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When one planet is not enough: Making progress in geology using other planets as full scale experiments

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Quantitative models of surface processes are often used to decipher the geologic archive. These models are largely derived from observations of modern natural systems and experiments, and calibrated to reproduce the range of processes observed on Earth today. However, new data from planetary exploration missions often defy our Earth-centric understanding of surface processes. Furthermore, we argue that ancient Earth, especially before there was macroscopic life, was a very different planet and that in many respects, its study falls within the realm of planetary science. We thus propose that significant progress in the geosciences can be accomplished through the study of extraterrestrial geologic records. We illustrate this paradigm with two example geologic systems – eolian sand ripples and river meanders. First, we present recent observations of a type of eolian ripple that is ubiquitous on Mars today but is not identified on modern Earth. We discuss potential implications for our understanding of the Red Planet's atmospheric history, as well as the derivation of a new predictor for the size of current ripples forming on Earth's riverbeds. Second, we build on observations of martian river-meander deposits to challenge the state-of-the-art hypothesis that vegetation is required for river meanders to form, and propose a physics-based model that allows single-thread rivers to form within unvegetated clay-rich banks. The latter has significant implications for our understanding of river and floodplain processes before the rise of land plants, and may help shed light onto the pace of (bio)geochemical cycles in the Precambrian. From dunes on the hellish surface of Venus to methane streams on Titan, nitrogen glaciers on Pluto, and moving ripples on comets, planetary bodies of the Solar System offer a multitude of opportunities for discovery in the geosciences in the decades to come.