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Editorial

Introduction to the special issue: Planetary geomorphology

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ABSTRACT

Planetary geomorphology is the study of extraterrestrial landscapes. In recognition of the promise for productive interaction between terrestrial and planetary geomorphologists, the 45th annual Binghamton Geomorphology Symposium (BGS) focused on Planetary Geomorphology. The aim of the symposium was to bring planetary and terrestrial geomorphologists together for symbiotic and synthetic interactions that would enrich both subdisciplines. In acknowledgment of the crucial role of terrestrial field work in planetary geomorphology and of the BGS tradition, the symposium began with a field trip to the Appalachian Mountains, followed by a dinner talk of recent results from the Mars Surface Laboratory. On Saturday and Sunday, the symposium was organized around major themes in planetary geomorphology, starting with the geomorphic processes that are most common in our Solar System—impact cratering, tectonism, volcanism—to set the stage for other geomorphic processes, including aeolian, fluvial, lacustrine, and glacial/polar. On Saturday evening, the banquet talk provided an historical overview of planetary geomorphology, including its roots in the terrestrial geosciences. The symposium concluded with a full-afternoon tutorial on planetary geomorphologic datasets. This special issue of Geomorphology consists of papers by invited authors from the 2014 BGS, and this introduction provides some context for these papers.

1. Introduction

Geomorphology, as its name implies, is the study (-logy, from λογος) of the forms (-morpho-, from μορφη) of the Earth (geo-, from γη). It is defined in the American Geological Institute glossary as "the science that treats the general configuration of the earth's surface," (Bates and Jackson, 1984). Discussion and depictions of terrestrial landscapes may be found throughout human history. Ancient Greek and Roman philosophers recorded their extensive discourses on natural landscape formation (see Chorley et al., 1964), and great artists over the ages have continuously shown us new views of landscapes. The stream meandering towards the viewer in the *Mona Lisa*, along with da Vinci's writings on the relationship between valleys and the rivers, is a well-known example. Geomorphology as a distinct scientific discipline may be dated to the late 19th and early 20th centuries, with the publications of the first conceptual models for landscape evolution, e.g., by William Morris Davis and Eduard Brückner (Kennedy, 2005).

The discipline of geomorphology has many subdisciplines. This variety is illustrated by a listing of the previous themes of Binghamton Geomorphology Symposia (Table 1). The oldest annual geomorphology meeting in North America, the Binghamton Geomorphology Symposium (BGS) has a decades-long history of generating new insights into terrestrial landscapes through in-depth discussion of new developments in geomorphology (Sawyer et al., 2014). As may be appropriate for a science about the surface of Earth, all of these subdisciplines previously highlighted at the BGS have focused on some aspect of terrestrial geomorphology. These aspects include traditional scientific fields (e.g., Fluvial Geomorphology in 1973, Glacial Geomorphology in 1974), theoretical geomorphology (e.g., Theories of Landform Development in 1975, Models in Geomorphology in 1983), and human interactions with geomorphic systems (e.g., Engineering Geomorphology in 1997, Dams and Geomorphology in 2002). This wide breadth of topics is natural to a discipline founded on observing the world around us. Thus, in some sense, geomorphology is the first geologic discipline: landscapes must be observed before being interpreted.

The primacy of geomorphology in the terrestrial realm is also true in the planetary realm. As celestial bodies become more than points of light through spacecraft exploration, a common first dataset returned from these spacecraft is images. Those celestial bodies with solid surfaces are commonly referred to as 'terrestrial bodies', even though they are clearly extraterrestrial. For solid surface bodies, this imaging dataset presents the geomorphology. Thus, whereas traditionally and etymologically, geomorphology is the analysis of the processes and resultant shapes of the landscapes of Earth, analysis of extraterrestrial landscapes is a substantial growth subdiscipline within the field of geomorphology.

The landscape morphology observed on other planets, however, is often very different than the landscapes of Earth. Sometimes, these differences are obvious, as in the case of the dense impact crater populations and preserved crater morphologies observed on other bodies compared to Earth, where impact craters are erased or modified by plate tectonic and atmospheric processes (Melosh, 1989; Barlow, 1990). Sometimes, these differences are more subtle, such as the difference in fluvial morphology between Earth and extraterrestrial settings (Mars Channel Working Group, 1983).

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Table 1
The topics of the Binghamton Geomorphology Symposia.

1.	**Environmental Geomorphology** D.R. Coates, 1970; Binghamton, NY
2.	**Quantitative Geomorphology** M. Morisawa, 1971; Binghamton, NY
3.	**Coastal Geomorphology** D.R. Coates, 1972; Binghamton, NY
4.	**Fluvial Geomorphology** M. Morisawa, 1973; Binghamton, NY
5.	**Glacial Geomorphology** D.R. Coates, 1974; Binghamton, NY
6.	**Theories of Landform Development** W.N. Melhorn & R.C. Flemal, 1975; Binghamton, NY
7.	**Geomorphology and Engineering** D.R. Coates, 1976; Binghamton, NY
8.	**Geomorphology in Arid Regions** D.O. Doehring, 1977; Binghamton, NY
9.	**Thresholds in Geomorphology** D.R. Coates & J.D. Vitek, 1978; Binghamton, NY
10.	**Adjustments of the Fluvial System** D.D. Rhodes & E.J. Williams, 1979; Binghamton, NY
11.	**Applied Geomorphology** R.G. Craig & J.L. Craft, 1980; Kent, OH
12.	**Space and Time in Geomorphology** C.E. Thorn, 1981, Urbana-Champaign, IL
13.	**Groundwater as a Geomorphic Agent** R.G. LaFleur, 1982; Troy, NY
14.	**Models in Geomorphology** M.J. Woldenberg, 1983; Buffalo, NY
15.	**Tectonic Geomorphology** M. Morisawa & J.T. Hack, 1984; Binghamton, NY
16.	**Hillslope Processes** A.D. Abrahams, 1985; Buffalo, NY
17.	**Aeolian Geomorphology** W.G. Nickling, 1986, Guelph, Ontario, Canada
18.	**Catastrophic Flooding** L. Mayer & D. Nash, 1987, Oxford, Ohio
19.	**History of Geomorphology** K.J.Tinkler, 1988, St. Catherines, Ontario
20.	**Appalachian Geomorphology** T.W. Gardner & W.D. Sevon, 1989, Carlisle, PA
21.	**Soils and Landscape Evolution** P.L.K. Knuepfer & L.D. McFadden, 1990; Binghamton, NY
22.	**Periglacial Geomorphology** J.C. Dixon & A.D. Abrahams, 1991, Buffalo, NY
23.	**Geomorphic Systems** J.D.Phillips & W.H. Renwick, 1992, Oxford, OH
24.	**Geomorphology: The Research Frontier and Beyond** J.D. Vitek & J.R. Giardino, 1993; Hamilton, Ontario
25.	**Geomorphology and Natural Hazards** M. Morisawa, 1994; Binghamton, NY
26.	**Biogeomorphology, Terrestrial & Freshwater Systems** C.R. Hupp, W.R. Osterkamp, & A.D. Howard, 1995, Charlottesville, VA
27.	**The Scientific Nature of Geomorphology** B.L. Rhoads & C.E. Thorn, 1996; Urbana-Champaign, IL
28.	**Changing the Face of the Earth: Engineering Geomorphology** J.R. Giardino, R.A. Marston & M. Morisawa, 1997; Bologna, Italy
29.	**Coastal Geomorphology** D.J. Sherman, P.A. Gares, 1998, Woods Hole, MA
30.	**Geomorphology in the Public Eye** P. Knuepfer & J.F. Petersen, 1999; Binghamton, NY
31.	**Modeling and Geomorphology** J.F. Shroder & M.P. Bishop, 2000, Binghamton, NY
32.	**Mountain Geomorphology—Integrating Earth Systems** D.R. Butler, S.J. Walsh, & G.P. Malanson, 2001; Chapel Hill, NC
33.	**Dams and Geomorphology** P.J. Beyer, 2002; Bloomsburg, PA
34.	**Ice Sheet Geomorphology** P.L.K. Knuepfer, J. Fleisher & D.R. Butler, 2003; Binghamton, NY
35.	**Weathering and Landscape Evolution** A.V. Turkington, J.D. Phillips, & S.W. Campbell, 2004; Lexington, KY
36.	**Geomorphology and Ecosystems** C.S. Renschler, M. Doyle, & M. Thoms, 2005; Buffalo, NY
37.	**The Human Role in Changing Fluvial Systems** W.A. Marcus & L.A. James, 2006; Columbia, SC
38.	**Complexity in Geomorphology** M.A. Fonstad & A.B. Murray, 2007; Durham, NC
39.	**Fluvial Deposits and Environmental History** P.F. Hudson, K.W. Butzer, & T.P. Beach, 2008; Austin, TX
40.	**Geomorphology & Vegetation: Interactions, Dependencies, & Loops** W.C. Hession, T.M. Wynn, J.C. Curran, & L.M. Resler, 2009; Blacksburg, VA
41.	**Geospatial Technologies & Geomorphological Mapping** L.A. James, M.P. Bishop, S.J. Walsh, 2010; Columbia, SC
42.	**Zoogeomorphology & Ecosystem Engineering** D.R. Butler & C.F. Sawyer, 2011, Mobile, AL
43.	**The Field Tradition in Geomorphology** C. A. Legleiter & R.A. Marston, 2012, Jackson Hole, WY
44.	**Coastal Geomorphology and Restoration** N. L. Jackson, K. F. Nordstrom, W. K. Smith and R. Feagin, 2013, Newark, NJ
45.	**Planetary Geomorphology** D. M. Burr & A. D. Howard, 2014, Knoxville, TN

In addition to differences in the landscapes, planetary geomorphology differs from traditional terrestrial geomorphology in its approach. Traditionally in terrestrial geomorphology, landscapes are encountered at small special scales, e.g., outcrop scales. Many local observations are then synthesized into a hypothesis for the entire landscape. In planetary geomorphology, a landscape is encountered first from above and at a large spatial scale. These remote observations are then synthesized into a hypothesis for the entire landscape, which is encountered later, if at all, at a small spatial scale by landers or rovers. Meteorite samples from some planetary bodies (e.g., Mars) provide a very small-scale sampling of a planetary landscape, but because tracing the meteorites back to its particular ejection location is unlikely, that planetary landscape is unknown.

The lack of tools for absolute age dating of planetary landscapes also contrasts with terrestrial geomorphic studies, where stratigraphy, radiocarbon, cosmogenic isotopes, and other techniques have revolutionized our understanding of sequencing, rates, and intensity of geomorphic processes. Age dating provided by crater counts on other planets and satellites gives information about age, but the low precision and accuracy of those ages can be crude by terrestrial standards (Doran et al., 2004). The traditional approach to terrestrial geomorphology has been rapidly changing, however. The advent of remotely sensed data of Earth from a variety of vehicles (e.g., airplanes, satellites) enables a first (or sometime the only) remote study of landscapes. This shift in perspective is illustrated by publication of the stunning images of landforms on Earth and other bodies viewed from space. Such remotely sensed data are now widely available, e.g., through Google Earth (http://www.google.com/earth/), the Earth explorer website (http://earthexplorer.usgs.gov/), websites hosted by the National Aeronautics and Space Administration (NASA), along with many commercial venues.

Thus, despite their differences, planetary geomorphology offers useful information to terrestrial geomorphology. It has a history of encountering landscapes remotely and so has resulted in development of tools and approaches for remote investigation. Hyperspectral datasets (including mineralogical and thermal inertia information) (e.g., Murchie et al., 2007) and gamma ray spectrometer data (e.g., Boynton et al., 2002) are more frequently used by planetary scientists to interpret surface and near-surface materials than is commonly done on Earth (in part because of vegetative cover). And planetary geomorphology presents new and distinctive landscapes that expand our thinking about planetary surfaces, including those of planet Earth and the processes that shape them. The discovery of fluvially-sculpted landscapes on Titan is a striking example of the universality of geomorphic principles, with dendritic valleys and slopes being created with a different fluid (methane) at a vastly different temperature on a different substrate (ice and possible organic compounds). At the same time,