Table 1. Summary of Methods Used in the Ephrata Boulder Study[a]

Breakdown Extent	Boulder Shape	Boulder Surface Texture
Number of fractures and detached blocks	*Axes length measurement*	Molding and laser scanning to generate surface digital elevation models (DEMs)
Percentage lichen cover estimation	Shape parameter calculation using *Sneed and Folk*'s [1958] sedimentological classification	Fractal analysis of roughness scaling behavior (*RMS height and deviation, H, breakpoints*)
Schmidt hammer rebound	Edge profiling to calculate *facet angle* and *radius of curvature ratio*	*Morphometric classification at multiple scales*
Thin section petrographic texture analysis		
Measurement of weathering rind depth		

[a]Italics indicate the measurement is part of the quantitative morphologic parameter set whose effectiveness was tested by this study.

between sites using the two-tailed t test; equal variances were not assumed.

3.1. Assessing the Extent of Rock Breakdown

[16] To verify that the extent and type of rock breakdown processes experienced by boulders at each site matched our expectations based on the overall geologic history of region, samples were collected for subsequent laboratory analysis and measurements made in the field. In the field fractures, lichen cover, and surface hardness were recorded as described below. Boulder surfaces were examined for fractures, whose number and length were recorded. Some fractures may have been obscured by lichen cover. Partially and completely detached pieces of the boulder were identified and measured. Percentage lichen cover across whole boulders and individual facets was estimated independently by two workers and an agreed figure recorded. A Schmidt rebound hammer was used to test surface mechanical strength. Measured rebound values are highly correlated with surface hardness which is in turn related to mechanical strength [*Day and Goudie*, 1977]. Ten hammer measurements were taken on each surface and values averaged. There are known limitations to the Schmidt hammer technique: rebound values are suspect on small, weak, fractured, or nonhomogenous rocks [*Dincer et al.*, 2004]. They also vary with moisture [*Sumner and Nel*, 2002] and are influenced by surface texture irregularities [*Williams and Robinson*, 1983; *McCarroll*, 1991]. In order to minimize errors from these factors we only sampled boulders with all axes >15 cm, pretreated the surfaces with carborundum, avoided heavily lichen-covered surfaces when possible and sampled under similar weather conditions.

[17] At least three samples were taken at each site for further laboratory analysis of the extent of weathering. Surfaces and cross sections of hand samples were examined with an optical microscope and thin sections were made, following impregnation in blue resin to minimize damage to potential weathering rinds and highlight porosity in the rock [*Curran et al.*, 2002; *Gordon and Dorn*, 2005]. These were then examined using a petrographic microscope for identification of constituent minerals and estimation of the depth of weathering.

3.2. Morphologic Statistics: Whole Boulder Size and Shape

[18] Photographs and field measurements were made in order to characterize boulder size, shape, and specific breakdown features. The principal boulder axes were measured, shape parameters calculated, and angularity and curvature of edges between facets recorded as described below.

[19] Long, intermediate, and short axes of the boulders were measured easily for outcrop and quarry samples where the entire boulder was visible. Some surface site boulders were partially buried by soil and grasses, and in such cases, soil was excavated on one side of the boulder until a trowel could undercut the boulder. Height to the undercut was measured. This may have resulted in underestimation of surface boulder heights, and measured values represent lower limits. For comparison of boulders to outcrop columns, photographs and column width measurements were taken every 5 m along the outcrop to characterize outcrop fracture patterns for comparison to boulder size.

[20] To assess boulder shape using standard sedimentological criteria, maximum projection sphericity (ψ), deviation from compactness (D), and the form factor (F) were calculated from axis measurements according to the respective formulae

$$\psi = \sqrt[3]{\frac{S^2}{LI}}, \tag{1}$$

$$D = \frac{S}{L}, \tag{2}$$

$$F = \frac{L - I}{L - S}, \tag{3}$$

where L, I, and S are the boulder's long, intermediate, and short axes [*Sneed and Folk*, 1958]. Values for these parameters range from 0 to 1. Maximum projection sphericity is defined as the ratio between the maximum projection area of a sphere with the same volume as the particle and the maximum projection area of the particle. Combined with the form factor and compactness, this allows form fields to be defined in which particles are compact, platy, bladed, or elongate (see section 3, Figure 8).

[21] To measure angularity and curvature of facet edges, a 40 cm carpenter's profile gauge was used to record a profile of boulder edges by pressing a row of pins, each 0.16 cm thick, against the meeting point of two facets. This was then traced to record the shape (Figure 3). Angle of the contact