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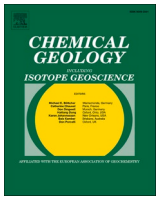

Biotic-abiotic mingle in rock varnish formation: A new perspective

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ABSTRACT

Rocks in arid to semi-arid regions all over the world have a naturally occurring coating called “rock varnish” or “desert varnish” on their surface. These lustrous, black-to-brown mesoscopic coatings on rocks have long piqued the interest of scholars from a wide range of disciplines. However, there are gaps in our understanding, particularly in relation to the formation of rock varnish. Rock varnish development is supported by competing evidence from the biotic and abiotic schools of thought. In the current investigation, we advance and support a previous polygenetic model by proposing that biotic and abiotic factors collaborate to form these microscopic coatings on the rock surfaces. Physicochemical evidences in this work points toward a new perspective, citing an initial abiotic triggering event followed by biotic processes.

1. Introduction

The dark-coloured coatings seen on many rocks throughout the world's arid and semi-arid regions are often referred to “Rock/Desert Varnish” in literature (Dorn and Oberlander, 1982), are made of clay minerals, trace elements, Fe and Mn oxides and hydroxides, and diverse bacteria thrive on them (Chaddha et al., 2021b; Dorn and Oberlander, 1981). Researchers from a variety of disciplines are interested in rock varnish because it requires a special mix of geological, chemical, physical, and biological investigations. These lustrous coatings' association with petroglyphs from antiquity (Dietzel et al., 2008; Whitley et al., 2017), paleoclimatic indicators (Goldsmith et al., 2012; Liu and Broecker, 2008), dating (Liu and Broecker, 2013), similarity to the Martian surface's rock coating (Krinsley et al., 2009; Lanza et al., 2012, 2015), and the recently accelerated use of these varnishes as an electrocatalyst in water splitting reactions (Chaddha et al., 2022).

Despite considerable interest, ongoing disagreement exists over the biotic/abiotic processes that produce rock varnish. One of the key aspects of rock varnish that must be explained is its extreme enrichment in manganese over possible source materials, which overshadows other elements such as Fe, Si, Mg, and Na, that do not exhibit as much enrichment (Otter et al., 2020). As a result, it is clear that the role played by manganese in the biogeochemical processes that produces rock varnish remains a key to understanding its formation process.

Numerous biotic (DiGregorio, 2005; Krumbein and Jens, 1981; Kuhlman et al., 2008; Wang et al., 2011) and abiotic (Elvidge and Moore, 1980; Moore and Elvidge, 1982) mechanisms have been proposed in an effort to explain the enhancement of Mn, but the slow rate of varnish growth on the order of micron per millennia in warm deserts (Liu and Broecker, 2000) makes the study of key processes challenging. Silica gelation theory proposes an alternative explanation for rock varnish formation, focusing on the role of silica. In this model, silica transitions from a sol to a gel state on rock surfaces, effectively capturing and stabilizing key varnish components like manganese (Mn) and iron (Fe). As the gel dries and hardens over time, it forms a varnish-like coating, consisting of both silica and the oxides of Mn and Fe, which contribute to the varnish's characteristic dark colour. This theory underscores the importance of silica in the geochemical processes involved in rock varnish formation (Perry et al., 2006). However, while this theory contributes valuable insights, it does not entirely address certain critical aspects. These include providing a comprehensive explanation for manganese (Mn) enhancement, incorporating the significant role of clay minerals in varnish formation, and elucidating varnish formation in colder environments where the requisite heat and sunlight are limited (Dorn, 2007). Therefore, acknowledging silica's role in varnish formation, it becomes imperative for researchers to undertake further extensive studies. The polygenetic model of rock varnish genesis actively elucidates the complex interplay of biotic and abiotic factors in its

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