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In-situ nitrogen chemical speciation of alteration minerals in terrestrial Mars analog

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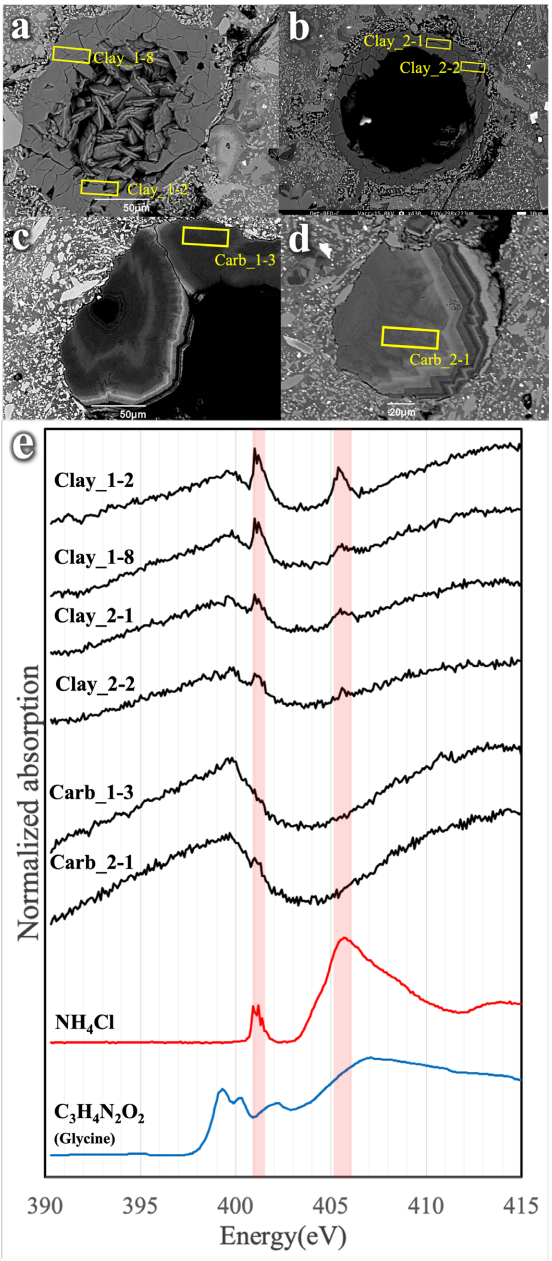
Presence of the liquid surface water on ancient Mars has been almost confirmed. Evolution of the Martian environment and its possible habitability are getting wide attention. Koike et al. [1] reported the presence of organic nitrogen in carbonate globules from a 4-billion-year-old Martian meteorite, Allan Hills (ALH) 84001, which may have been preserved since Noachian era. In this study, we focus on the nitrogen speciation of "Martian analog" in order to understand behaviors of nitrogen (N) on early Mars. Our study ultimately aims to complement the current knowledge from Martian meteorites.

Bockjford Volcanic Complex (BVC) in Svalbard, Norway, is a basaltic complex formed by an ice-bed eruption about 1 million years ago [2]. Secondary minerals such as carbonate minerals crystallized in the interstitial spaces of the host lava breccia due to aqueous alteration. The morphology of the carbonate globules is like those in ALH 84001 [2,3], making the BVC as a potential Mars analog.

Polished sections of the BVC basalt are observed using a SEM-EDS. Major elemental compositions of the secondary minerals are further by EPMA. Finally, nitrogen species in these minerals are investigated by nitrogen X-ray absorption fine structure (μ-XAFS) conducted at BL27SU in the SPring-8 synchrotron facility (Hyogo, Japan).

Secondary Mg-Fe-Ca carbonate minerals, clay minerals, and silica minerals (SiO2) in various forms are observed among the sample sections. EPMA analysis of the carbonate minerals reveals two trends, i.e., the iron-poor dolomite trend and the iron-rich siderite trend, consistent with the previous study [4]. XAFS spectra of the BVC carbonate do not show absorption peaks derived from nitrogen-related species, indicating that their nitrogen concentration is under the XAFS detection limit (less than a few ppm). On the other hand, XAFS spectra of the clay minerals show ammonia-related absorptions, suggesting the presence of ammonium ions which may have been incorporated into the clay minerals during the crystallization.

Ref. [1] Koike et al. (2020) *Nature Comm. 11,1988.* [2] Amundsen et al. (2011) *LPSC abstract #1608.* [3] Treiman et al. (2002) *EPSL. 204,323-332.* [4] Wang et al. (2022) *LPSC abstract #1799.*



(a)~(d) BSE images of carbonate minerals and clay minerals measured by N-XAFS. (e) N-XAFS measurement results.