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Calcium carbonate crystal fans: Geologic occurrences and controls on growth

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Fans and hemispheres comprised of crystals of calcium carbonate that directly grew on the seafloor are an intriguing feature of ancient carbonate environments. Calcium carbonate fans from across Earth history are typically made up of crystals of neomorphosed calcium carbonate that maintain an acicular morphology that is pseudohexagonal in cross – section with blunt terminations, pointing to an aragonite precursor. Crystal fans may occur as isolated bodies, or may form larger aggregates that are sometimes associated with microbialites, and form larger, reef – like structures. Some of the first occurrences of these features are within Neoarchean carbonates, when the crystals fans grew to impressive sizes, with lengths of over 1 m, formed layers of marine cement that reached thicknesses of up to several meters, are laterally continuous over 10s of km or more, and formed across carbonate platform settings from high energy subtidal settings to lower intertidal environments. Crystalline carbonate fans become less common and smaller (cm – scale) in the Paleoproterozoic, and nearly disappear prior to the Neoproterozoic, when they are associated with cap carbonates, and are primarily found in deeper water or outer shelf settings with low sedimentation rates. Seafloor cements are rare during the Phanerozoic, and are typically limited to small geographic areas with unusual sedimentary conditions, or are found in void spaces, where seawater chemistry was able to undergo modifications that would allow precipitation of cement fans. The exception is during the interval of time that followed the Permian – Triassic mass extinction, when small, cm – scale fans and hemispheres are found in Lower Triassic and lowermost Middle Triassic rocks. These cement fans occur in a variety of settings, although they are typically found in deeper water environments. Calcium carbonate fans that formed following the Permian – Triassic extinction may have microbial remains preserved within the cements, and are frequently found in close lateral or stratigraphic association with microbialites. However, some examples of post – extinction carbonate fans appear to have formed abiotically, without any microbial influence. Overall, crystalline calcium carbonate fans signal high levels of calcium carbonate supersaturation in ancient oceans. The initial decline in seafloor cement growth from the Neoarchean into the Proterozoic may have been the result of accelerated micrite production, while Neoproterozoic calcium carbonate fan growth is associated with glacial decay and retreat. Lower Triassic seafloor cements are likely the result of stratification and stagnation of the deep oceans that led to enhanced alkalinity. Calcium carbonate crystal fans are an intriguing feature of ancient carbonates that signal depositional systems and ocean chemistry that is much different from modern ocean, and provide a fascinating glimpse into non – uniformitarian sedimentary environments.