



**Figure 7.** Petrographic thin sections from (a) a quarry boulder, (b) an outcrop boulder, and (c) a surface boulder with lichen cover. At the grain scale the surface interface of the blue resin with the quarry boulder is smooth while the jagged interface on the outcrop boulder may result from granular disintegration. For the surface boulder, resin penetrates into fractures beneath lichen and oxidation of iron-bearing minerals is evident.

the different sites. Volumetrically, boulders in the quarry ( $0.25 \pm 0.18 \text{ m}^3$ ) are larger than those on the surface ( $0.16 \pm 0.17 \text{ m}^3$ ) which in turn are significantly larger than those from outcrop talus slopes ( $0.04 \pm 0.03 \text{ m}^3$ ). However, volumetric differences between the quarry and surface are likely due to measurement technique, i.e., underestimation of buried surface boulder height due to insufficient excavation when taking measurements. When only the boulder long axis is considered, differences between the quarry and surface boulders are negligible, with long axes of  $79 \pm 26$  and  $81 \pm 44$  cm, respectively (Table 3). This is comparable to the average measured width of basalt columns at the outcrop site,  $74 \pm 57$  cm. Average outcrop boulder long axis is  $40.5 \pm 11$  cm, significantly different from the other two locations and from the columns ( $p < 0.01$ ).

[37] Average sphericity of boulders ranged from 0.7 to 0.9. Compactness was 0.5–0.7 and form factor 0.35–0.5. Boulders at all sites are generally compact to subcompact (Table 3, Figure 8). For shape parameters, the only significant difference in boulders at the three sites was in sphericity and compactness of the surface boulders relative to the quarry boulders; however, this is likely to be an effect of systematic underestimation of surface boulder height due to their partial burial.

[38] For the quarry boulders, the average angle at which facets met was  $115^\circ \pm 12^\circ$ . Average angles for surface and outcrop boulders were  $109^\circ \pm 15^\circ$  and  $102^\circ \pm 11^\circ$ , respectively (Figure 9, Table 3). Surface and quarry samples were

not statistically different; however, outcrop boulders were significantly different from both. Surface sample mean is shifted to smaller angles by a tail of low values (Figure 9a).

[39] Differences in the radius of curvature ratio were not statistically significant between quarry ( $0.13 \pm 0.06$ ) and surface ( $0.14 \pm 0.11$ ) boulders (Table 3, Figure 9b). There are obvious and significant differences in curvature between the flood-transported boulders and outcrop talus ( $0.02 \pm 0.02$  cm). Surface boulders have a greater range in values, nearly spanning the range found on boulders at the other two sites.

#### 4.3. Morphological Statistics: Surface Texture Analysis

[40] Horizontal resolution of the molding technique is  $\sim 1:1$ , however, vertical resolution of the molding technique for whole surface samples is no more than  $500 \mu\text{m}$  as determined by scanning test rock surfaces and molds of the same area and comparing profiles of the resultant digitized surfaces (Figure 10). Reproductions of the original rock surface are high fidelity for clean, smoothly curving areas. However, in areas with lichen coverage, plaster tended to stick to the rock or to the lichen. In these isolated patches, discrepancies between rock surface and mold may exceed 2 mm. Fortunately, for most molded surfaces, lichen covered less than 10% of the surface area so their overall impact is minimal.

[41] Because of a loss in vertical resolution in the plaster surface model relative to the original rock ( $500 \mu\text{m}$  instead

**Table 3.** Boulder Form Statistics

	<i>N</i> Sampled	Long Axis, cm	Sphericity	Deviation From Compact	Form Factor	Radius of Curvature Ratio	Facet Edge Angle, °
Quarry boulders (Q)	25	$78.5 \pm 25.6$	$0.82 \pm 0.09$	$0.68 \pm 0.17$	$0.37 \pm 0.31$	$0.13 \pm 0.06$	$115 \pm 12$
Surface boulders (S)	46	$80.6 \pm 44.4$	$0.69 \pm 0.14^b$	$0.51 \pm 0.18^b$	$0.47 \pm 0.25^b$	$0.14 \pm 0.11$	$109 \pm 15$
Outcrop boulders (O)	11	$40.5 \pm 10.9$	$0.77 \pm 0.09$	$0.62 \pm 0.13$	$0.44 \pm 0.34$	$0.02 \pm 0.02$	$102 \pm 11$
Outcrop columns (C)	24	$74.2 \pm 56.8$	–	–	–	–	–
Significant differences <sup>a</sup>		O-S, O-Q, O-C	b	b	b	O-S, O-Q	O-S, O-Q

<sup>a</sup>Comparisons were made using a two-tailed t test, without assumed equal variances. Significant differences are reported when  $p > 0.05$ .

<sup>b</sup>Systematic underestimation of surface boulder short axes biases these parameters. No significant differences were found between the quarry and outcrop boulders.