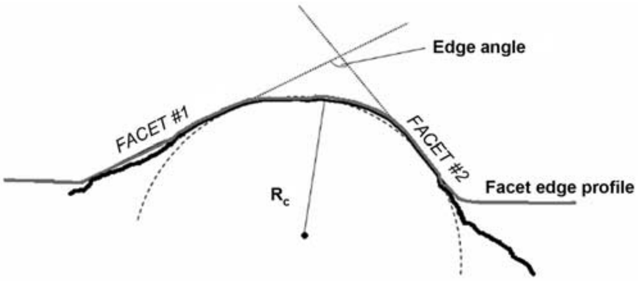

Figure 3. Profile of the edge at which two boulder facets meet (gray). Note that the gauge was not in contact with the surface at the beginning and end of the profile. The boulder outline is shown in black. The edge angle parameter is the interior angle at the intersection of two best fit lines to the facet faces. R_c denotes the radius of curvature and is the radius of the largest circle which can be inscribed in the facet edge.

and radius of curvature were calculated from best fits to the trace of the profile. This was done for three facet edges on each boulder. Radius of curvature values are reported as a ratio of R_c/R_a where R_c is the radius of the largest circle that can be inscribed within the natural curve of the boulder surface at the meeting point of the facet edges and R_a is the average radius of the boulder. Similar relative curvature measures have also been employed by *Durian et al.* [2006]. In this case, because of the uncertainty in height of surface boulders, we used only the other two axes in all cases to calculate R_a in the radius of curvature ratio. The curvature ratio will yield a value of 1 if the profile is taken from a sphere and 0 if taken from a perpendicular edge, e.g., from a cube, or other sharp edge such as that formed by two concave facets.

3.3. Morphological Statistics: Surface Texture Analysis

[22] In order to quantify surface texture a digital model from which boulder surface roughness and surface morphology could be analyzed quantitatively was required, however, boulders were too large for transport and laser scanning in the field was not possible. Use of molding and casting to capture detail of surfaces is a well-established method for recording archeological artifacts and sedimentary surfaces [e.g., *Dowman*, 1970; *Buffin-Bélanger et al.*, 2003] and a similar technique, using plaster of paris, was used here.

[23] At each field sampling site, 10 boulders with relatively horizontal facets of at least 15 × 15 cm were selected. This minimum size was necessary to ensure sufficient area for computing statistics for quantitative parameters measuring surface texture. The boulder surface was brushed clean and sprayed with an oil-based separator. Plaster of Paris was mixed and applied in a ~2 cm thick layer atop the boulder. After drying for approximately 30 min, the mold was removed. In the laboratory, whole molds were scanned at a minimum resolution of 0.4–0.7 mm point separation with a Konica Minolta VI-9i three-dimensional digitizer. A 10 × 10 cm subset of each mold was scanned at 0.2 mm resolution. Any losses in horizontal and vertical resolution of the impression of the surface induced by the casting technique were determined by scanning the surface of a control boulder in the laboratory, taking a mold, and then scanning the mold and the rock postmold. The boulder chosen was composed of sandstone but was similar in surface texture to the Ephrata basalt boulders. The control rock had a smooth, fine-grained surface, a portion of which was covered by lichen so we could assess its effects on the molding process.

[24] Prior to analysis, raw x, y, z point data from scanning were detrended, processed into raster format using a smooth quintic polynomial interpolation, and then inverted to reflect the topography of the original boulder surface rather than the mold. At the end of this preprocessing, a regularly spaced gridded array of boulder surface elevation values was obtained. Elevation was relative to a mean z value for the surface. With this digital elevation model of the surface, systematic investigation of surface texture via fractal analysis and morphometric classification could be performed.

3.3.1. Fractal Analysis of Roughness Scaling

[25] Fractal analysis considers the scaling behavior of topographic surface roughness. For this study, following the conventions argued for by *Shepard et al.* [2001], three fractal parameters were reported to characterize the surface roughness and roughness scaling of boulders: Root mean square (RMS) height, RMS deviation, and the Hurst exponent (H), including breakpoints in H. RMS height (ξ) is the standard deviation of heights above the mean for a given sample area according to the equation

$$\xi = \left(\frac{1}{n-1} \sum_{i=1}^{n} \left(z(x_i, y_i) - \bar{z} \right)^2 \right)^{1/2},$$

where n is the number of sample points in the area under consideration, $z(x_i, y_i)$ is the height of the surface at point (x_i, y_i), and $\bar{z}$ is the mean height of over all x, y. RMS height is calculated for the whole sample or over a selected window size. High RMS height values indicate rough surfaces, since points in a given sampling window show large deviation from the mean value.

[26] A similar measure, RMS deviation, reports the height difference between points separated by a lag or step Δd and is calculated

$$v(\Delta d) = \left(\frac{1}{n} \sum_{i=1}^{n} \left[z(x_i, y_i) - z(x_i + \Delta x, y_i + \Delta y) \right]^2 \right)^{1/2},$$

where n is the number of sample points in the sample, $z(x_i, y_i)$ is the height of the surface at point (x_i, y_i), and $z(x_i + \Delta x, y + \Delta y)$ is the height of the surface at a distance $\Delta d = \sqrt{\Delta x^2 + \Delta y^2}$ from (x_i, y_i). (RMS deviation is also sometimes reported as RMS slope $\theta(\Delta d) = \tan^{-1}(v(\Delta d)/\Delta d)$). High values correspond to greater roughness, i.e., adjacent points show steep elevation differences.

[27] Surface roughness as measured by RMS height and RMS slope varies as a function of scale [*Turcotte*, 1997], and for natural surfaces, the vertical scale, elevation, does not increase as quickly as the horizontal scale increases in size [*Shepard et al.*, 1995]. Instead the increase with scale follows a power law relationship whose slope, H, in a log-log plot relates to the surface roughness scaling. H, also known as the Hurst exponent, usually varies from 0 to 1.