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STROMATOLITES: CAPTIVATING RECORDS OF EARTH'S EVOLVING BIOGEOCHEMICAL PROCESSES

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In the 1920s, University of Wyoming geology professor Sam Knight drafted students to help him build a field station in the Medicine Bow Mountains of southeastern Wyoming, USA. The rustic lodge and cabins were only a few miles from the spectacular stromatolites of the Paleoproterozoic Nash Fork Formation. Generations of students have visited the outcrops of tan, silicified, stromatolitic metadolomite with interbedded phyllite and quartzite deposited on the passive margin of the Archean Wyoming province about 2 billion years ago. These budding geologists examined exposures of classic stromatolite domes of varied shape and size from giant spheroids to small domes and thin wavy laminae. Over the years some of the outcrops acquired affectionate nicknames, such as "Big Daddy," on which I sit in FIGURE 1.

FIGURE 1 The Principal Editor relaxes on "Big Daddy" along the shores of Prospector Lake, Medicine Bow Mountains, Wyoming, USA. This stromatolite dome has a radius of more than 5 meters. UTM 13T 0392838N 4579590E.

Although he did not call them stromatolites, in 1926, Eliot Blackwelder described the domes in the Nash Fork Formation as composed of alternating bands of dolomitic and siliceous rock. He interpreted them to "have been built by colonial organisms, such as calcareous algae" and he noted that the microorganisms are not preserved due to recrystallization. Not until Sam Knight—builder of the geology field station—retired and had time to study the Nash Fork Formation stromatolites were their physical characteristics described in detail (Knight 1968). Bekker and Eriksson (2003) interpreted changes in relative sea level from stratigraphic characterization of lithologies, sedimentary structures, and stromatolite features in the Nash Fork Formation, although Lageson and Boyd (2013) noted that the microbial mats may have been deformed by downslope sliding or pre-lithification compaction and cautioned against over-interpreting present stromatolite morphology. To this day, field trip participants debate the Nash Fork stromatolites' origin and meaning while admiring their varied and intricate structures and pondering what can be learned from these recorders of ancient life.

Stromatolites are certainly captivating, but why are they a topic for *Elements*, an international magazine of mineralogy, geochemistry, and petrology? The answer is that biological processes have been intertwined with Earth's physical and chemical cycling for at least 3.5 billion years. Stromatolites exemplify this interaction, forming through a combination of microbial mat growth, sediment deposition, and mineral precipitation. The link between biology and mineralogy is direct, as microbial oxygenic photosynthesis elevates pH, which in turn promotes carbonate precipitation. The microbial mats contain sticky biofilms that trap and bind sediment to build the stromatolite structure (Zeyen et al. 2026 this issue). The microbes that constructed stromatolites also affected the geochemistry of the Earth's surface environment. Notably, they provided molecular oxygen to the oceans and atmosphere, first by anoxygenic photosynthesis in the Paleoarchean, then by oxygenic photosynthesis starting around 3 billion years ago (Hofmann et al. 2026 this issue).

Stromatolites are fundamentally linked to the subaerial emergence of continents, which in turn reflects changing tectonic and petrologic processes in the early Earth. The initial crust was likely mafic, weak, flat, and flooded (Rey et al. 2024). The formation of felsic crust and secular cooling created a stronger, subaerial crust able to support mountains. Blocks of continental crust stabilized into cratons, and the shallow margins of these stable cratons provided a substrate soon covered by thick carbonate platforms. The oldest known stromatolites formed around 3.5 billion years ago but stromatolites are most abundant in the Paleoproterozoic, when the Nash Fork stromatolites formed on the margin of the Wyoming province. By this time, subaerial continental crust was widespread and favorable atmospheric and oceanic conditions promoted widespread shallow marine carbonate precipitation. The near-ubiquity of Paleoproterozoic stromatolites is direct and visible evidence of microbial ecological success.

Stromatolites declined in abundance towards the end of the Proterozoic, coincident with life diversifying and oxygenating the oceans and atmosphere. Some stromatolites still form today in the presence of multicellular animals, raising the question of whether ancient and modern stromatolites result from the same processes of formation. Clearly, stromatolites have survived over much of Earth history in starkly different, evolving environmental conditions. Might they also help us identify signs of microbial life on other planets?

Geologists wandering over stromatolites like those exposed in the Nash Fork Formation are fascinated by these ancient records of early life. The articles in this issue of *Elements* help us to build on that curiosity and to delve deeper into the origins of stromatolites and what they disclose about the interplay of biological, chemical, and geological processes that created the planet we inhabit today.

Carol Frost, Principal Editor

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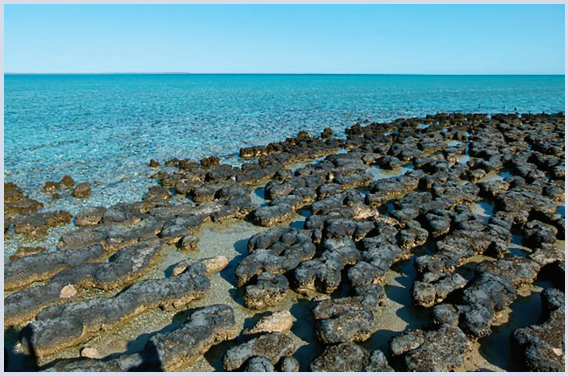
ABOUT THIS ISSUE

Stromatolites and other microbialites are remarkable bio-mineralising structures that are abundant throughout Earth's history. Formed in the presence of microbial communities, these bio-sedimentary rocks provide a continuous record of microbial evolution over the last 3.5 billion years. Thus, stromatolites provide unique archives of microbial habitats, revealing their interactions and coevolution with Earth's continents, atmosphere, and life. Stromatolites were first described 120 years ago by the German geologist Ernst Louis Kalkowsky and have recently gained extensive interest across the interdisciplinary fields of the bio-geosciences. Current research is advancing our ability to reconstruct ancient aqueous environments and their associated microbial communities, shedding light on their role in shaping biogeochemical cycles. Moreover, stromatolites are recognised as possible analogues in the search for extra-terrestrial life within our Solar System.



Modern stromatolites forming at Hamelin pool in the hypersaline Shark Bay, Western Australia. These biosedimentary archives are present throughout the geological record and offer scientists unique snapshots of microbial evolution and their habitats on Earth and beyond.

This issue of *Elements* explores the latest advances in stromatolite and microbialite research from a combined geobiology, mineralogy, and (isotope) geochemistry perspective. This volume underscores the urgent need to protect these endangered microbial ecosystems. It highlights key scientific challenges and pathways ahead to understand how microbial ecosystems respond to environmental changes and to predict their evolution on a fast-changing modern Earth.

ELEMENTS AT GOLDSCHMIDT 2026

The 19th annual Goldschmidt Conference, held in Montréal, Canada, on July 12–17, 2026, was bustling with growing camaraderie and renewed enthusiasm across the geoscience community. *Elements* was honored to host a gallery and information booth alongside the Geochemical Society and the European Association of Geochemistry—Goldschmidt's organizers and two of the 18 participating societies that jointly publish *Elements*.

As always, the conference offered a full week of inspiring presentations, lively discussions, and valuable opportunities to build and renew personal connections within our diverse international community.

Elements feels right at home at Goldschmidt, and we look forward to seeing you again at Goldschmidt 2027 in Paris, France, on July 11–16, 2027!

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Tom Sisson, **Carol Frost**, **Penny King**, **Matt Kohn**, and **Esther Posner**

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