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Non-classical carbonate crystallisation in the Tonian Draken formation

PETER METHLEY[1], CLANCY ZHIJIAN JIANG[1], JUSTIN STRAUSS[2] AND NICHOLAS J. TOSCA[1]

[1]University of Cambridge
[2]Dartmouth College
Presenting Author: pm631@cam.ac.uk

The Precambrian carbonate record contains well-documented secular variations in both mineralogy and rock fabric. Neoproterozoic marine carbonates in particular commonly exhibit distinctive syndepositional calcite microspar cement in subtidal facies, while intra- to supratidal facies are dominated by syndepositional/early diagenetic dolomite. However, the mechanisms responsible for such variations are poorly understood, meaning these rocks are often difficult to interpret as environmental indicators and as geochemical archives.

These textural and mineralogical variations could be explained through "non-classical" crystallisation: crystal growth through metastable intermediates such as amorphous calcium-magnesium carbonate (ACMC), carbonate nanocrystals, or hydrated carbonate minerals. This could be achieved if the direct precipitation of calcite and aragonite is kinetically inhibited by an impurity such as dissolved phosphate [1], combined with a process such as evaporation or photosynthesis to increase local carbonate supersaturation.

To test this hypothesis, we combine and apply experimental, theoretical, and analytical techniques to the Tonian Draken formation, Svalbard, Norway, which largely comprises intra-/supratidal dolostones [2]. Petrographic and isotopic data suggest that the fine dolomicrite in the Draken is formed syndepositionally, and could potentially act as an archive of marine geochemistry.

Our experimental data show that the evaporation of artificial Tonian seawater containing 50 µmol/kg of dissolved phosphate is able to precipitate ACMC and other metastable calcium-magnesium carbonates, and form textures such as fibrous cements.

In addition, numerical models show that the crystallisation of ACMC results in textures and grain-size distributions consistent with those measured in the Draken formation. High-resolution transmission electron microscopy and scanning electron diffraction reveals the presence of relict amorphous phases and nanometre-scale variations in crystal orientation within Draken dolomicrite, which have been interpreted to result from non-classical crystallisation [3].

Together, these results suggest that non-classical crystallisation could be responsible for some of the mineralogical and textural variations in late Proterozoic carbonates, with implications for the interpretation of palaeo-environmental conditions and isotopic evolution of Precambrian carbonate systems.

[1] Roest-Ellis, Strauss & Tosca (2020), *Geology* 49, 561-565.
[2] Fairchild, Knoll & Swett (1991), *Precambrian Research* 53, 165-197.
[3] Meister & Frisia (2019), *Rivista Italiana di Paleontologia e Stratigrafia* 125, 183-196.