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Exploration of carbonate and clay mineral on Mars: clues for climate, atmosphere, and deep hydrosphere of early Mars

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High-resolution remote sensing data of Mars Noachian terrains show the widespread existences of clay minerals formed by groundwater circulations [1]. This suggests that hydrothermal activity in deep crusts may have played a major role in hydrological cycles on early Mars [1], which is contrast to those on current Earth and might be similar to those occurred on Europa or Enceladus [2, 3]. To date, however, Mars rovers have performed analyses at outcrops of sedimentary rocks formed mainly by open water activity [4, 5]. Lack of knowledge on the nature of groundwater activity obscures us to understand a whole picture of hydrological cycles, aqueous geochemistry, and habitability on early Mars.

Recent observations and models suggest that there are some locations where groundwater upwelled on the surface of early Mars [6]. These include one of the deepest craters on Mars, McLaughlin Crater, which exhibits layered deposits of carbonates and Mg-Fe-bearing phyllosilicates on the crater floor [6]. The proposed mineral assemblages suggest the occurrence of geochemistry between CO2-bearing, alkaline groundwater and ultramafic rocks [6]. This implies that the outcrops of McLaughlin Crater could serve as a unique window to look into the nature of groundwater activity and its interactions with the atmosphere of early Mars.

Here we propose a Mars rover mission to perform geological and geochemical analyses of outcropped carbonates and clay minerals on McLaughlin Crater. Geological observations of the outcrops would determine the formation processes of these layered deposits. The aqueous geochemical conditions (e.g., the composition, redox state, and pH of groundwater, water-rock ratio, and temperature) would be determined based on results of detailed chemical and mineralogical compositions of the outcrops. These observational data enable us to constrain redox potentials of groundwater, which could support deep biosphere on Mars. In addition, we can estimate the partial pressure of atmospheric CO2 equilibrated with the groundwater. This, in turn, means that our mission will be able to answer the long-standing question whether early Mars had a dense CO2 atmosphere, which will provide critical insights into the habitable zone [7] and formation process of terrestrial planets in the solar system and beyond.

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