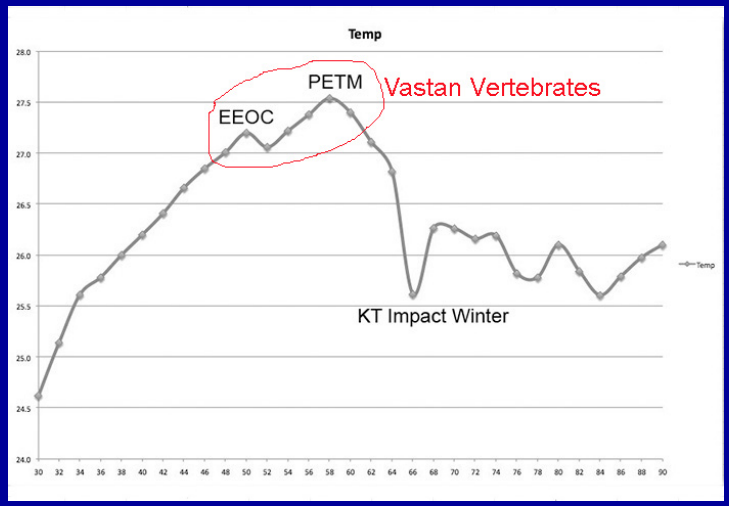
K/T Extinction is a Game Changer in the Early Eocene Placental Radiation

Rich fossil record in the Vastan Lignite Mine

Aftermath of Dinosaur Extinction

- Vastan Lignite Mine formed during the PETM transition
- Ecologic Opportunity
- Warm climates
- Explosive evolution of Placental mammals
- Out-of-India hypothesis





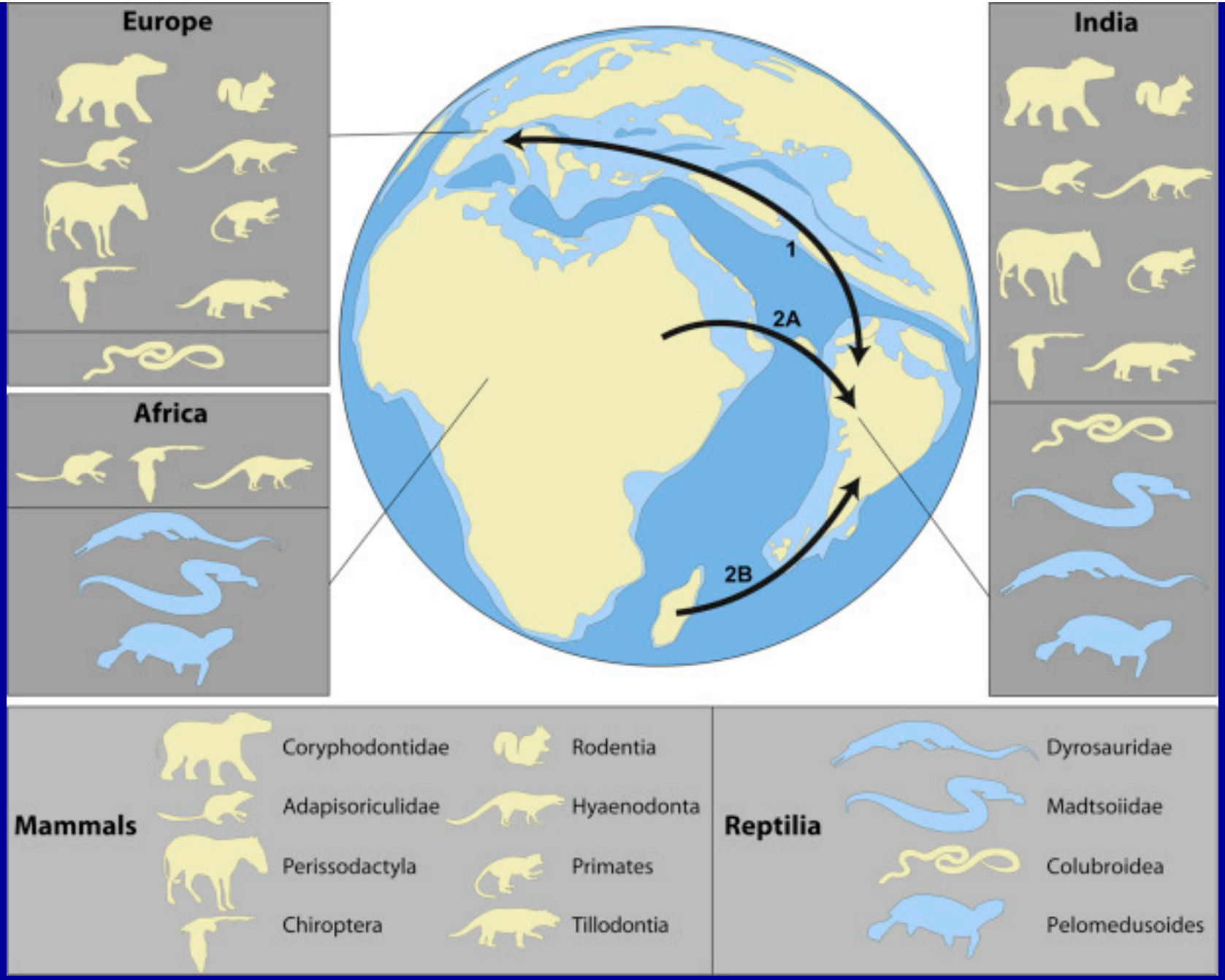
A

B

Vastan Lignite Mine

Explosive Evolution of Placental Mammals

Cambaytherium, Ancestors of horses, Tapirs, rhinos



(after Smith et al., 2016)

About 50% of European vertebrates are common in India;
25% with Asia, and 7% with Gondwana

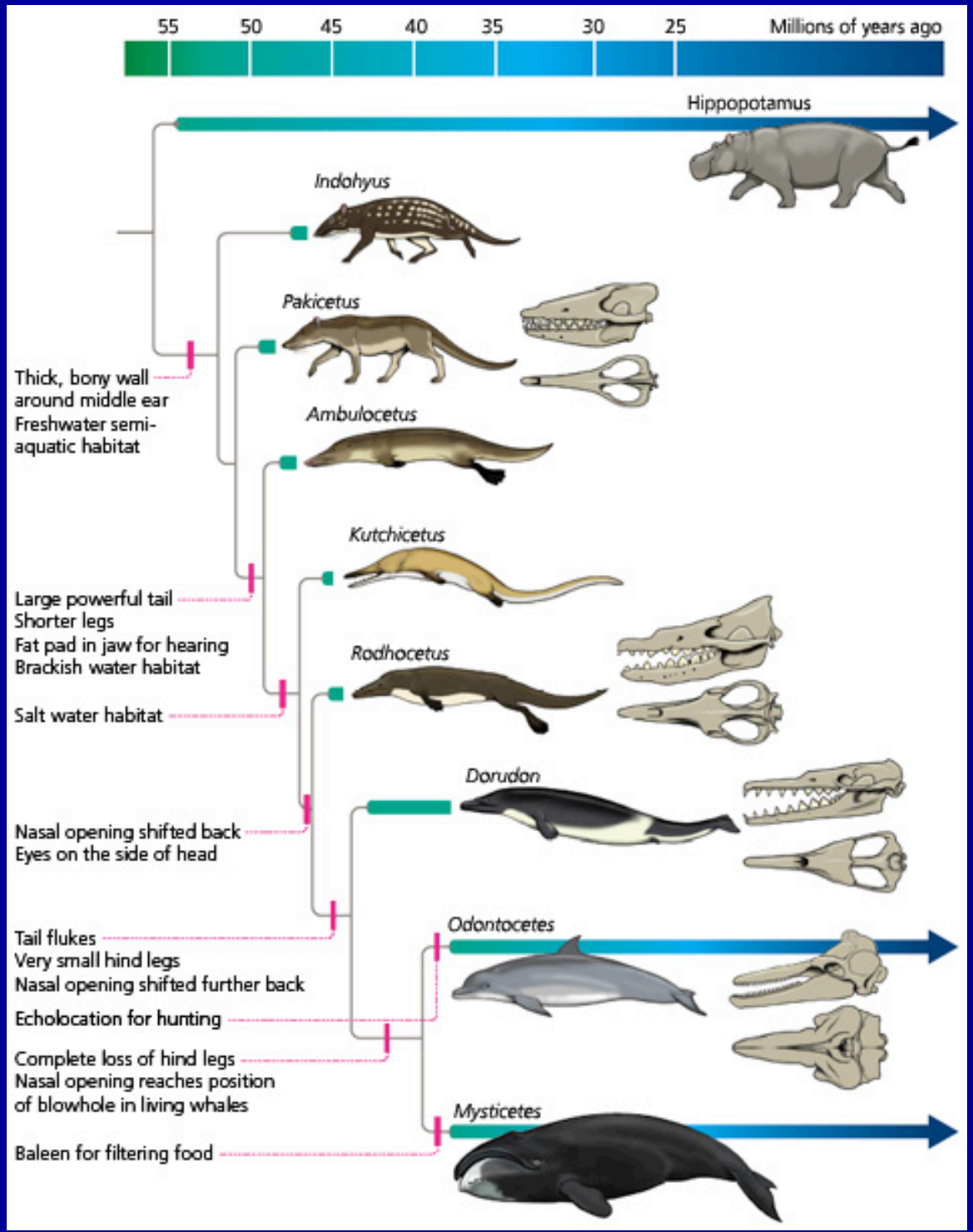
Vastan Vertebrate Fauna

Placental Mammal Diversity Blossomed After the Age of Dinosaurs: Ecologic Opportunity

Out-of-India Hypothesis
Several Modern Orders of Mammals including

- Perissodactyls
- Primates
- Artiodactyls
- Whales
- Bats

probably originated in India



Early Whale Evolution in Eocene, India