AN OVERVIEW OF METEORITES FOUND ON MARS AND WHAT THEY TELL US ABOUT MARS.

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Introduction: More than 50 meteorite candidates have been discovered on Mars [1-10], 15 of these are officially recognized in the Meteoritical Bulletin Database [11-13]. They were discovered in Gusev crater with Mars Exploratio Rover (MER) Spirit, at Meridiani Planum with MER Opportunity, and in Gale crater with the Curiosity rover. Because the current cold and dry climate of Mars preserves meteorites for longer timescales compared to Earth [14,15], and because landed missions favor deflationary surfaces where ancient bedrock is exposed, ongoing and future landed missions will likely discover more meteorites. The same types of meteorites fall to both Earth and Mars. Meteorites found on Mars therefore act as mineralogically, geochemically, and isotopically well-characterized standard probes inserted into and interacting with the martian environment. A community interested in studying these meteorites is evolving [16], and we provide an overview of what we have learned about the Red Planet from their investigation.

Identifying Meteorites on Mars: The meteorites found on Mars so far are mostly iron meteorites [1,3-7,9,10] but stony irons or achondrites [1,2] and ordinary chondrite candidates [8] have also been discovered. Large iron meteorites are easily identified visually, and smaller fragments can be reliably identified using spectral parameters in the visible and near-infrared [6,7]. Stony meteorites are visually indistinguishable from martian rocks and need to be identified on the basis of their mineralogical (e.g. presence of metallic Fe) or geochemical (e.g. high Ni content) composition.

Discussion: Meteorites on Mars help to constrain a variety of atmosphere-surface interactions. The ability of a meteorite to survive impact depends on its mass, atmospheric entry velocity and angle, and atmospheric density. Large iron meteorites discovered at Meridiani Planum and in Gale crater require atmospheric densities greater than at present and therefore constraint atmospheric evolution [17-20]. Clustering of unpaired meteorite fragments at certain areas in Gale crater suggest transport mechanism [7]. The time of fall of paired stony meteorites at Meridiani Planum was constrained by their erosional state and the ages of the surfaces they were found on. Iron oxidation states were then used to determine a chemical weathering rate for the Amazonian, which is 1 to 4 orders of magnitude slower than the slowest rates observed on Earth [15]. Patches of iron oxide coatings have been observed on iron meteorites at Meridiani Planum [1,3,21] but not in Gale crater. The formation of these coatings is recent and their removal ongoing [22], indicating differences between the current conditions at those landing sites. Chondritic meteorites are quickly colonized by microorganisms on Earth because they contain nutrient elements, chemical gradients for energy production, and are hygroscopic [23]. Similarly, they would provide microhabitats on the martian surface [23]. They have been shown to preserve microbial fossils and organic molecules [24]. Because they can preserve biosignatures, and these would be much easier to identify against the well-known backdrop of a chondrite composition compared to the less well-constrained starting composition of any martian sedimentary rock, a meteorite might thus be worth considering for sample return under specific conditions [25]. There are currently no plans to collect any meteorite for return with the ongoing Mars 2020 Perseverance rover. However, a regolith sample is among those planned for collection and subsequent return, and such a sample may contain micrometeorites with a significant degree of probability [26].

Conclusions: Meteorites on Mars have been discovered serendipitously so far, which has opened many questions. For example, most of the meteorites on Mars are irons whereas ordinary chondrites are by far the largest fraction of meteorites found on Earth. Is this the result of a sampling bias because iorn meteorites survive as larger masses and are easier to recognize? Or does this reflect a weathering bias, where chondrites even under current martian conditions weather much faster than irons? A more directed and systematic way of looking for and investigating meteorites on Mars is therefore a valuable approach to learn more about the Red Planet itself.

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