MESOZOIC HISTORY

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Summary

The paleogeography of the Mesozoic world was dominated by gradually fragmenting immense Pangea continental assemblage. In spite of several orogeneses which happened during the 160 Ma of the Mesozoic Era, the surface of dry lands was almost flat, being affected by graben-and-horst tectonism only. Volcanism occurred typically in rift valleys and on midoceanic ridges. Oceanic regimes were mostly affected by prevailing hot and dry climate, interrupted by short colder and more humid periods. The Mesozoic time, called the "age of dinosaurs" (or the "age of ammonites"), was characterized by an important evolutionary step of life. Important coal seams originated during late Triassic and early Jurassic in paralic and lacustrine basins; 63% of the world’s giant oil fields have reservoirs of the Mesozoic age.

1. Mesozoic Paleogeography

1.1. Continent Distribution

The start of the Triassic period was dominated by processes which led to the gradual disintegration of the gigantic Pangaea supercontinent. In the first stage, after being separated by the Paleotethys Ocean, two super-peninsulas came into existence: Laurasia (Canadian and Eurasian Shields) in the northern hemisphere, and Gondwana (South America, Africa, India, Australia, and Antarctica) in the southern hemisphere. Eventually, new oceanic crust (and lithosphere) was produced as the continent separated further and an oceanic rise system came into existence. Remnants of basaltic flows and sills and clastic sediments reflecting early stages of the rupturing are often preserved in former grabens on retreating continental margins.

The breakup of Pangaea (or alternatively, Laurasia and Gondwanaland) began in the late Triassic, when South America and Africa began to drift apart and India separated from Africa and Australia and Antarctica. The counterclockwise motion of Africa closed the Tethys Ocean, while Laurasia moved in a clockwise direction. The Central East Iran microplate drifted southwards and rotated 65° counterclockwise at that time.

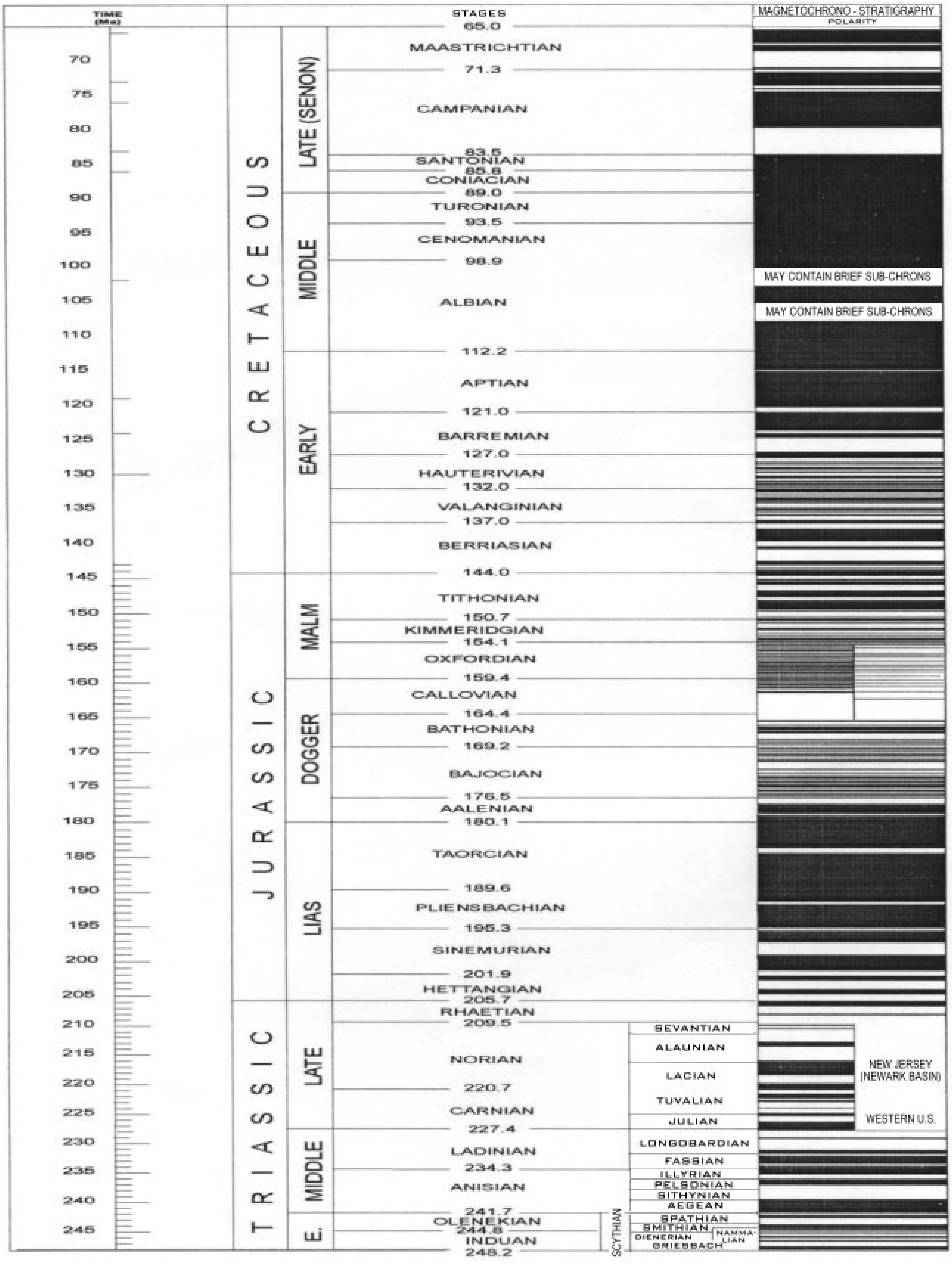

Figure 1. The stratigraphic divisions of the Mesozoic.

The early Jurassic period was characterized by the continued breakup of Pangaea. South America separated from Africa during the Jurassic, and about 140 Ma, the Walvis Hot Spot appeared. The first volcanism, produced by this hot spot at or just after the time when the two continents began to separate, appeared in the southwest African Keoko Basin and in the Brazilian Serra Geral Basin. The sea-level highstand enabled an epicontinental seaway to originate between the Tethys and the Caribbean–Andean regions.

The Jurassic–Cretaceous boundary was characterized by the opening of the southern Atlantic, leading to major changes in Tethys. Isolated marine plus evaporite basins between South America and Africa at the beginning of the Cretaceous were soon followed by the establishment of a continuous, open ocean environment which was present by about 108 Ma. Africa and South America moved northward; as a result, Tethys recorded compressive tectonic events between North and South America and between the Arabo-African block and Eurasia. This Neo-Cimmerian event marks the onset of Cretaceous flysch, a clear indication of the start of the Paleoalpine orogeny in Tethys. In western North America, three oceanic domains vanished at that time (Cordilleria, Klamathia, Talkeetnia).

During the Cretaceous, Africa completely separated from South America and the presumed paths of separation are defined by the trace of the Walvis and Rio Grande Ridges. The major rifting of North America from Eurasia occurred during the early Cretaceous. During the mid-Cretaceous, the Bay of Biscay opened, and during the late Cretaceous, Greenland began to separate from Norway and the Labrador Sea opened. In the late Cretaceous, Australia began to separate from Antarctica and the Tasman Sea began to be opened. Most of the separation of these areas, however, occurred during the early Tertiary. In the late Cretaceous or early Tertiary, spreading also began in the Arctic Basin.

Eastern Asia (the Kolyma Block) was in contact with the American Pacific coastal block during the late Mesozoic. However, Euramerica was separated from Asiamerica by two epicontinental seas, the Mid-Continental Seaway on one side and the Turgai Sea on the other. The Greater Antilles formed on a fracture zone in the eastern Pacific Ocean during the Cretaceous. As North and South America moved westwards, the Greater Antilles moved into the gap between the two continents. For a general overview see *Mesozoic* in chapter *History of Earth*.

1.2. Paleogeomorphology of Dry Lands

The long-lasting peneplenization of the Variscan mountain systems produced mature morphology of the continents at the end of the Paleozoic. On the other hand, Late Permian/Scythian mantle plumes and/or upwelling convection currents caused thinning and fracturing of the lithosphere and crust into a series of grabens, which collected clastic sediments from intervening horsts, and basaltic magma was injected into the axial part of the graben system.

The Triassic paleogeographic setting placed the Tethys Ocean between the elevated landmasses of the Angara Shield, Paleoeurope, Greenland, and North America in the north, and positive elements such as the Sahara and Arabia platforms, India, and Australia in the south. Global regression due to thermal collapse of oceanic ridges lowered the erosion base on continental margins. Subsequently, immense alluvial plains that had accumulated in slowly rising sea level conditions created low and flat morphology of nearshore lowlands. The Late Scythian/Anisian transgression produced an extremely broad and flat shelf sea rim along all continents with a carbonate ramp and platform sedimentation. During the middle and late Triassic, extreme evaporization in intracontinental basins and in the shoreward portion of nearshore plains in the subtropics may have resulted in the creation of local hypersaline basins of the Dead Sea type.

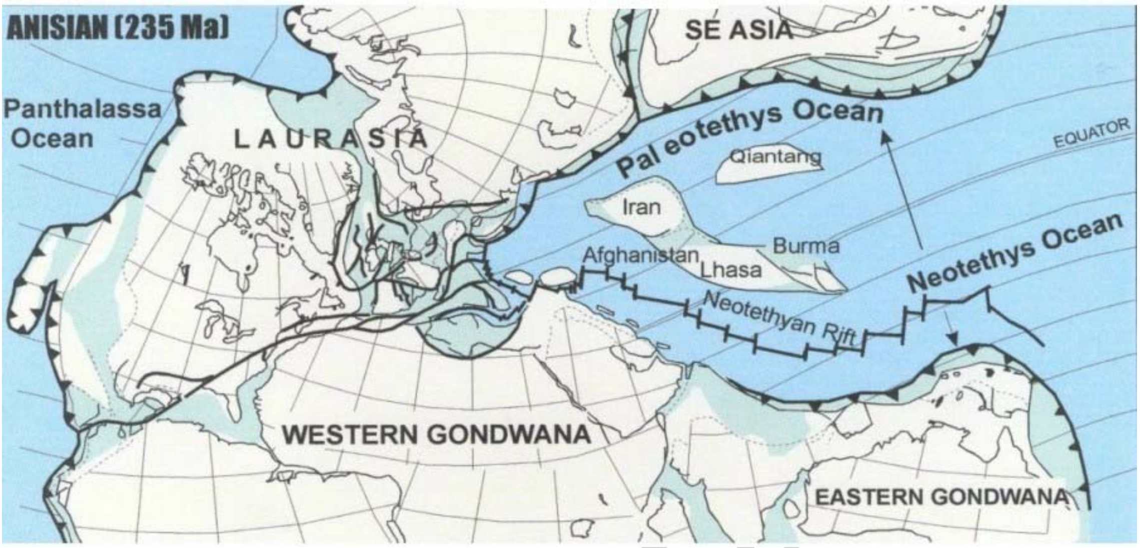

Figure 2. The paleogeography in Anisian before 235 Ma

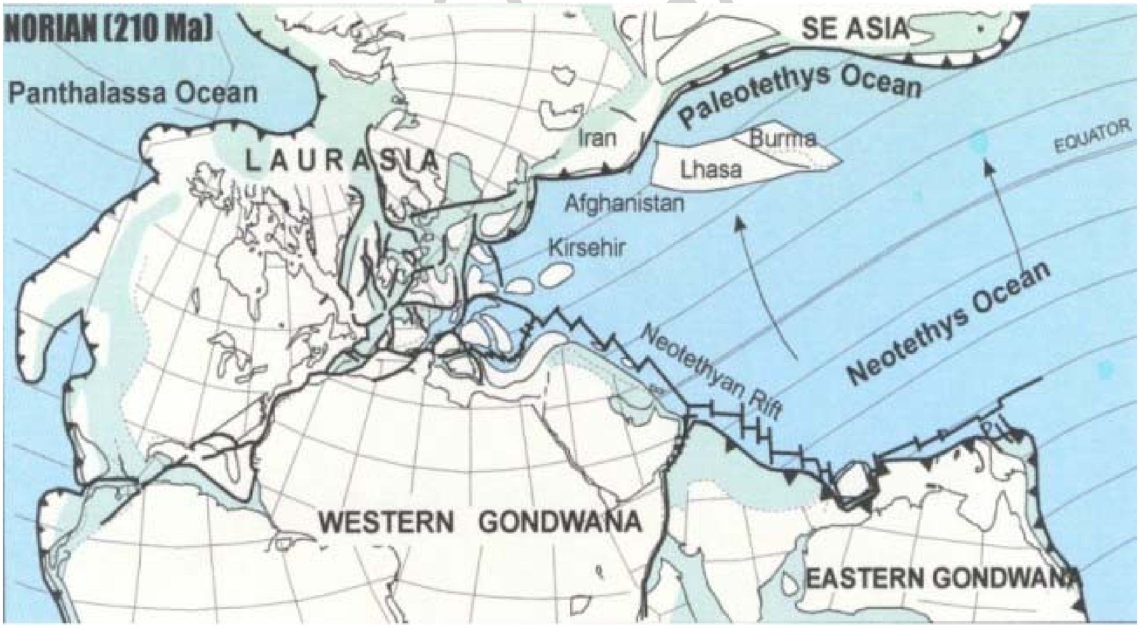

Figure 3. The paleogeography in Norian before 210 Ma

Figure 4. The paleogeography in Toarcian before 175 Ma

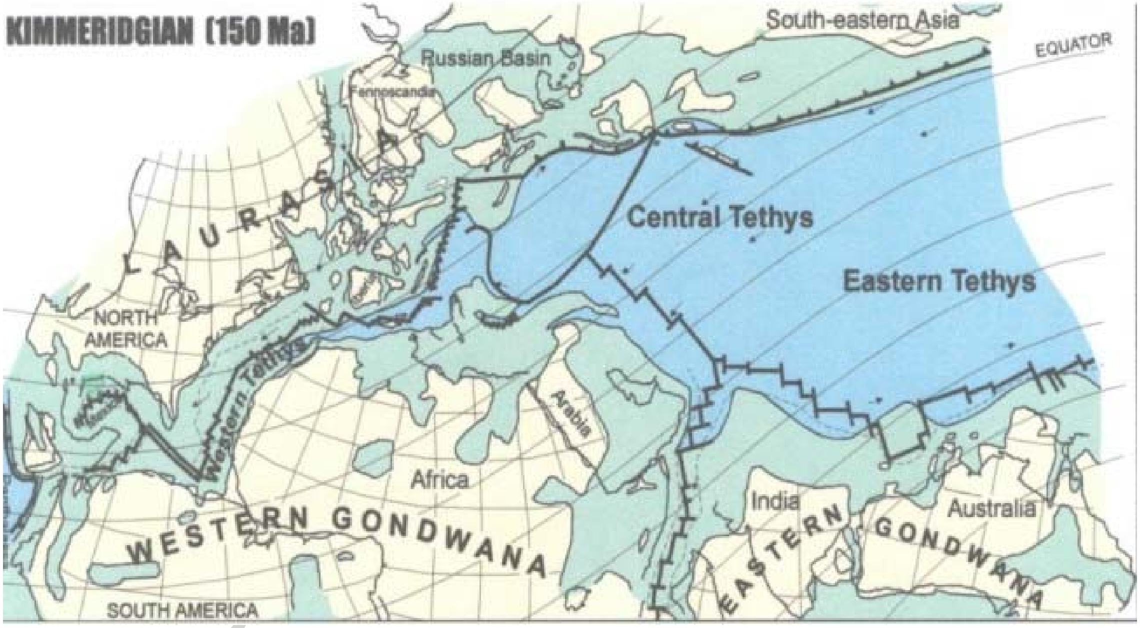

Figure 5. The paleogeography in Kimmeridgian before 150 Ma

The Triassic/Jurassic boundary period was characterized by rebuilding of paleotectonic patterns, bathymetry of sedimentary basins, current systems, climatic regime, and morphology of adjacent continents. A huge mountain chain started to form along the southeastern border of Eurasia. The shelves were affected by a new transgression, during which the coastline prograded deeply into the former continental interior. Lakes formed in rift valleys and extensive river systems transported great amounts of clastics into deltaic cones. The easterlies blowing over northern Africa, which lacked soil moisture, created an inland sand sea. In northern Texas and Georgia, coastal dunes formed. These eolian deposits may have been Milankovitch forced. See chapter ***Internal Forces***.

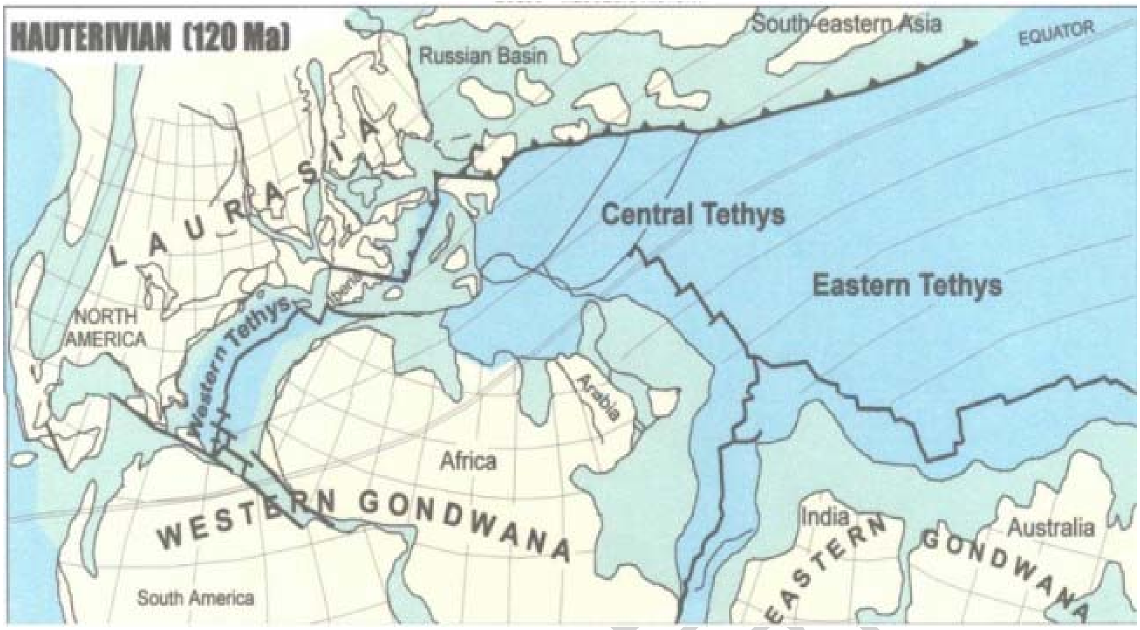

Figure 6. The paleogeography in Hauterivian before 120 Ma

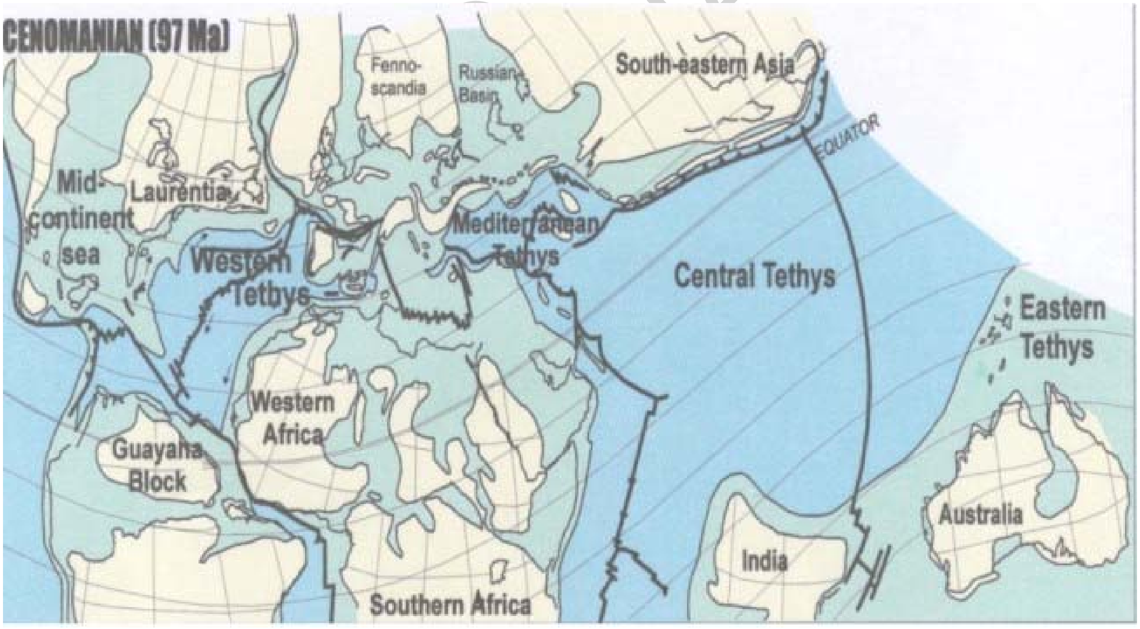

Figure 7. The paleogeography of Cenomanian before 97 Ma

During the middle and late Jurassic and early Cretaceous times, substantial areas of land were being actively created in the southwest Pacific. For the first time and possibly the only time in their geological history, it is likely that New Caledonia and New Zealand had major land links to neighboring countries. The landmasses of the Rangitata Orogeny, which in middle and late Jurassic times provided migration routes for terrestrial and shallow-water marine organisms, were much reduced in size and elevation by extensive erosion throughout the early Cretaceous, culminating in Aptian-Albian times with substantial marine incursions across the bevelled land (a global eustatic rise of sea level is also likely to have occurred at about this time). See ***Sea Level Rise*** in chapter ***Epeiric Seaways: Sea-Level Rise in Geological History***.

The history of the Cretaceous Tethys is marked by short phases of high geodynamic activity, alternating with relatively longer quiet periods. Tethyan margins reached a mature stage in which the oceans were wide enough to control the climate at the adjacent landmasses. The coastal plain, shelf, and the slope became mainly stabilized; integration of rivers and streams into large drainage basins that fed a limited number of large rivers reaching the coasts was nearly complete; and a pattern favoring carbonate sedimentation developed under suitable climatic conditions. See ***Limestones***.

1.3. Paleoceanography

The Permian–Triassic boundary interval was associated with the largest Phanerozoic regression on continental shelves (several authors have even hypothesized glaciation of polar regions). The area of exposed shelves doubled in comparison to the mid-Permian time. This regression was probably induced by a tectono-eustatic lowering of the sea level. Assuming that the hypsometric curve of Permian–Triassic relief was similar to the Recent one, sea level would have dropped about 210 m. This drop has been interpreted as a 5 cm y^{-1} decrease in oceanic bottom spreading rate over at least 8 Ma.

During the Scythian, the gradual rise of the sea level caused a marine transgression in shelves and intracontinental basins. In Europe, the transgression from the southeast peaked with the penetration of the sea through the Polish Trough, and later through the Burgundy Trough and Hessian Depression into the German Basin. During the middle Triassic, the sea filled the Rift of Biscaya, and, at the end of the Triassic Period, also the graben systems of northwest Africa and southern Iberia.

The global oceanic regime was modified during the early Anisian, when huge amounts of saline water were produced by the arid climate in the subtropical shallow sea belt where evaporation greatly exceeded precipitation. The water was made denser by an increase in its salt content. In the case of competing sources, the denser water with the greatest buoyancy flux became the bottom water and the source with the lesser buoyancy flux became the intermediate water layer. A rather stagnant salinary oceanic regime interrupted by sinking flows of warm and heavy brines from hypersaline shallows characterized the early Mesozoic oceans. This model was interrupted at least twice by cooler and more humid periods (the early Carnian and Hettangian).

In Europe, Rhaetian times were characterized by a renewed transgression of Tethyan seas. These reached the southern and central North Sea area mainly via southern England, the Celtic Sea–Western Approaches rift system, the Bay of Biscay, the Burgundy Trough, the Paris Basin, the Hessian Depression, and the Polish Trough. A connection between the Arctic and Tethys seas may have been established for the first time via the Irish Sea and the Rockall-Faeroe Rift.

The onset of the Jurassic time was characterized as one of the major paleoceanographic events, accompanied by continental rifting and by thinning of crust between North America and Africa. Arising rift valleys were filled by lacustrine and evaporitic sedimentation. Differing patterns of oceanic currents in the northern and southern hemispheres during the Jurassic may account by themselves for the observed faunal differences, without the necessity of change in paleolatitudes of the southern continents. All the continental reassemblies based on paleomagnetism agree in indicating that, throughout the Jurassic period, the North Pole was more closely hemmed-in by landmasses than the South Pole, and this by itself would lead to a buildup of cooler water in the higher latitudes of the Northern Hemisphere and in turn produce more marked faunal differentiation northwards than southwards. The highly irregular paleobathymetry in a warm tropical sea was an ideal setting for the extensive development of two reef varieties (demospongians/corals and demospongians/algae) characteristic of the late Jurassic. Intense winter coastal upwelling occurred along the southern Tethys margin, while the northern margin mostly lacked upwelling. The Tethys was isolated from any source of high latitude water.

The primary cause for the appearance and disappearance of two gigantic Jurassic to Paleogene epicontinental seas in Laurasia (the Mid-Continental and Turgai seas) was eustasy, or changes in the sea level of the world ocean. The Turgai Sea lasted from the mid-Jurassic to the Oligocene. The formation of the mid-Cretaceous Mid-Continental Seaway in the western part of Euramerica produced three northern land masses, the Beringia connection reduced the three to two, and the desiccation of the Mid-Continental Seaway reduced the two to one.

During the early Cretaceous, polar regions, where sea ice was produced, started to supply the deep water of the world ocean. This was a return to the "glacial" oceanic regime with sea currents driven by temperature gradients. A special paleogeographic condition that may have played a role in the Cretaceous ocean was the presence of meridional seaways that connected regions with surface waters having similar densities but different temperatures and salinities. If the water masses have very different characteristics, their mixing results in catastrophic rapid downwelling "caballing," which can cause a high oxygen content in deep waters (as in today's Japan Sea). The early Cretaceous ocean including its general temperature, salinity, and density patterns, may have been similar to the modern Pacific Ocean, with a large marginal central Atlantic–western Tethys Sea.

Enhanced nutrient supply and increased paleoproductivity during the Aptian–Albian time were connected with a volcanically and tectonically induced increase in atmospheric CO_2 levels, which resulted in global warming. This favored intensification of oceanic thermohaline circulation of the intermediate layer mainly due to increased salinity contrasts in the mid-Cretaceous Ocean. The mid-Cretaceous waters of the Gulf of Mexico, Central Atlantic, and western Tethys were much more saline than the modern North Atlantic, and may have been a source of warm saline water, dense enough to sink to the bottom. The black shales in the Central Atlantic and western Tethys have been attributed to stagnant pools of warm saline bottom water or to O_2 depletion in response to the periodic development of positive freshwater balance and estuarine circulation. The warm Tethyan waters caused a regional increase of the hydrological cycle (it was 25% greater at that time than it is today), and increased runoff from the adjacent lands. In the middle Tethys, sea surface temperatures of 31^{o}C were indicated by oxygen isotopes during the Cenomanian and Turonian.

Late Cretaceous sea surface temperatures declined to 29°C in the Santonian, with a minimum of 21^{o}C in the late Campanian. At the same time (late Campanian–Maastrichtian), low-latitude Pacific waters were in the range of 20–24^{o}C, with deep waters consistently about 10–16^{o}C cooler. Although the polar waters were cooler, the thermal contrast with tropical waters was less than it is today. Ocean deep waters had a high salinity. Subtropical and polar fronts were driven by winds. The subtropical front formed beneath the equatorial boundary of the zone of maximum westerly wind stress, and the polar front was along the poleward boundary of this zone. Between the subtropical and polar fronts, both the temperature and salinity of the water decreased, representing an outcrop of the lower part of tropical–subtropical pycnocline. Upwelling in each hemisphere reached 36 Sverdrups; the present circum-Antarctic current has a vertical circulation of 70 Sverdrups. During the late Cretaceous, the contrast between surface gyre waters and intermediate waters was less than it is today, making them easier to upwell. However, because they were more easily upwelled, their residence time in the oxygen minimum was less and they contained less nutrients. This is why the Cretaceous ocean productivity was low. A special peculiarity is the deposition of a typical open ocean pelagic sediment, chalk. This was possible because the shelf break front separating the open ocean and shelf seas did not exist in conditions of very high sea level stand. For some 30 million years the ocean and epeiric seas behaved as a single unit. See ***Mesozoic Climates*** in chapter ***Atmosphere and Climate***.

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Biographical Sketch

Dr. Jozef Michalík graduated from both the principal and secondary schools in Dubnica nad Váhom and in Ilava during 1952–1964. In 1964–1969, he studied geology in the Department of Paleontology, Faculty of Sciences of the Charles University in Prague with Professor Z. Špinar, Professor V. Pokorný, and Professor J. Augusta. Since his graduation (1969), Dr. Michalík is working in the Geological Institute of the Slovak Academy of Sciences in Bratislava. He has expanded his Ph.D. thesis (*Uppermost Triassic Stratigraphy, Paleogeography and Brachiopod Associations in the Western Carpathians*), studying paleoecological and paleodynamic aspects, distinguishing lithological zones and biofacies, estimating biotop successions and relationships between communities of organisms. He has reconstructed a model of sedimentary and life environment in three (Fatra, Tomanová, and Norovica) Triassic formations. During this study, he (together with Dr. M. Sýkora) has found dinosaur footprints, the first in the Slovak territory at all. A series of noteworthy results concerning the architecture of Lower Cretaceous complexes, their fauna, lithostratigraphy, and paleogeography has been applied in the projects of cooperation with the Geological Survey, Concern of Cement Works, but also in the UNESCO IGCP international projects. In 1986, Dr. Michalík started to organize a new research team composed of younger scientists of the SAS Geological Institute. This was the beginning of the most successfull stage in his scientific activity, which peaked with submitting of his doctoral dissertation (*Mesozoic Sedimentary and Life Environments in the Western Carpathians*). He was an organizer and co-leader of the IGCP UNESCO Project No. 362 (*Tethyan and Boreal Cretaceous*). Dr. Michalík represented his home institute with over two hundred scientific papers, which have wide response (600 annotations). He is the President of the Paleontological Group of the Slovakian Geological Society. He is the Editor-in-Chief of the *Geologica Carpathica* Editorial Board, the only geological journal evided in ISI (Current Contents) in the Central Europe. At present, Dr. Michalik is the director of the Geological Institute of the Slovak Academy of Sciences.