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Mesozoic and Cenozoic carbonate factories: reexamining responses to global-scale changes

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Understanding biological and geochemical processes associated with carbonate- producing biotas, while recognizing the limitations of uniformitarianism, are essential to interpreting carbonate sedimentation. CO2 is fundamental for primary organic production, and, with Ca concentration in seawater, for carbonate precipitation. Moreover, photosynthesis and bio-calcification are linked, especially in low nutrient conditions. Thus, atmospheric CO2 and Ca concentrations, interacting with and controlling alkalinity in seawater, are major controls on evolving carbonate-producing systems.

With metazoan consumer diversity reduced by the end-Permian extinctions, excess photosynthesis by phytoplankton and microbial assemblages in surface waters, induced by moderately high CO2 and temperature during the early Mesozoic, supported proliferation of non-tissular metazoans (e.g., sponges) and heterotrophic bacteria at the sea floor. Metabolic activity by those microbes resulted in abundant biologically induced geochemical carbonate precipitation on and within the seafloor. E.g., with the opening of Tethyan seaways during the Triassic, massive sponge/microbe boundstones (the benthic automicrite factory) formed steep, massive and thick progradational slopes and, locally, mud-mounds.

As tectonic processes created shallow epicontinental seas, photosynthesis drove lime-mud precipitation in the illuminated zone of the water column. The resulting neritic lime-mud component of the shallow-water carbonate factory became predominant during the Jurassic, paralleling the increase in atmospheric CO2, while the decreasing importance of the benthic automicrite factory parallels the diversification of calcifying metazoans, phytoplankton and zooplankton. High CO2 in the Mesozoic, peaking in Middle-Late Jurassic, promoted excess photosynthesis that supported bacterial blooms. As sea-level rose and epicontinental seas developed, neritic photosynthesis in seawaters with high Ca and HCO3- concentrations triggered widespread precipitation of oolites and fine-grained lime-muds (neritic lime-mud factory).

Seawater Ca concentrations, which peaked during mid-Cretaceous, promoted biotically controlled calcification (skeletal factory), as decreasing atmospheric CO2 diminished neritic lime-mud production. Strategies that link photosynthesis and calcification subsequently promoted major changes of the skeletal factory. Rudists dominated shallow production during middle to Late Cretaceous, paralleling diversification of calcareous phyto- and zooplankton. Cenozoic carbonate-producing ecosystems evolved as the warm alkaline oceans of the Greenhouse World gave way to increasing latitudinal and bathymetric temperature gradients, along with declining atmospheric CO2, Ca concentrations and alkalinity, as Icehouse conditions emerged.

Calcitic larger benthic foraminifers (with algal symbionts) dominated during the Eocene and coralline red algae during the Miocene, accounting for significant carbonate production in the deeper oligophotic zone. Zooxanthellate corals became increasingly important since the Oligocene, as decreasing Ca and atmospheric CO2, and increasing Mg/Ca ratio in seawater favored aragonite hypercalcification. The Neogene shift to construction of shallow-water, low-latitude coral reefs paralleled both global cooling and diversification of zooxanthellae in scleractinian corals.