12.1.2. **The meeting of continental masses.**

- The formation of Pangea (reunion of all continents in one block) led to the reduction of the surface of heavily populated seas.

- The lowering of 250 m of the sea level following the generalized regression (with a sea level the lowest of all time at this limit) sets up shallow seas with stagnant and warm waters, poorly oxygenated and therefore unfavorable to animal life.

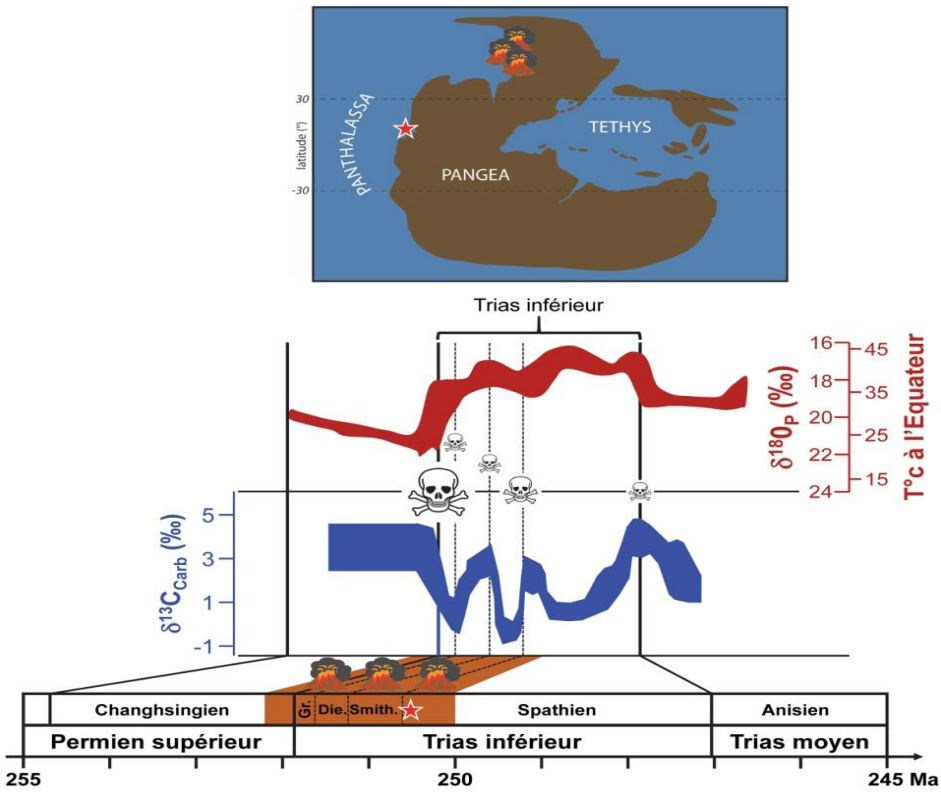


Fig.90: Equator evolution temperature during Pangea formation (P/T period).

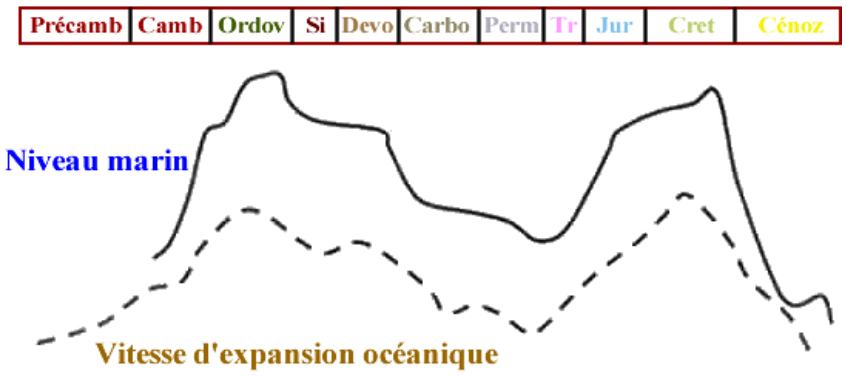


Fig.91: Sea level and ocean expansion evolution during P/T period.

12.1.3. **The drop in salinity of ocean waters.**

- The drop in salinity may explain the rarefaction or extinction of marine organisms sensitive to salinity variations (stenohaline animals = which can only live in waters of constant or similar salinity).

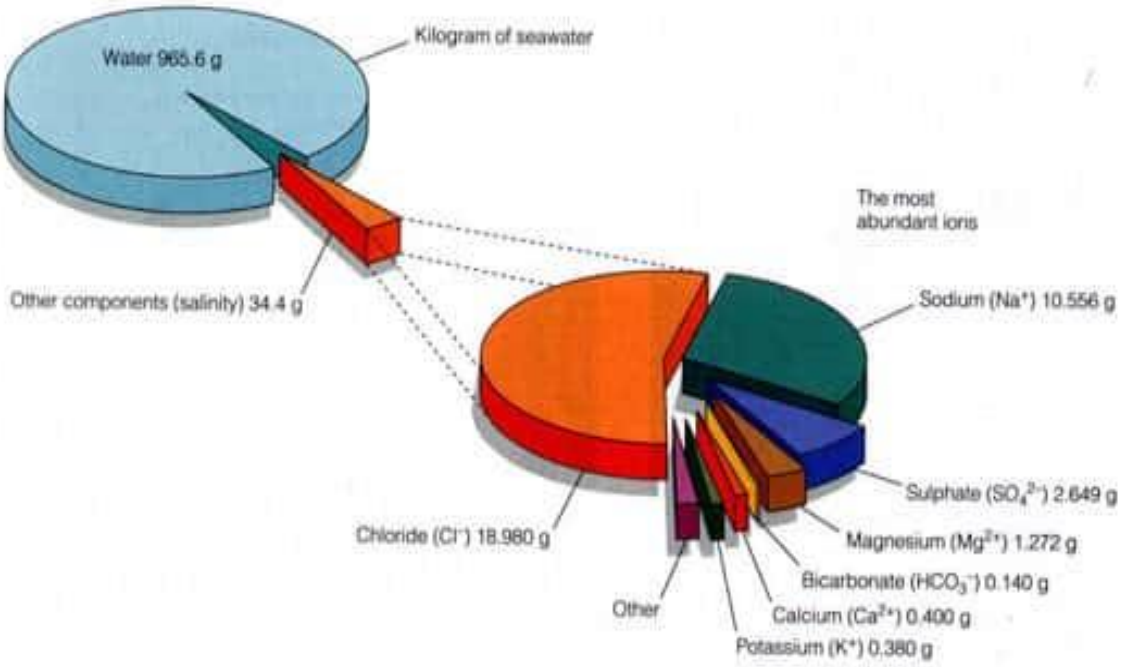


Fig.92: Seawater components

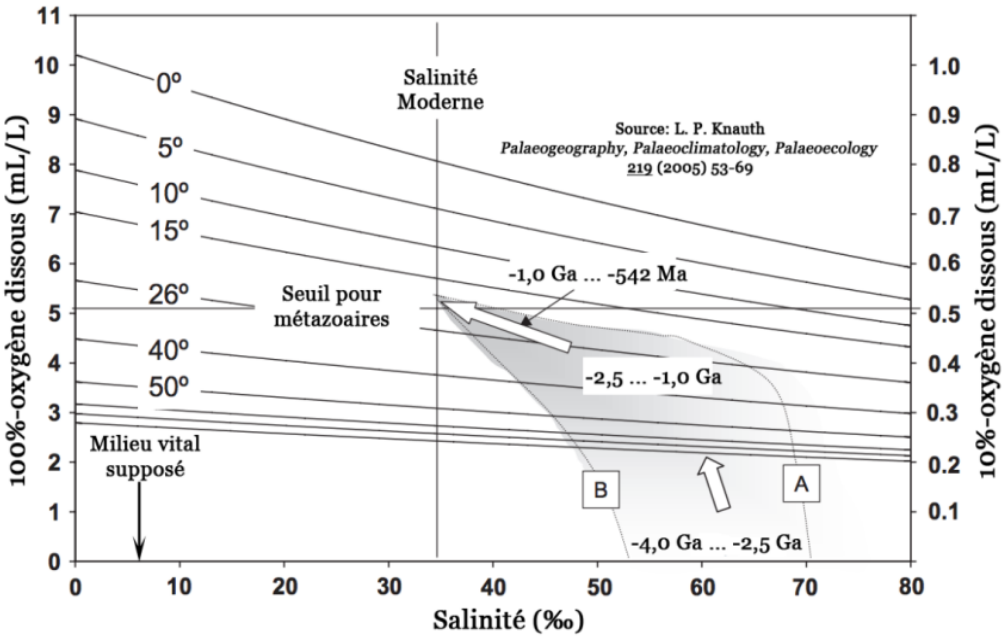


Fig.93: Seawater salinity evolution over time

12.1.4. **A collision of a meteorite with Earth?**

- A generalized planetary warming is observed: transition from a climate with glaciation to a hot semi-arid climate without glaciation (from Upper Permian to Lower Triassic).

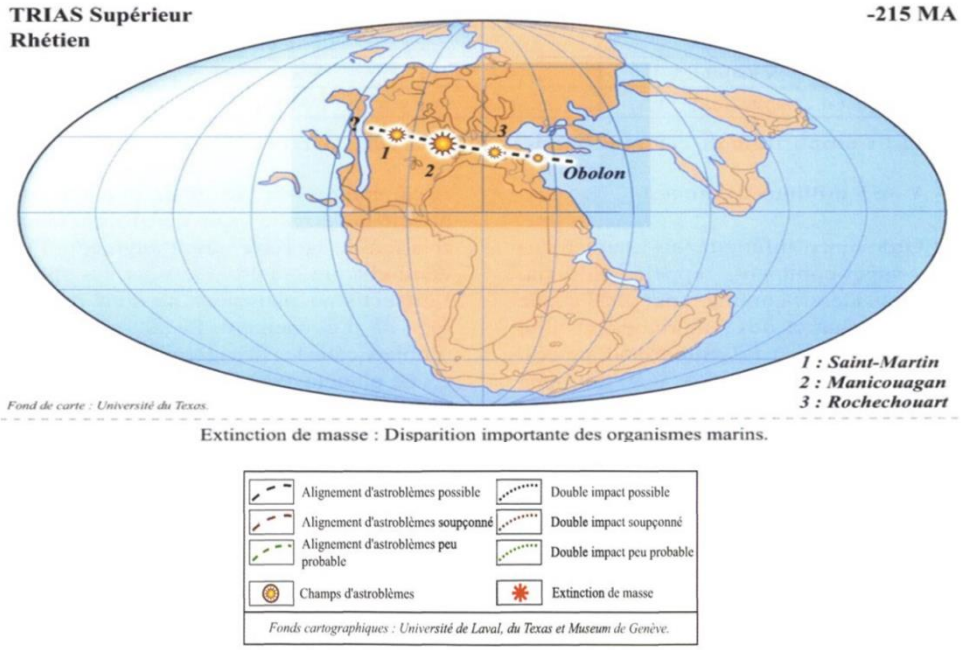


Fig.94: The alignments of Triassic astroblemes.

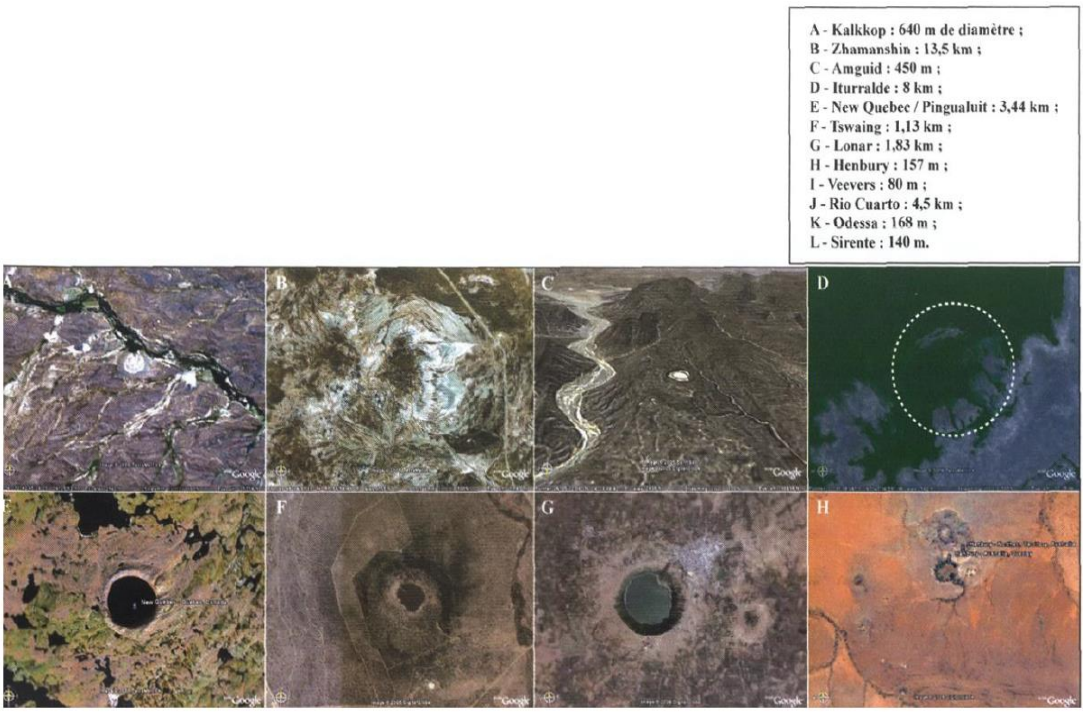


Fig.95: Recent Astroblèmes

13. Paleo-geographic evolution in the Paleozoic

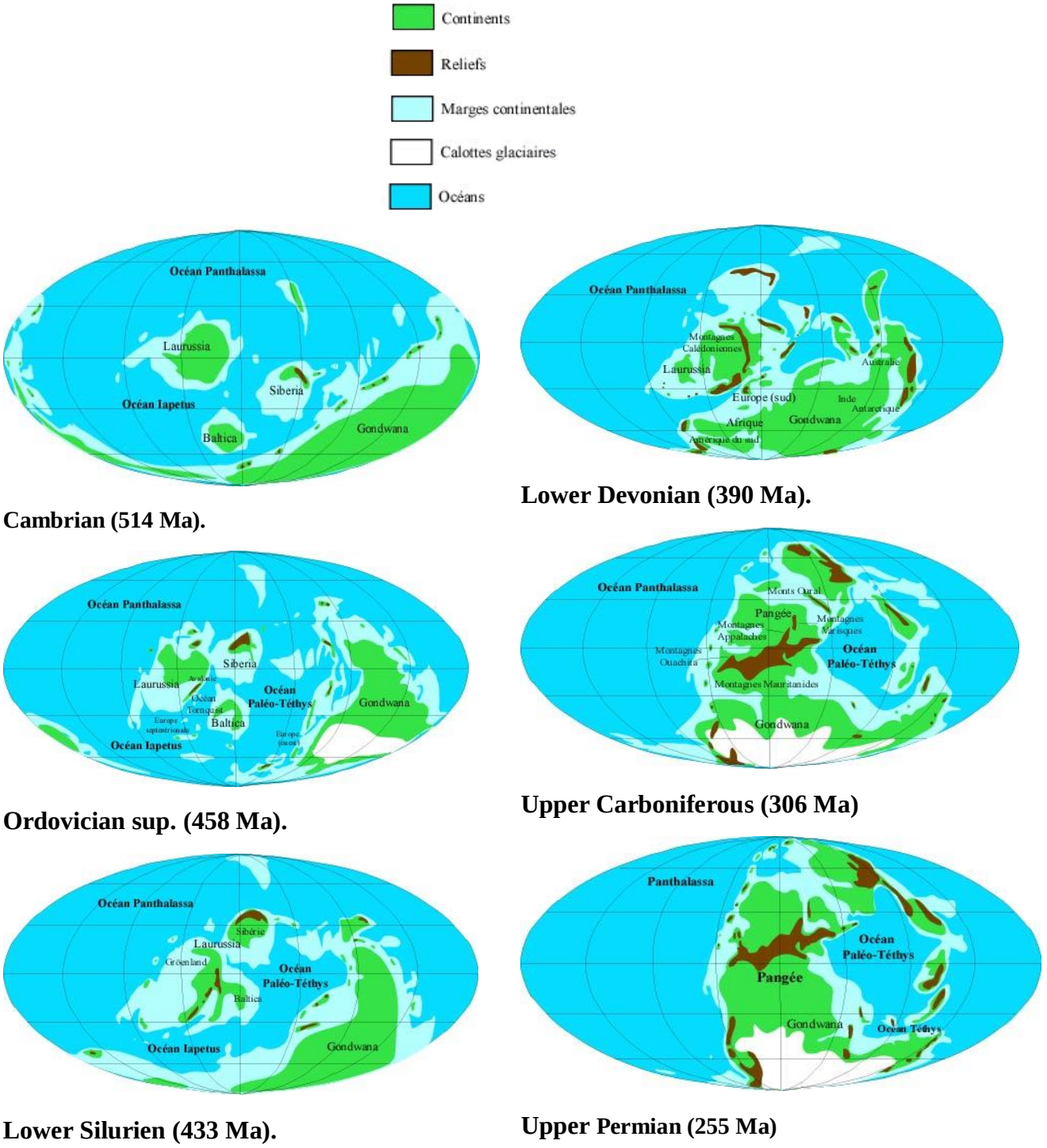


Fig.96: Paléo-géographique Evolution in the Paleozoic

The Mesozoic

The Mesozoic is the second of the three major geological eras of the Phanerozoic. Its name is derived from the Greek term for "middle life". The Mesozoic era began 252.2 Ma ago, after the end of the Paleozoic era, and ended 66 Ma ago, at the dawn of the Cenozoic era.

7. Limits of the Mesozoic

As its beginning was after the greatest biological crisis on the Planet (Permian-Triassic crisis), its end also experienced a remarkable extinction that is improperly called: "The K-T Crisis" = Cretaceous-Tertiary Crisis or Cretaceous-Paleocene Crisis instead of: Cretaceous-Paleogene Crisis.

8. Upper limit of the Mesozoic

Globally, the K-T boundary is recognized and studied at about a hundred sites. Among the best known, let's mention:

- El Kef (Tunisia): the World Stratotype (GSSP)
- Stevns Klint (Denmark)
- Gubbio (Italy)
- Caravaca (Spain)
- Bidart (France)
- ODP Site 761C (Indian Ocean)

Fig.97: Localization of El Kef Stratotype (Tunisia) [46]

Paleocene Series							
Thanetian Stage	59.2	Zumaia section, northern Spain	43.3006°N 2.2594°W	30.5m above the base of Itzurun Formation	Magnetic - Base of Chron C26n	Ratified 2008	*Episodes* 2011; 34: 220-243
Selandian Stage	61.6	Zumaia section, northern Spain	43.3006°N 2.2594°W	base of the red marls of Itzurun Formation	2nd radiation of the calcareous nannofossil group Fasciculithus and sea-level fall	Ratified 2008	*Episodes* 2011; 34: 220-243
Danian Stage	66.0	Oued Djerfane, west of El Kef, Tunisia	36.1537°N 8.6486°E	reddish layer at the base of the 50cm thick, dark boundary clay	Iridium geochemical anomaly. Associated with a major extinction horizon (dinosaurs, ammonites, foraminifers, etc.)	Ratified 1991	*Episodes* 2006; 29: 263-278

Cretaceous

Stage	Age (Ma)	GSSP Location	Latitude, Longitude	Boundary Level	Correlation Events	Status	Reference
Phanerozoic Eonothem							
Mesozoic Erathem							
Cretaceous System							
Upper Cretaceous Series							
Maastrichtian Stage	72.1±0.2	Tercis les Bains, Landes, France	43.6795°N 1.1133°W	level 115.2 on platform IV of the geological site at Tercis les Bains	Mean of 12 biostratigraphic criteria of equal importance. Closely above is FAD of ammonite *Pachydiscus neubergicus*. Boreal proxy is FAD of belemnite *Belemnella lanceolata*.	Ratified 2001	*Episodes* 2001; 24: 229-238
				Level 221.53 m in the	The magnetic polarity reversal from		*Episodes* 2023; 1st

Fig.98: Information details of El Kef Stratotype (Tunisia) [46]

https://stratigraphy.org/gssps/#cretaceous

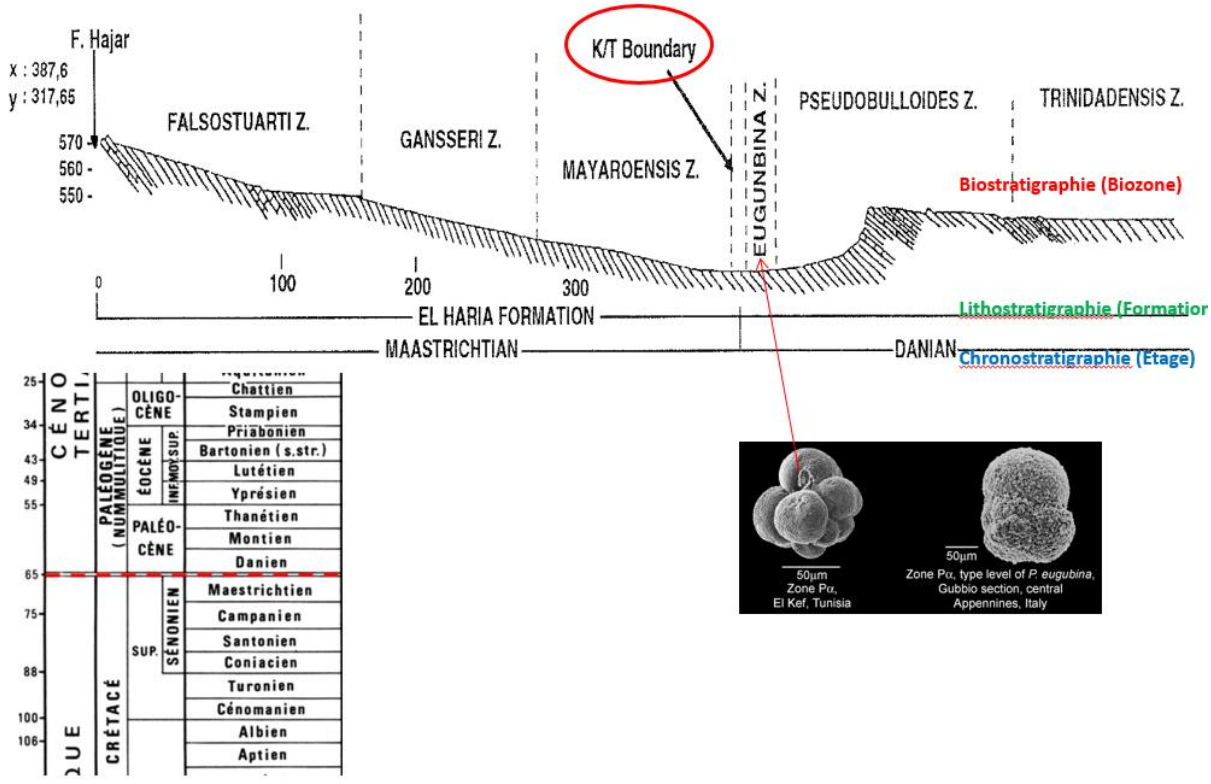


Fig.99: Geological cross section showing El Kef Stratotype (Tunisia) [47]

Hypothesis of an extraterrestrial event

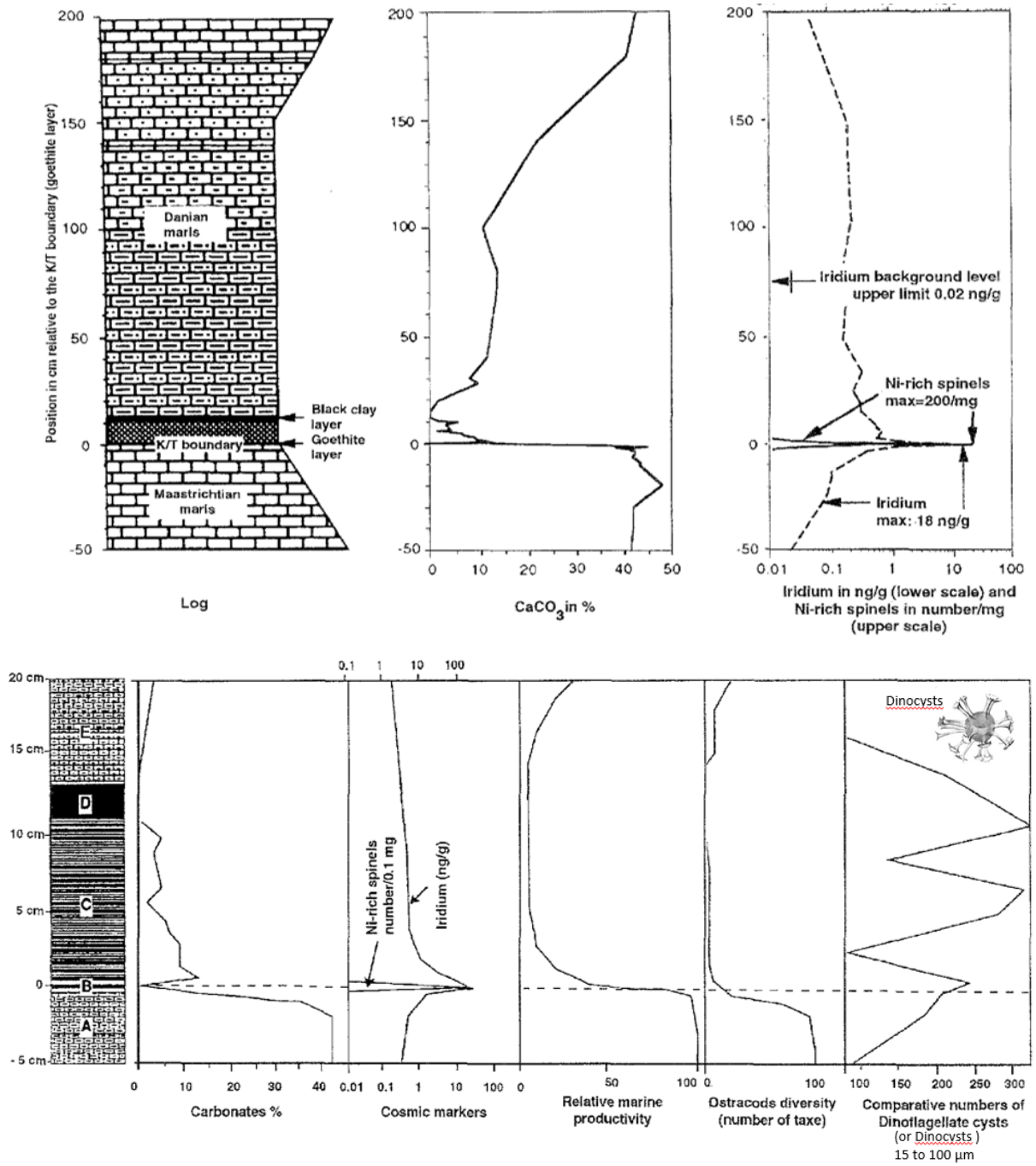
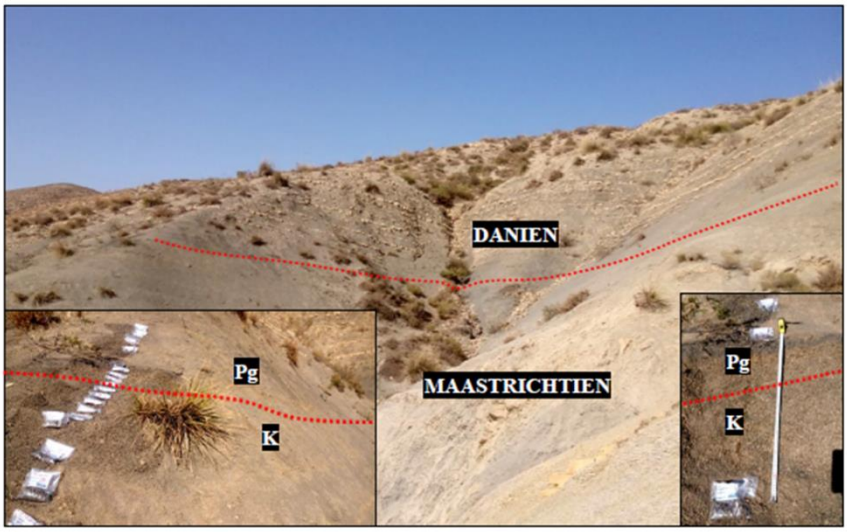
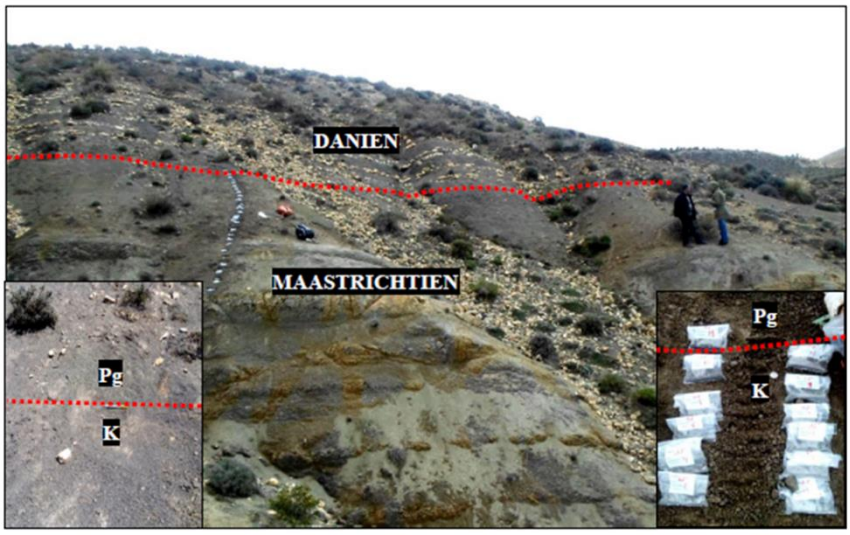


Fig.100: The K/T stratotype section of El Kef (Tunisia): Events and biotic turnovers [47]

K/Pg Boundary in Algeria (Média and Sétif)



Vues sur le passage K/Pg dans la section du Dj. Zakhamoune.



Vues sur le passage K/Pg dans la section de Sidi Ziane.

Photo. 19: K/Pg Boundary in Algeria (Sidi Ziane - Médéa) [48]

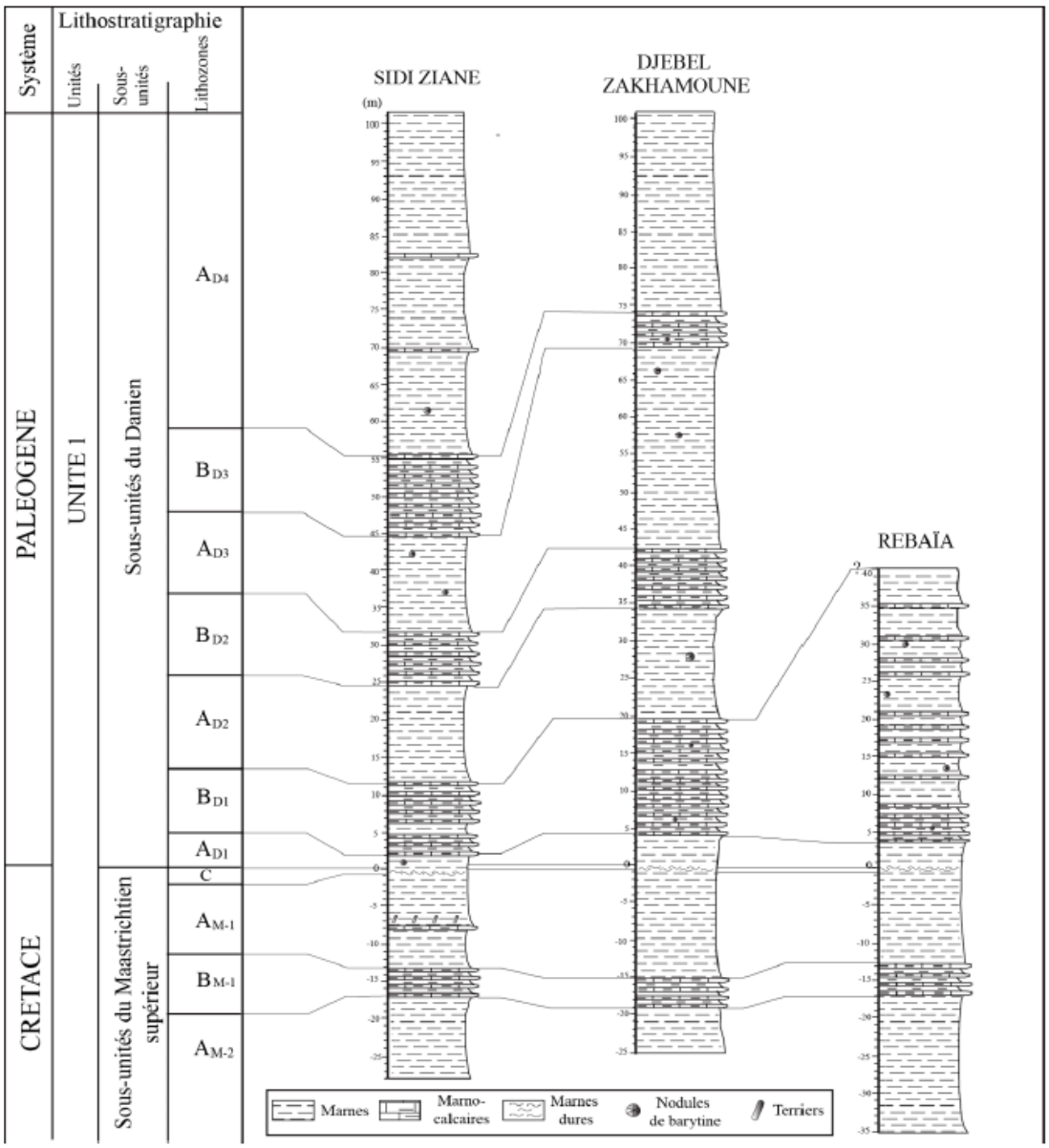


Fig.101: Lithostratigraphic correlation of K/Pg Boundaries in Algeria (Médéa) [48]

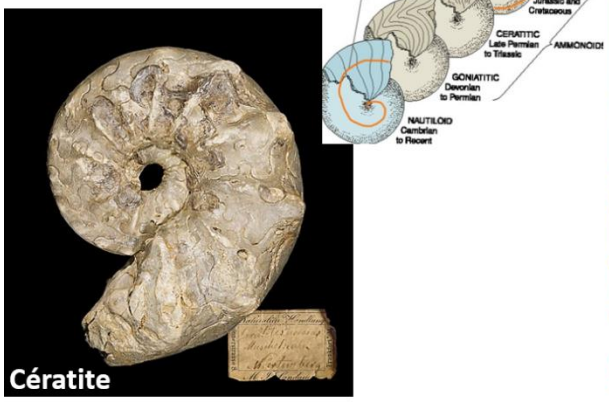
9. Evolution of animal life in the Mesozoic

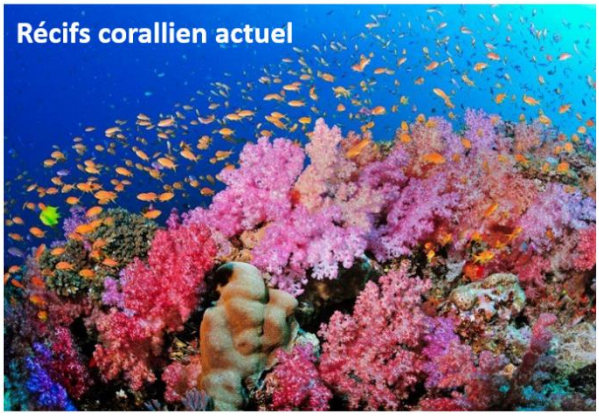
Marine animals:

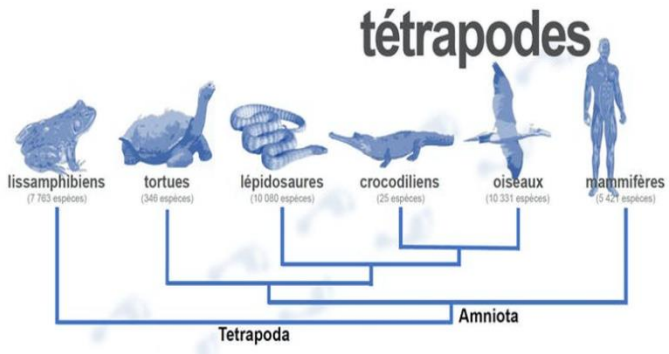
- Ceratites* (appeared in the Permian) were replaced by ammonites.
- Coral reefs (decimated by the Carboniferous extinction) came back to the forefront with the evolution of new groups of builder animals and algae.
- Modern bony fish evolved and began to compete with ammonites as swimming predators.

Land animals:

- Rise of large tetrapod groups: dinosaurs and mammals and the subsequent advent of birds.
- Tetrapods took new environments in the air as well as a secondary return to waters.







*Order of the subclass Ammonoidea, which also includes goniatites and ammonites.

10. Evolution of plant life in the Mesozoic

Flowering plants finally appeared about 140 million years ago and became the dominant floral component of many regions of the planet. Forests took on an increasingly modern appearance.

Photo. 20: Flowers and forest

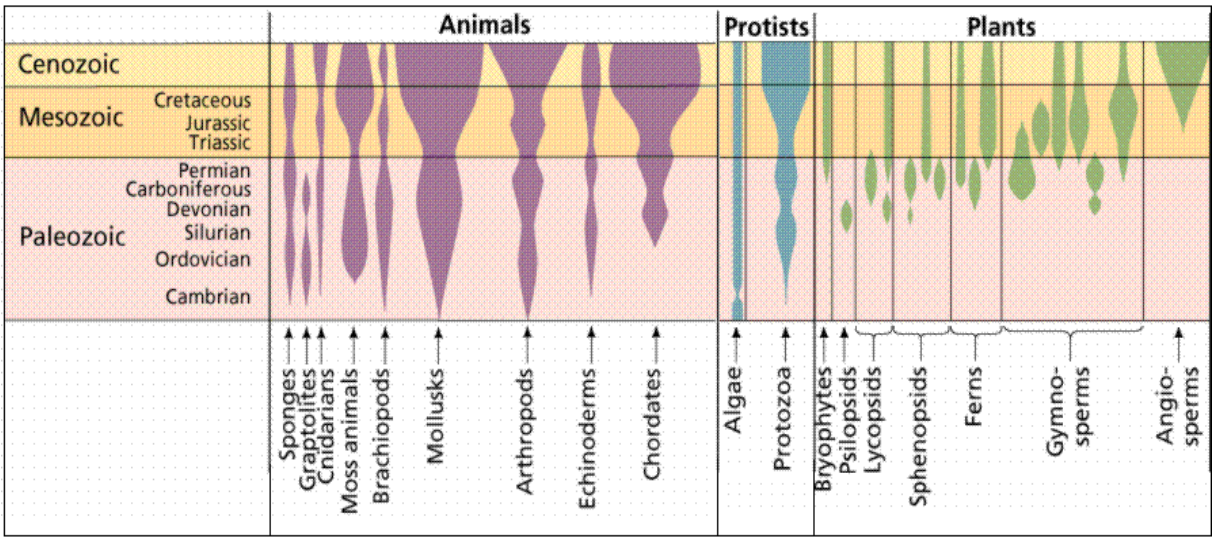


Fig.102: Some organisms' evolution over Phanerozoic eon

Photo. 21: Jurassic age fossil Camarasaurus skull (crâne), Dinosaur National Monument, Colorado and Utah. NPS image

Photo. 22: Triassic age fossil vertebrate footprint, Petrified Forest National Park, Arizona. NPS image

11. The K-T Crisis

- The Mesozoic ended with a great mass extinction that eliminated nearly 75% of all species, including dinosaurs, swimming and flying reptiles, and ammonites.
- The causes of this extinction have long been speculated and are not currently conclusively resolved.

Probable causes of the K-T crisis

The most likely causes:

1. Great marine regression of the Upper Cretaceous (following the Cenomanian maximum at 96 Ma)
2. The fall of a meteorite (Chicxulub crater in Mexico dated to -65 Ma).
3. Eruptions at the end of the Cretaceous of the Deccan Traps* (India).

11.1. Great marine regression of the Upper Cretaceous

This theory no longer has many supporters; indeed, many authors suggest that these occurring over a fairly long period, marine species have time to migrate or adapt, not being able to explain alone the high rate of extinctions of the crisis.

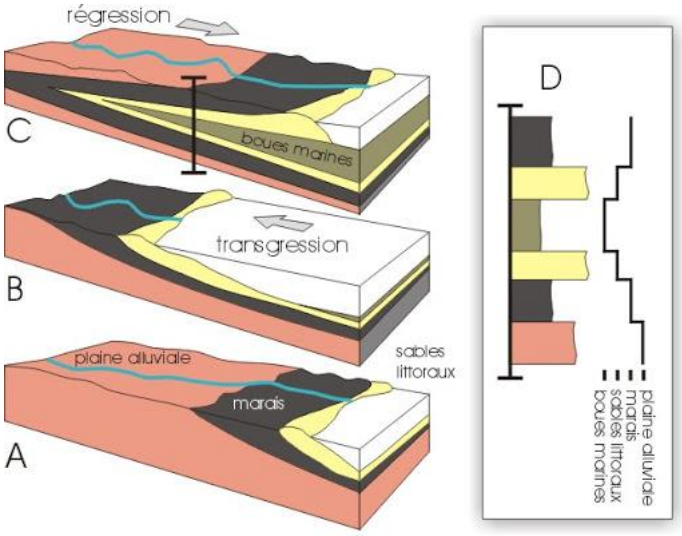


Fig.103: Marine regression and transgression

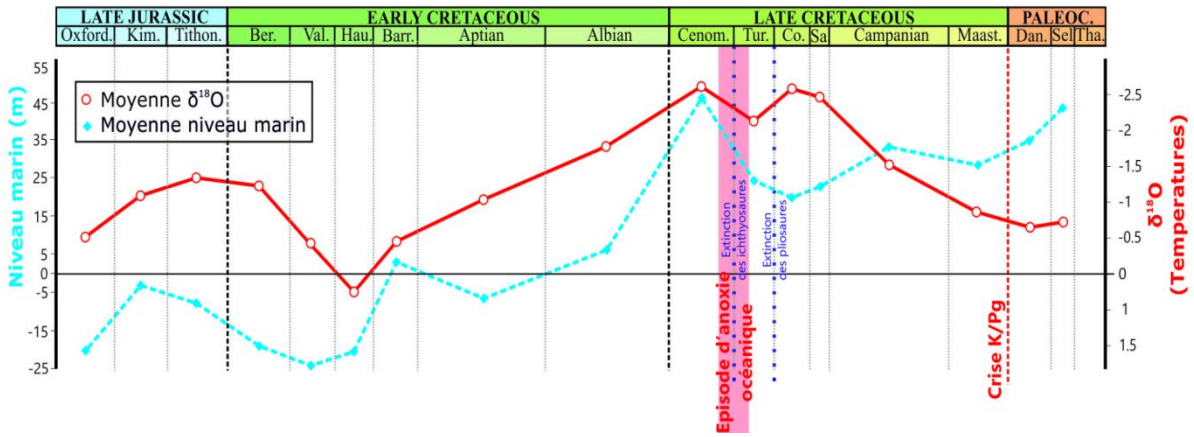


Fig.104: Sea level and temperature evolution during Mesozoic

11.2. The fall of a meteorite

- This hypothesis, very popular at the end of the 20th century (1991), proposes that the Chicxulub crater (Yucatan, Mexico) is an impact crater of a meteorite.

Photo. 23: Meteorite impact in Chicxulub (Yucatan, Mexico)

- The meteorite about 10 km in diameter struck the Earth about 65 million years ago (end of the Cretaceous).
- The diameter of the crater, about 180 kilometers (explosion power = billions of times that of the Hiroshima bomb).
- The crater basin, buried under about a thousand meters of limestone, extends half under land, and half under the Gulf of Mexico.

Chicxulub Crater: The Chicxulub crater contained sulfur-rich sediments. The impact would have injected large amounts of sulfur aerosols into the atmosphere, causing a terrible cooling by reflecting the Sun's rays. This cooling would have contributed to the disappearance of the dinosaurs.

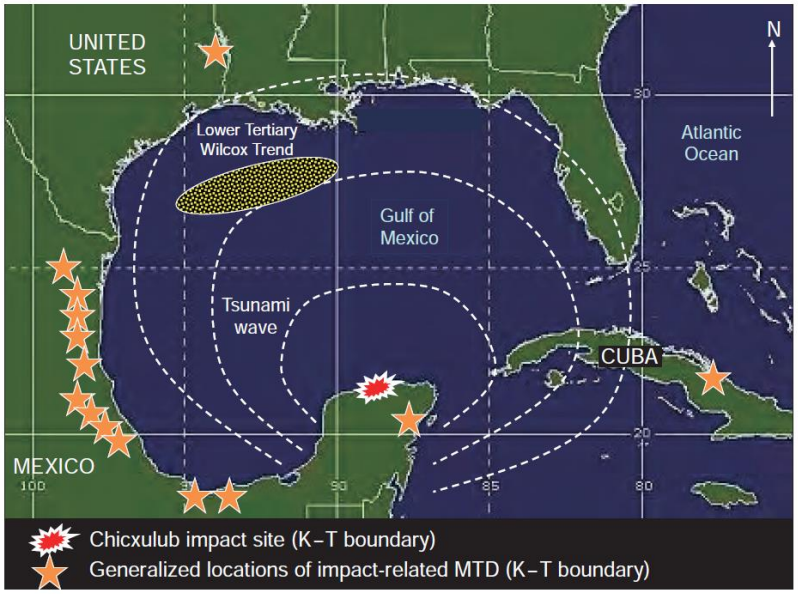


Fig.105: Tsunami waves of meteorite impact in Chicxulub (Yucatan, Mexico)

11.3. Eruptions at the end of the Cretaceous of the Deccan Traps (India)

The Deccan Traps (India) are the remains of the gigantic basaltic lava flows that the Cretaceous experienced.

Only a third of the volume remains because the lava, when cooling, releases a lot of gas. This led to climate changes that could have caused the disappearance of most dinosaurs.

The period of these eruptions is quite short compared to geological times (less than 400,000 years distributed in several pulses of short period).

The cumulative thickness of the Deccan Traps reached 3km over a very large area.

Fig.106: Deccan Traps location (India)

Photo. 24: Deccan Traps (India)

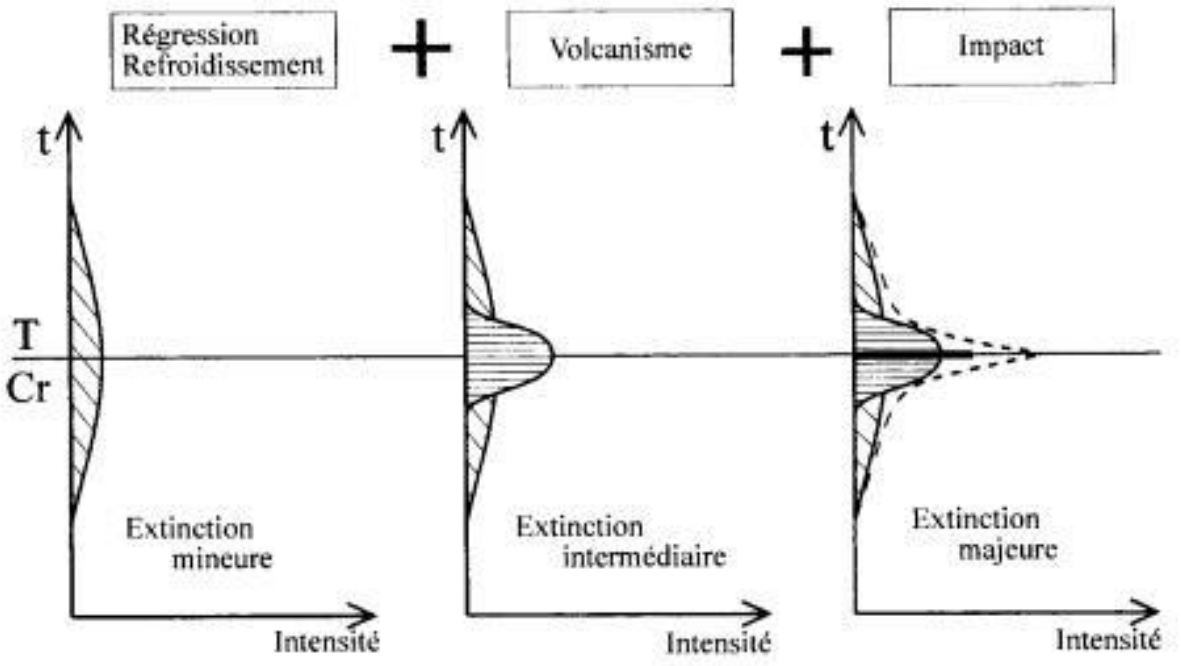


Fig.107 : Superposition de phénomènes permettant d'expliquer les extinctions majeures à la limite K-T

12. The consequences of the crisis

Among the victims during the K-T crisis:

1. Ammonites (cephalopod mollusks of open water, characteristic of the Mesozoic, close to the current nautilus), extinct;
2. Belemnites (idem, close to the current cuttlefish), extinct;
3. Rudists (fixed lamellibranch mollusks adapted to a reef-type life), extinct;
4. Inoceramids (lamellibranch mollusks frequent in seas that produced chalks), extinct;

5. Foraminifera, those typical of the Cretaceous disappear and new forms succeed them in the Tertiary;

6. Brachiopods suffer a hecatomb, but do not become extinct;

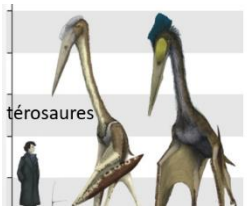
7. Bryozoans were hard hit;

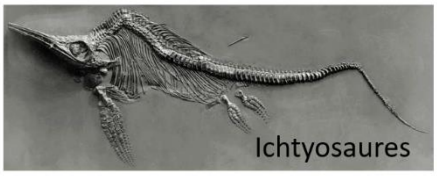
8. Various marine reptiles disappear, notably plesiosaurs (sauropterygians), ichthyosaurs (ichthyopterygians, though they were already gone by the beginning of the Late Cretaceous); mosasaurs (close relatives of monitor lizards);

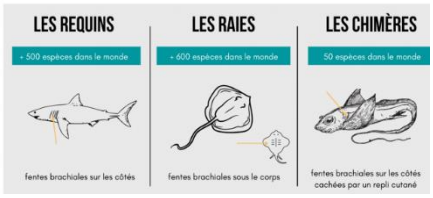
9. Dinosaurs (all extinct except birds);

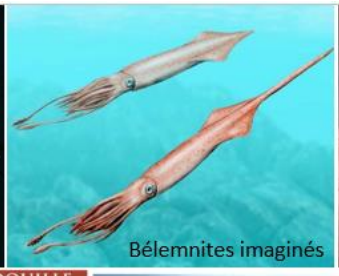
10. Pterosaurs disappear (flying reptiles closely related to dinosaurs and crocodiles);

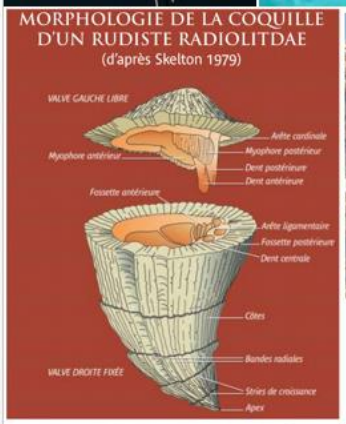
11. Chondrichthyans (a group of marine vertebrates including modern sharks, rays, and chimaeras) suffer a massacre but do not completely disappear.

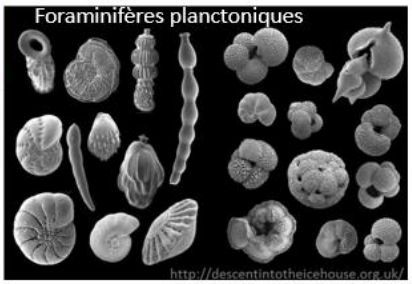


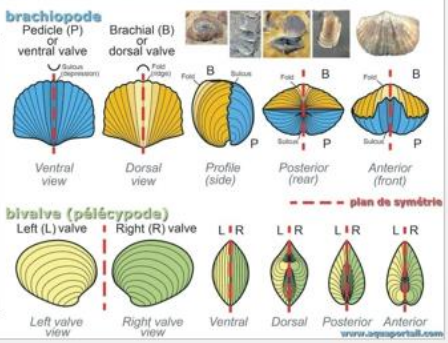












7. Plate Tectonics

• The Mesozoic period was the time when Pangaea began to break up approximately 225 to 200 million years ago.

• This supercontinent eventually fragmented into several continents (the modern continents).

• This breakup had profound consequences for living things, just as the earlier formation of Pangaea during the Paleozoic era did.

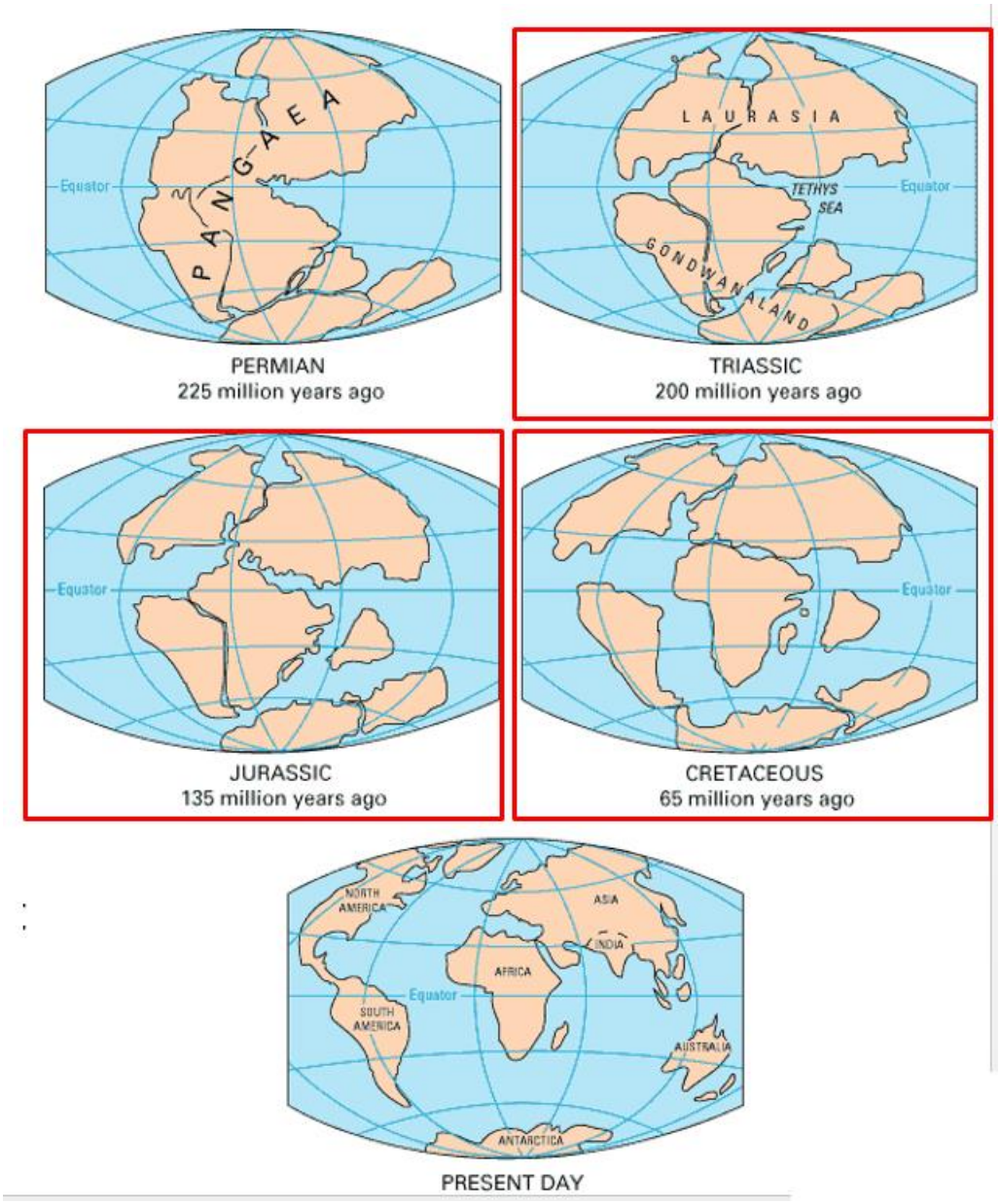
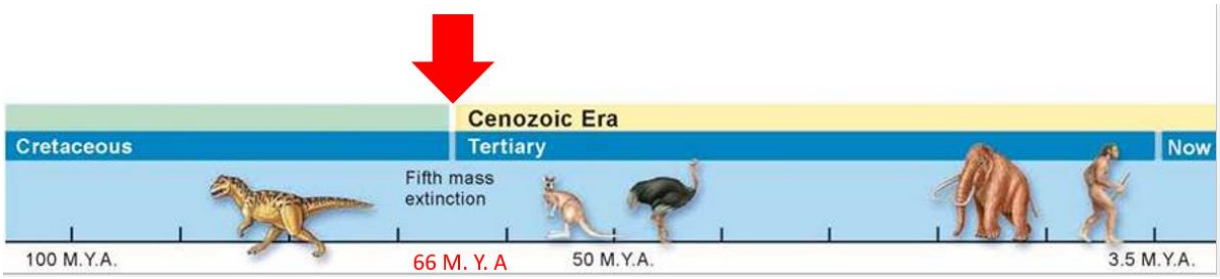


Fig.108: Plate Tectonics movements during Phanerozoic eon

The Cenozoic

The Age of Mammals

This is the last era of the Phanerozoic and the most recent on the geological time scale. Beginning 66 million years ago, after the Cretaceous extinction, the Cenozoic continues to the present day. Its name means "new life" and comes from the Greek *kainos*, new, and *zoe*, life.



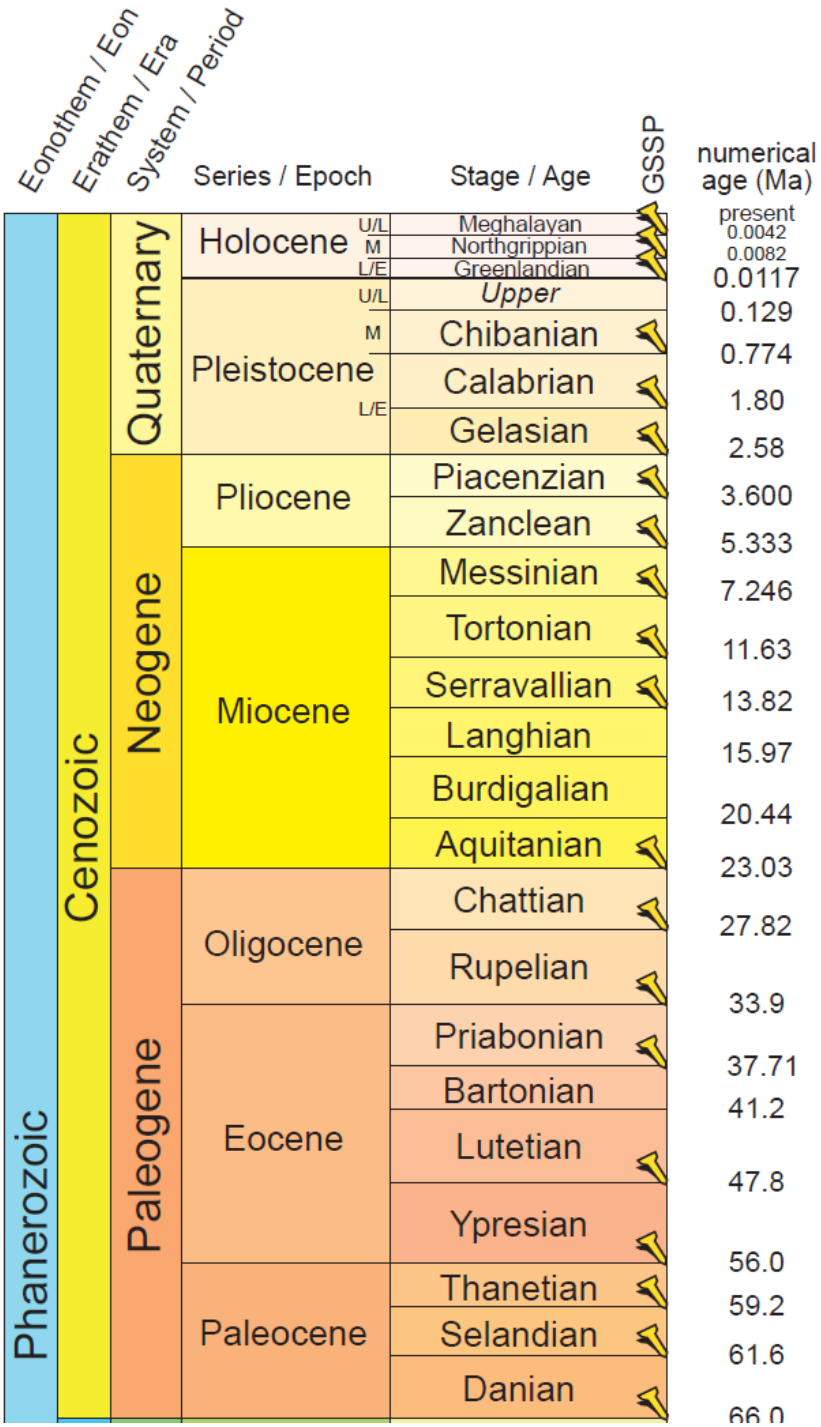


Fig. 109 : Cenozoic details - International Chronostratigraphic Chart (2024/12 version.) [42]

7. Life, Tectonics and Climate

- Following the disappearance of dinosaurs (except birds), mammals developed considerably on all continents, to the point of conquering all environments (terrestrial, aquatic and aerial).
- The continents continued their drift until reaching their current position. This means, among other things: