Experiments in Reduced Gravity Sediment Settling on Mars

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PREFACE

The final lines of this book were written on the first anniversary of the Mars Science Lab *Curiosity's* landing, 686 days on Earth or 666 sols on Mars. This year on Mars coincided with so far the most active part of our experiments on Martian surface processes. On August 6, 2012, our first reduced gravity flight for the *Mars Sedimentation Experiments* (**MarsSedEx**) was still about 3 months away and we had a very limited idea what to expect. At the day of the landing, the work I was doing was also very much down to Earth. After breakfast, I was anxiously watching CNN in a hotel in Ongwediva in northern Namibia where I was part of a team of researchers studying the livelihood of small-scale farmers. There we hoped to make a little contribution to both improving their crop yields as well as finding ways to use their land sustainably. This unquestionably more typical work for a geographer raises the question of how I ended up doing work on Mars and maybe even more importantly, why?

The answer to this question is straightforward: geography is driven to a large extent by curiosity and exploration of spaces, and for a trained geomorphologist, the surface of Mars offers a new world to explore. Having used experiments in much of my work, including the study of soil hydrology in northern Namibia, provided a tool for researching the Martian environment. Finally, understanding and studying Mars helps, in my mind, to learn about Earth. Taking an Environmental Systems Science perspective, one must always wonder why Mars is cold and dry now, but was once more habitable, and most importantly: why did Earth stay warm and wet for over three billion years and how stable this habitability actually is? Furthermore, in the context of studying and teaching, Mars also provides an opportunity to move outside the realm of conventional data collection and analysis, and therefore would allow students to be creative and think critically. If these reasons are not sufficient, the exciting scientific findings of the first year of the *Curiosity* mission (Life would have been possible!) and certainly the fascinating imagery of landscapes formed by the erosion of layers of sedimentary rocks might be an explanation in itself (at least to true geographers).

More immediately, the research on sedimentation on Mars was also driven by the question of how well the models we use on Earth to describe the processes that form these landscapes capture the effect of the different environmental conditions on our neighbor planet. A key driver in most models describing erosion, transport, and deposition of the eroded material is gravity. On Mars, it is reduced to 38% of the gravity we experience on Earth. As a consequence, for example, water flows much more slowly, achieving, in theory, a flow velocity of only 60% of the one it would achieve on Earth. The lower flow velocity reduces the kinetic energy of an identical mass of water moving downslope to, again in theory, approximately 33%. Apart from stretching the imagination, there are two drawbacks with these estimates: first, flowing water shapes the channel it is moving through, so calculations along the lines of "a given slope" or "a given stream channel" on Earth and Mars are not correct because there is a good chance that the relationship between form and process differs between the two planets. Second, most conventional models describing the relevant processes are highly empirical, i.e., based on observations made on Earth. The mathematical equations therefore often describe a process only within the boundary conditions of a terrestrial environment, raising questions about their applicability on Mars. From these considerations, which will be explained in more detail in Chapters 1 and 4 of this book, the question arose how sensitive the quality of the model output is to a change in gravity.

Discussions with colleagues on testing the quality of empirical models on flow hydraulics, erosion, and sediment movement quickly pointed toward an experimental approach onboard a reduced gravity plane. Experiments have a long tradition in geosciences and have also been used in planetary geomorphology. Some geomorphic research on mass movements had already been done on reduced gravity flights before, incidentally supporting our skepticism about semiempirical models. A cost analysis also showed that an experiment would be a more feasible way than numerical modeling based on first principles because the programming of a sophisticated computational fluid dynamics model takes a lot of time. Besides, wouldn't it be much better to actually see the sediment settling in reality than just on a computer screen?

The experimental approach chosen for this research reflects what experiments, and to a large extent, this book, are all about: measure something that cannot be calculated or monitored properly, or only with great effort.

Out of the range of processes that would be affected by gravity on Mars, settling velocity of sediment was selected because the results relate to many other processes and the way they are modeled. This is a further benefit of experiments: they can be designed to get a maximum number of answers, not hav"for".ing to submit to the constraints of the naturally occurring process domains. This book tries to illustrate the use and limits of experiments in geosciences. The reduced gravity conditions are both a stark contrast to Earth, enabling the identification of limits of existing models as well as the challenges of conducting a meaningful experiment on one of the recent and most exciting fields of geomorphic research: Mars.

Reporting ongoing research, some of the scientific results are preliminary and conclusions remain tentative. However, this serves the purpose of this book because the use of experiments is put into the larger context of Mars exploration. A further aim for setting a focus on experiments is to reach out to the wider geomorphic community, especially young researchers, and to share some conceptual thoughts on the purpose of experiments, their design, and the practical considerations that should be put into conducting them. This intention is reflected by the structure of this book. First, the need for experiments on Martian surface processes is explained, both from the perspective of current research questions as well as the quality of the models used to simulate these processes. A short overview of Mars follows to illustrate some of the major differences between Earth and Mars as well as our scientific interest. Moving toward experiments, the search for life on Mars is briefly presented, especially to document the cycle of scientific enquiry, swinging back and forth between observations, hypothesis, and the development and use of new research tools. Chapter 4 introduces sediment settling and the modeling of settling velocity as the main scientific theme of this book, followed by conceptual thoughts on experiments, the development of instruments for the measurement of settling velocity during reduced gravity flights of the MarsSedEx I and II missions. Chapters 7 and 8 give some practical advice on conducting the experiments themselves. Having young researchers in mind, the two chapters are also intended to introduce some critical thinking about preparing experiments in general. The following three chapters focus on the scientific outcome of the MarsSedEx I and II missions. The book concludes by putting the results of the missions in a preliminary perspective related to looking for traces of life on Mars and the further work that is required to improve our ability to model Martian surface processes properly.