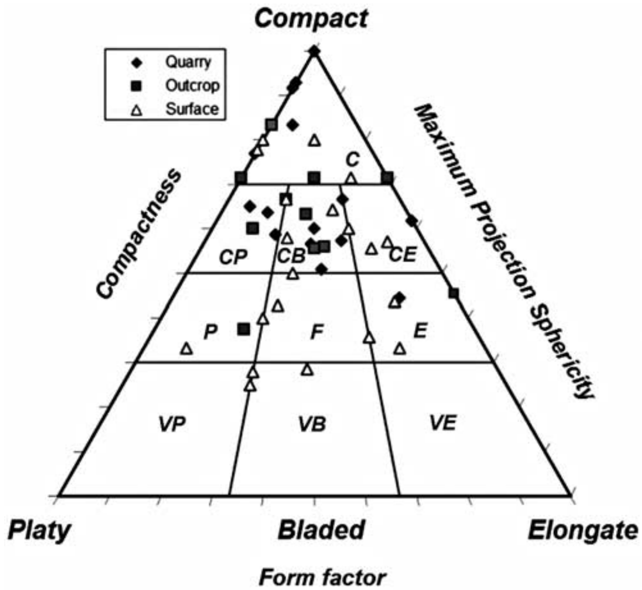

Figure 8. Channeled Scabland boulder data plotted on a *Sneed and Folk* [1958] particle shape diagram (C, compact; P, platy; B, bladed; E, elongate; V, very). Values for each parameter range from 0 to 1. Most boulders plot in the compact field and no site-to-site significant differences are apparent. Note that surface boulder data is likely affected by systematic underestimation of the short axis as discussed in the text (plot produced using the software of *Graham and Midgley* [2000]).

of the 200 μm scan resolution), molds will display less roughness, in absolute terms, than the corresponding actual rock surface. This behavior was characterized by computing and comparing roughness statistics at multiple scales for an actual rock surface, a mold of the surface, and the rock surface postcasting (Figure 10). Plotting a deviogram of step size versus change in height reveals that in absolute terms, the mold is 25% less rough than the actual rock surface. The rock itself, postmolding, was 16% less rough than the original surface. There is no scale dependency of reduction in roughness, i.e., RMS height and RMS deviation reduction is the same percentage when considering millimeter or centimeter scales. Thus, the Hurst exponent and breakpoint scale should not be affected in fractal analysis and relative roughness comparisons between the sites can be made.

[42] Results show that quarry boulders are the smoothest and surface boulders are the roughest. This is true regardless of the scale considered and whether the parameter used to measure roughness is RMS height or RMS slope (Table 4). Surface boulders and outcrop boulders have relatively similar roughness while quarry boulders are obviously different from both. Small sample size (10) and a high degree of variance mean most differences are not statistically significant, although the greater surface boulder RMS height versus that of the quarry is statistically significant at the $p < 0.05$ level for both scale sizes. RMS height plots did not show breakpoints (probably because only small scales were considered in order to have sufficient independent samples), though boulder RMS deviation deviograms exhibit breakpoints which differed between the sites (Table 5, Figure 11). Outcrop boulder deviograms had breakpoints over 50% of the time and on two exhibited more than one breakpoint. Quarry boulders had fewer breakpoints although these occurred at roughly the same point as for outcrop boulders, $\sim$3–5 mm. Only one surface boulder had a breakpoint in roughness scaling (at 1.3 cm).

[43] Hurst exponents, H, are between 0.76 and 0.82 for RMS height and RMS deviation (Table 5). In those boulders with breakpoints, the Hurst exponent ($H2$) was lower at $\sim$0.65. For both RMS height and RMS deviation, quarry boulders had the highest Hurst exponent ($H1$) and outcrop boulders the least, although such small differences fall within the margin of error.

[44] In percent area of morphometric classes, at most scales and for most classes, there were no significant differences ($p < 0.05$) between sites (Table 6, Figure 12). A few exceptions apply, however. At the smallest scale, a window 3 $\times$ 3 pixels corresponding to $\sim$1.5 mm, many significant differences existed between quarry and outcrop boulders and quarry and surface boulders. On average, quarry boulders had more planar classes (64%) than outcrop (52%) or surface (45%) boulders. Surface boulders had more channel features (22%) and ridge features (25%) than the quarry boulders (17% and 17%). Outcrop boulders had more point features (pit, peak, and pass were 1.1%, 1.1%, and 3.5%, respectively), than the quarry boulders (0.5%, 0.5%, 1.5%).

[45] At larger scales, statistically significant differences are fewer. At 1 cm, outcrop boulders had slightly more pits (1.9%) than surface boulders (1.0%). Surface boulders again had more channel features (28%) than quarry boulders (22%). At the 3 cm scale, outcrop boulders had more pass features (10%) than surface boulders (4.4%) (Table 6, Figure 12). At both 3 and 5 cm scales, quarry boulders had more ridges (28% for both scales) than outcrop boulders (18% and 15%).

[46] Variation in class abundance versus scale was also examined to see whether site-specific differences exist (Figure 12). As scale increases, marked differences in percent abundance of features at a single site or differences in rank ordering of sites occasionally occur. For example, while quarry boulders have the fewest pits at the 1.5 mm scale, they have the greatest number of pits at the 5 cm scale. The number of ridge features drops sharply with scale for outcrop boulders while increasing with scale for surface and quarry boulders. The number of pass features on outcrop boulders increases with scale as well.

5. Discussion

[47] Observations and measurements of weathering extent were consistent with the inferred history of the boulders at the 3 sites. The assumption that quarry boulders are relatively ‘‘pristine’’ examples of flood-transported debris appears valid. Quarry boulders have characteristic features of flood transport and significantly higher Schmidt hammer rebound values than the other boulders. In thin section, quarry boulders show no signs of chemical alteration, or weathering of the outer mineral grains.

[48] In contrast, boulders at the surface of the Ephrata Fan show signs of extensive breakdown and alteration. The large number of detached rock fragments composing surface