JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, F02012, doi:10.1029/2007JF000872, 2008

Quantitative morphologic analysis of boulder shape and surface texture to infer environmental history: A case study of rock breakdown at the Ephrata Fan, Channeled Scabland, Washington

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Received 11 July 2007; revised 2 November 2007; accepted 1 February 2008; published 6 May 2008.

[1] Boulder morphology reflects both lithology and climate and is dictated by the combined effects of erosion, transport, and weathering. At present, morphologic information at the boulder scale is underutilized as a recorder of environmental processes, partly because of the lack of a systematic quantitative parameter set for reporting and comparing data sets. We develop such a parameter set, incorporating a range of measures of boulder form and surface texture. We use standard shape metrics measured in the field and fractal and morphometric classification methods borrowed from landscape analysis and applied to laser-scanned molds. The parameter set was pilot tested on three populations of basalt boulders with distinct breakdown histories in the Channeled Scabland, Washington: (1) basalt outcrop talus; (2) flood-transported boulders recently excavated from a quarry; and (3) flood-transported boulders, extensively weathered in situ on the Ephrata Fan surface. Size and shape data were found to distinguish between flood-transported and untransported boulders. Size and edge angles ($\sim$120°) of flood-transported boulders suggest removal by preferential fracturing along preexisting columnar joints, and curvature data indicate rounding relative to outcrop boulders. Surface textural data show that boulders which have been exposed at the surface are significantly rougher than those buried by fan sediments. Past signatures diagnostic of flood transport still persist on surface boulders, despite ongoing overprinting by processes in the present breakdown environment through roughening and fracturing in situ. Further use of this quantitative boulder parameter set at other terrestrial and planetary sites will aid in cataloging and understanding morphologic signatures of environmental processes.

Citation: Ehlmann, B. L., H. A. Viles, and M. C. Bourke (2008), Quantitative morphologic analysis of boulder shape and surface texture to infer environmental history: A case study of rock breakdown at the Ephrata Fan, Channeled Scabland, Washington, *J. Geophys. Res.*, *113*, F02012, doi:10.1029/2007JF000872.

1. Introduction

[2] Environmental processes leave morphological imprints on rock surfaces at scales from nm to km [*Viles*, 2001]. Many previous studies have used such imprints to infer environmental histories at sand grain [e.g., *Mahaney*, 2002] and landscape [e.g., *Lancaster*, 1995; *Evans and McClean*, 1995; *McClean and Evans*, 2000] scales, but the record provided by boulders has not been well explored. Previous work has tended to focus on size and sorting of boulder populations as evidence of process histories [e.g., *Noormets et al.*, 2002; *Williams*, 1983] or on boulder weathering rinds, hardness and lichen populations as geochronological tools [e.g., *Boelhouwers et al.*, 1999; *Sak et al.*, 2004; *Smith et al.*, 2005]. *Birkeland* [1999] provides a good review of the range of quantitative weathering rate data used in such studies. Boulder morphologies should also provide records of environmental processes, possibly over thousands to millions of years, if signatures in their shape and surface texture can be identified and interpreted. This work develops a comprehensive parameter set for quantifying boulder morphology (size, shape, and texture) and applies this in a pilot study to assess whether boulder populations with different known transport and weathering histories can be distinguished. Our parameter set has applications to planetary environmental histories as well as those on Earth. Landed planetary missions encounter predominantly float rocks, which have no obvious associated outcrop and frequently must rely on these for interpreting environmental history. Recent imaging by the Spirit rover on Mars [e.g., *Arvidson et al.*, 2006], for example, reveals diverse boulder morphologies which could be related to spectroscopic, microscopic and abrasion tool information on the degree and nature of rock breakdown.

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0148-0227/08/2007JF000872$09.00