Solid–gas carbonate formation during dust events on Mars

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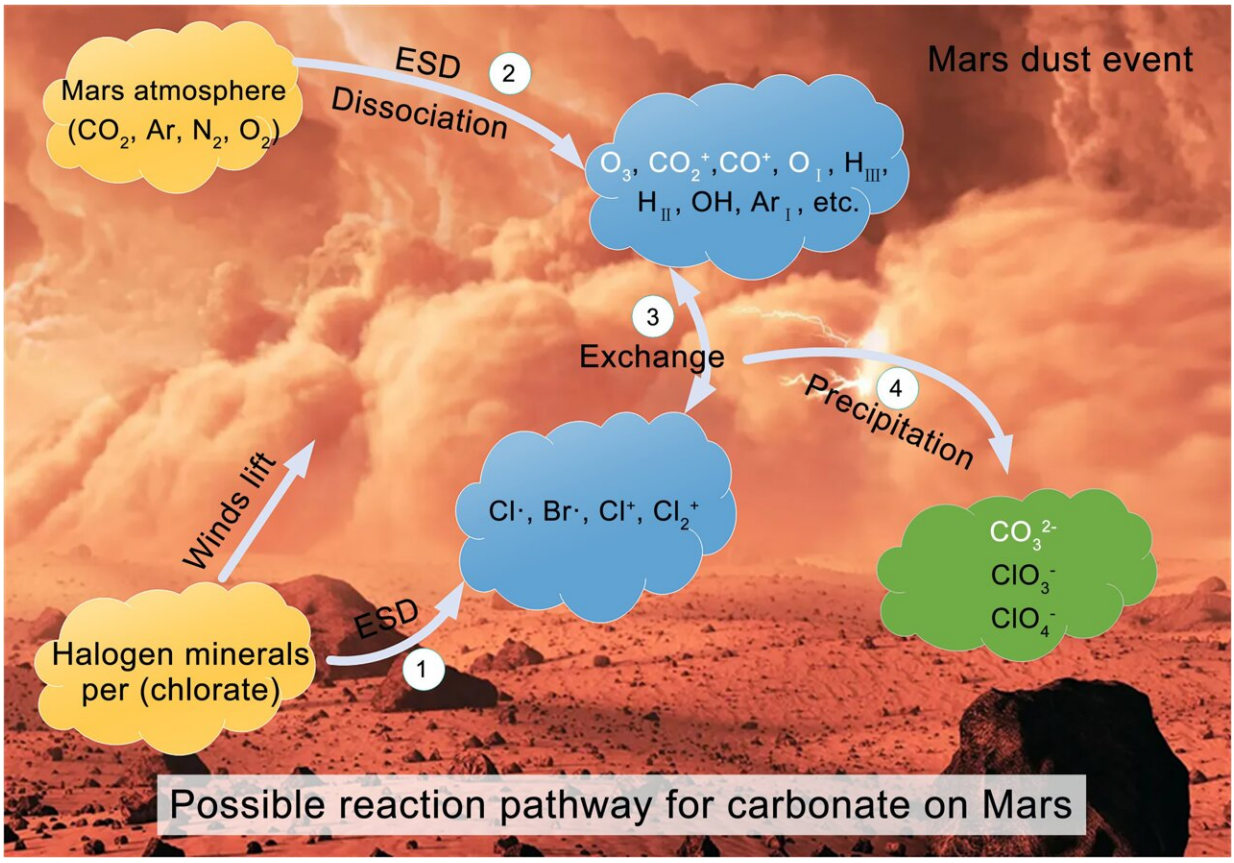

The pathway for the formation of carbonates includes four steps: 1) gaseous species are released from halogens and/or per(chlorate); 2) atmospheric ionization or dissociation occurs; 3) a gas phase reaction occurs between free species (CO^{2+}, CO^+) and different oxidants to produce different carbonate species; and 4) carbonates are deposited on the surface materials of Mars. Credit: Science China Press

A joint research team led by Dr. Xiaohui Fu and Dr. Zhongchen Wu from Shandong University, China, proposed a new carbonate formation mechanism in Martian dust activities based on simulation experimental studies.

Carbonates are general products of aqueous processes on Earth. For Mars, carbonate minerals have been considered a sink for an early dense CO_2 atmosphere. Orbital spectroscopic investigations have identified carbonates in a few isolated localities across the Martian surface. Trace amounts of carbonate have been detected in modern global dust both by orbiters and by rovers.

However, their sources and formation mechanisms are still unclear. The team hypothesizes that carbonate could be formed directly in the CO_2-rich atmosphere by electrochemical processes during Martian dust activities.

To test this, they simulated electrostatic discharge (ESD) under Mars-like atmospheric conditions. Various minerals identified in Martian dust (silicates, Ca sulfates, halogen minerals and (per) chlorate) were exposed to ESD process in a Mars chamber. New generated carbonates were identified by Raman and mid-infrared spectroscopy during ESD reactions with halogenides (NaCl, $MgCl_2$, NaBr) and (per)chlorate ($NaClO_3$, $NaClO_4$) as starting minerals.

Based on the simulation experiments, they proposed gas-solid heterogeneous electrochemical reactions during dust activities as a new mechanism for Martian carbonate formation. "The formation and the scarcity of carbonate outcrops on Mars still remains a mystery up to now. Unlike the conventional formation mechanisms of carbonates, the solid-gas interactions induced by ESD in Martian dust activities are independent of liquid water," Fu said.

The electrochemical processes resulting from dust activities can remove significant quantities of CO_2 gas from the Martian atmosphere and store it over geological timescales. Atmospheric CO_2 on Mars appears to have solidified as carbonates from at least the early Amazonian to present. "These new exciting results add to the growing evidence that atmospheric CO_2 is solidified as carbonates from at least the early Amazonian to present on Mars," Wu said.

The total amount of CO_2 sequestered by Mars dust activities s in the Amazonia era has been estimated based on the carbonate yield of ESD experiments, which possibly converted ~ 0.56 mbar of CO_2 into carbonate by Martian dust activities in the past 3.0 Ga.

Mars dust activities occur frequently on present-day Mars. They last a very long time and cover large areas of Mars. This study further demonstrates the active chemical interactions are still ongoing on Mars between the surface and the atmosphere. Mars' dust activities play a key role in the evolution of the Mars atmosphere and carbon/chlorine cycles on present-day Mars.

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