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The Mid-Cretaceous Superplume

The mid-Cretaceous period in Earth's geologic time scale ranging from 120-80 million years ago is a time that is characterized by warmer oceans, a warmer climate, a large absence of ice, broad-leafed vegetation, and animals that are adapted to warmth , like dinosaurs, that were found in areas north of the Arctic circle (Ruddiman, 2008). The mid-Cretaceous superplume episode was first suggested by Roger Larson, where he explained that a superplume is a large zone of mantle upwelling that rose because it had been overheated and thus had a lower density (Larson, 2005). This superplume originated 120 million years ago with a sudden onset, and lasted tens of millions of years until crustal creation rates gradually returned to normal. Although there are many speculated causes for the rapid rise in sea level and atmospheric temperatures during the mid-Cretaceous, they may have mainly been due to the increased amount seafloor volcanic activity like large scale mantle plumes.

The superplume that affected the Pacific ocean had minimum dimensions of 6000 by 10,000 kilometers (Larson, 2005). It created a large basaltic magma generation that arose beneath the Pacific ocean, which was the area most strongly affected at this time, along with events in the Indian, Caribbean and South Atlantic oceans (Jahren, 2002). Superplumes should not be confused with hot spots, since they occur at the mantle-core boundary while hotspots occur at the mantle-crust. This means that there must have been widespread volcanic eruptions, because typically seafloor spreading rates generate oceanic crust at a much slower rate. Oceanic crust that is created at normal seafloor spreading rates are covered in fracture zones that are perpendicular to the spreading zones, but in the western Pacific, the ocean floor has many chains of seamounts and plateaus which are a result of mantle plumes. The cause of this large increase of oceanic crustal spreading according to Larson, was from the penetration of a large slab of crust into the lower mantle (Seton, Gaina, Muller, Heine, 2006).

This increased volcanic activity may have also contributed to the increase in global atmospheric temperature during this “greenhouse” period, as massive amounts of carbon dioxide were released when the molten lava erupted. This large amount of carbon raised global temperature by around ten degrees celsius (Larson, 2005). If there is an increased amount of carbon dioxide in the atmosphere, that means that there is an increased amount of chemical weathering of silicate rock but in order for the process to be balanced, enough weathering has to occur to counteract the input of CO_2 (Calderia, Rampino, 1991). During this superplume event, carbon dioxide levels were around 1,000 ppm and were expelled from subduction zones, superplumes, and mid-ocean ridges (Calderia, Rampino, 1991). With increased oceanic crustal activity, there is an increased amount of CO_2 that is emitted into the atmosphere, which thus creates a greenhouse effect and increases the overall global atmospheric temperature.

During this time in the mid-Cretaceous, the world wide sea level was around 250 meters higher than it is today, which was an effect of a rise in the level of the sea floor and increased temperatures from increased amounts of carbon dioxide in the atmosphere (Seton et. al., 2006). This was especially true for the waters in the Pacific ocean, since the crust that had formed there was new, relatively warm and less dense, which therefore made it expand (Larson, 2005). This was a period of rapid crustal formation, meaning the seafloor was situated at a higher elevation which created a higher sea level. The increased atmospheric temperature also contributed to the rise in sea level, since warmer water is less dense and is more expanded.

These high sea levels and warmer waters led to large phytoplankton and zooplankton populations, and after they died, they sank to the bottom of the ocean, onto the crust. Normally, their skeletons dissolve rapidly because of the enormous pressure of the overlying ocean, but during the mid-Cretaceous these skeletons fell onto the continents that were temporarily underwater and were left preserved (Erba, Larson, 1999). These well preserved calcium carbonate skeletons combined with surrounding sediments contributed to the White Cliffs of Dover in England (Larson, 2005). A large amount of this carbon from exoskeletons was also deeply buried and eventually turned into oil that constituted over half of the worlds oil supply (Larson, 2005).

Since the superplumes originate at the mantle-core boundary, Larson suggested that the plumes affected the processes that usually result in the reversal of earth's magnetic field every few thousand years. The very hot iron that is present in the outer core is what most affects earth's magnetic reversals, and when an increase in the boiling rate of the outer core occurs during these superplume events, the heat gets trapped in the lower mantle where it accumulates and eventually volcanically explodes. During the superplume of the mid-Cretaceous, there was a long interval of normal polarity in which no magnetic field reversals occurred that is referred to as a Long Normal Superchron (Ratajeski, 2013). Approximately 80% of the Cretaceous period had normal polarity and there was a 50-75% increase in production of oceanic crust during the Long Normal Superchron of the Cretaceous, so this suggests that there is an inverse relationship between earth's magnetic reversals and superplume events such as when there is active superplume events, there is no magnetic change (Larson, 2005).

The superplume of the mid-Cretaceous was the first to ever be identified, and there is large evidence for other superplume events in the Jurassic, the Proterozoic and the Archean periods (Ratajeski, 2013). Although there could have been other factors that led to the drastic changes that took place in this time period, I believe that the superplume in the Pacific basin played a large part. The carbon dioxide that was emitted during this time caused a lot of other reactions, which makes me believe that it was the most prevalent effect of the superplume. This undoubtedly contributed to the changes in production of oceanic crust, seafloor spreading rates, earth's global temperature and eustatic sea levels that took place during the mid-Cretaceous. This past greenhouse earth temperatures and sea levels could be a sneak peek at what could climate conditions possibly lie ahead, in the human-induced, carbon dioxide infatuated anthropocene, even in the absence of a superplume.

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