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# The modern ocean is a poor analog for the Cretaceous

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Perceptions of the Cretaceous ocean rest on analogy with the modern ocean, but comparative physiographic analysis shows that the differences between the two are so great that the analogy may not be valid. The present ocean covers 71% of the planet, with the Pacific covering 35%, Atlantic-Arctic 21% and the Indian Ocean 15%, including their marginal seas. 61% of the Earth is in the three major ocean basin complexes, which communicate at high southern latitudes. Deep marginal seas with restricted communication to the major basins occupy 6% of the Earth's surface, and 4% is in shallow seas and shelf regions along the continental margins. Both poles are ice covered. During the glacial episodes of the Quaternary, the shelf areas were exposed; the ocean covered only 67% of the planet, a minimum for the Phanerozoic.

In contrast, at the sea-level high stand, about 90 Ma, the ocean covered 78% of the planet. There was one large ocean basin, the Panthalassa-Eastern Tethys, which occupied 51% of the planet's surface. All but 10% of this area has been lost to subduction. A myriad of restricted marginal seas occupied the remaining 27% of the water-covered planetary surface. Most of our knowledge of the Cretaceous oceans comes from these areas. Restricted deep basins formed 11% of the Earth's surface and 16% was shallow seas. This is twice the present area of deep marginal seas and four times the area of modern shallow seas and shelves. The western Tethys and North Atlantic formed a tropical latitudinal seaway for surface waters, but had a highly complex bathymetry with many isolated deep basins separated by platforms. Both poles were free of any major ice cover.

To sink into the ocean interior, surface waters must be modified to become denser by evaporation or chilling and sea-ice formation. This requires isolation, and today marginal seas play a major role as sources of water to the ocean interior. Intermediate waters can form in the open ocean, isolated between the subtropical and polar fronts generated by the westerly winds. Most of the cool, low-salinity intermediate water

masses of the South Pacific, southern Indian and South Atlantic oceans form in this manner. However, modern intermediate waters are also be generated by cold and/or saline outflows from marginal seas where sea-ice formation or high evaporation rates modify the water (e.g., Mediterranean and Red Seas; Norwegian-Greenland Sea and Sea of Okhotsk). Marginal seas in the region of high evaporation between 20˚ and 40˚ N and S latitude have areas of 3.6 and 6.1 x $10^6$ $km^2$ respectively, and about 1/3 of these produce ocean intermediate waters. About half of the modern ocean deep waters form in high-latitude marginal seas and half in shelf regions, none in the open ocean.

In the Cretaceous there was no persistent polar ice to stabilize the westerly winds and induce the subtropical and polar frontal systems. Open ocean formation of intermediate water was unlikely. The north polar South Anyui Ocean Gulf would have been a likely source of polar deep waters until it was isolated to become the Arctic Basin at the end of the Albian. Marginal seas in the region of high evaporation had areas of 27 and 41 x $10^6$ $km^2$ in the N and S hemispheres respectively. This is five times the area of modern marginal seas that may potentially generate warm saline ocean interior waters. With such extensive isolated areas, the Cretaceous ocean interior must have been dominated by outflows from both shallow and deep marginal seas.