Characterizing Crystalline Volcanic Rock (CVR) Deposits from Galiano Island, B.C., Canada: Implications for Lithic Material Procurement at the Dionisio Point Locality

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ABSTRACT

We define the elemental signatures of crystalline volcanic rock (CVR) found within the Dionisio Point archaeological locality on Galiano Island in coastal southwestern British Columbia. CVR is the dominant toolstone found in archaeological assemblages at Dionisio Point and many other sites in the region. The quality of these materials for chipped stone tool manufacture and use is dependent in part on the silica content, which is highly variable. Basalt is considered a poor quality toolstone due to its low silica content of 45-55%, while andesite, dacite, and rhyolite are considered higher quality materials with silica content above 55%. Elemental composition analyses were performed using WDXRF in the WSU Geoanalytical Lab to determine whether local secondary CVR deposits had high silica content. Results show that low and high quality CVR cobbles were locally available to the precontact communities of the Dionisio Point locality, with basalt being the most abundant.

1. INTRODUCTION

The pre-contact Coast Salish of the Salish Sea region of northwest Washington and southwest British Columbia have long held significance in literature theorizing sedentary foragers and small-scale complex societies (e.g., Ames, 1994, 1995, 2010; Angelbeck and Grier 2012; Kim and Grier, 2006; Grier 2014; Moss, 2011) (Figure 1). However, limited attention has been directed toward examining practices such as the acquisition and consumption of toolstone. This is partly due to the widespread use of bone, antler, and shell for tool manufacture, and their widespread preservation in the archaeological record (Stein, 1992; Stewart, 1996). However, formal and expedient chipped stone lithic technologies remained in use for a wide range of activities including hunting (terrestrial and marine), fishing, plant processing, and woodworking (Ames, 2009; Kornbacher, 1989; Stewart, 1996), and provide an important window into the organizational complexity of these practices.

The materials primarily utilized for chipped stone technologies in the Salish Sea have been referred to as basalts (Bakewell, 1996, 2005; Kornbacher, 1989, 1992; Kwarsick, 2010; Morgan, 1999; Wessen, 1993), crystalline volcanic rock (CVR) (Close, 2006), and fine-grained volcanic rock (FGV) (Taylor, 2012). All of these labels refer to the same general class of igneous materials and will be referred to as crystalline volcanic rock (CVR) in this study. As specific types of CVR such as basalts and dacites typically cannot be distinguished without elemental analyses, variation in the quality of these toolstones has been underexplored in the Northwest Coast literature.

Figure 1 The location of the Dionisio Point locality and referenced lithic sources in the Salish Sea.

The quality of CVR has been argued to be poor, which some suggest is why ground stone (slate, schist), bone, and antler technologies were so widely utilized (Ames, 2009; Graesch, 2007). Compared to obsidian or chert, CVR is more difficult to initially reduce, but it does keep a better edge and requires less retouch during use (Terry et al., 2009: 265; William Andrefsky Jr., personal communication, 2013). Despite the apparent diversification of materials used for tools manufacture through time (Ames, 2009), throughout the Holocene chipped stone technologies formed a key part of the tool kit and lifeways of the Coast Salish. Some have suggested that individuals traveled considerable distances to acquire higher quality CVR (Bakewell, 2005; Close, 2006).

Sourcing studies have been employed to examine questions of regional exchange in the Salish Sea (Bakewell, 2005; Close, 2006; Kwarsick, 2010; Morgan et al., 1999; Reimer, 2011; Sobel, 2006; Taylor, 2012). Here we target the study of one major precontact village location, Dionisio Point, to consider tool acquisition strategies from the vantage point of an intensive habitation location with a large resource catchment zone (Grier 2003). We characterize the composition of locally available toolstone, lithic debitage, and formed chipped stone tools from this village locality to provide a focused study with regional implications, and which furthers our understanding of the organizational complexity of lithic procurement on the Northwest Coast.

To that end, we have sampled and characterized toolstone collected from beaches within the Dionisio Point locality and debitage and formed tools recovered from DgRv-6, a Late Period plankhouse and associated shell midden next to the beaches. The two questions we address are: 1) was there high quality toolstone available within the Dionisio Point Locality? and 2) is there evidence of selection for higher quality materials? If both are the case, long distance toolstone acquisition is unnecessary.

We begin this paper with a brief regional background and a review of past toolstone procurement studies in the Salish Sea, then provide a brief discussion of the Dionisio Point locality and its context in Coast Salish archaeology. Following this we discuss our sampling strategy for natural (beach and glacial till-derived) cobbles and cultural (debitage and formed tools) lithic materials at Dionisio Point. We then present the results of our Wavelength Dispersive X-ray Fluorescence Analysis (WDXRF) analysis. We conclude that high quality toolstones were readily available in secondary glacial till deposits at the Dionisio Point locality, and that there is evidence for the selection of higher quality toolstone. Finally, we discuss trace elements that can be used to distinguish between low and high quality CVR toolstones using non-destructive XRF analyses in future studies.

1.1 Study Area

The focus of our study is the Dionisio Point locality in the southern Gulf Islands of coastal British Columbia. The

southern Gulf Islands are located in the archaeologically-important Salish Sea region of the Northwest Coast culture area (Figure 1). In terms of its natural, ethnographic and archaeological characteristics, the Salish Sea is a unique and distinct region of the Northwest Coast (Mitchell, 1971a).

At contact with Europeans, the southern Gulf Islands were inhabited by Hul'q'umi'num and Straits-speaking Coast Salish peoples. These First Nations were complex hunter-gatherer-fishers that lived in seasonally permanent villages. Their economies emphasized salmon procurement and storage but also gathered a wide range of marine and terrestrial resources (Bilton, 2014; Duer and Turner, 2005; Grier, 2006, 2014; McKechnie, 2014; see papers in Moss, 2011). While centered on the southern Gulf Islands and southeastern Vancouver Island, they maintained close historical ties with other Coast Salish speaking communities on the Fraser River and elsewhere (Grier, 2003; Mitchell, 1971a). Resources documented at the Dionisio Point locality were acquired from throughout the Salish Sea (Grier 2001, 2003).

This study focuses on the last 1500 years of Coast Salish prehistory, which includes the Marpole Period (2400-1000 BP) and Late Period (1000 BP- Contact). Marpole lifeways have received significant attention in the literature, as it is the first period on the southern BC coast with substantial large cedar plankhouse villages (Burley, 1980; Matson and Coupland, 1994; Thom, 1995). Archaeologists have long hypothesized significant connections between the development of large houses and villages on the Northwest Coast and the emergence of new forms of social inequality and, germane to our current study, formalized regional interaction networks (Ames, 1995: 181; Ames and Maschner, 1999; Beattie, 1981; Burley, 1980; Burley and Knusel, 1989; Lepofsky et al., 2009; Moss, 2011; Schaepe, 2009).

Importantly, the Marpole and subsequent Late Period are characterized by formalized regional exchange networks of lithic materials, both raw and finished (Grier, 2003). Exotic toolstone (e.g., nephrite, obsidian) moving over large distances has been interpreted as reflecting prestige exchange among elites and, more broadly, that exotic toolstone

was a highly valued commodity. This has, as we discuss below, influenced how CVR distributions have been viewed. In this study, we provide an alternative to regional procurement hypotheses for CVR toolstone, arguing that, despite evidence for trade in exotic materials, locally available toolstone can account for the materials observed in archaeological assemblages from the Dionisio Point locality.

1.2 Toolstone Procurement Studies in the Salish Sea

Considerable debate has emerged regarding the locations where tool stone was procured in the Salish Sea region (Bakewell, 2005; Close, 2006; Kwarsick, 2010; Morgan, 1999; Reimer, 2011; Sobel, 2006; Taylor, 2012; Taylor and Skinner, 2010). Studies of Northwest Coast toolstone have emphasized obsidian sourcing (Carlson, 1994; Reimer, 2011; Sobel, 2006) and nephrite (Darwent, 1996; Morin, 2012), both of which have wide distributions derived from limited and localized sources. Toolstone obsidian recovered from archaeological sites in the Salish Sea predominantly comes from Mt. Garibaldi, and two sources on the central coast (Kingcome Glacier [Central Coast A] and Central Coast B) (Carlson, 1994; Reimer, 2011; Rorabaugh and McNabb, 2014; Skinner, 2009). Nephrite found throughout the Salish Sea comes from interior areas up the Fraser River several hundred kilometers inland. Given their wide distribution, these materials have been used primarily to examine the emergence of long distance exchange systems.

Despite the emphasis on obsidian and nephrite studies, CVR was a key resource for the manufacture of lithic technologies for pre-contact Coast Salish communities. Several studies exploring its sources and distribution have appeared (e.g., Bakewell, 2005; Kwarsick, 2010; Taylor, 2012; Taylor and Skinner, 2010). CVR, which include basalt, andesite, dacite, and rhyolite, comprise the majority of toolstone seen in many archaeological assemblages. A key aspect of the suitability of these materials for tool manufacture and use is their silica content, which is highly variable. Basalt is considered a poor quality toolstone due to its silica content of 45-55%, while andesite, dacite, and rhyolite are considered higher quality materials with silica contents above 55% (Le Maitre et al., 2002).

Some of the highest quality CVR used in the Salish Sea has been identified as dacite from the Watts Point source in the Coast Range of British Columbia (Figure 1). Petrographic and elemental sourcing of Watts Point dacite has led to far reaching conclusions regarding toolstone procurement, with Bakewell (2005), Stein (2000), and Close (2006) proposing that dacite cobbles were procured directly from Watts Point in British Columbia and transported by canoe throughout the region. Recent analyses suggest that although Watts Point materials were widely distributed in the Salish Sea, this is likely the result of glacial movement and not human transport (Kwarsick, 2010; Taylor, 2012). CVRs may have been primarily collected from local contexts, as argued in a recent study by Taylor (2012) on San Juan Island. Several researchers have also noted CVR suitable for toolstone is present in local secondary beach deposits near archaeological sites (Conca, 2000; Herbel et al., 2001; Kenady et al., 1973; King, 1950; Kornbacher, 1992; Schalk, 1988; Wessen, 1993). If dacite is readily available from local secondary deposits, high quality CVRs may not serve as a strong indicator of regional exchange, as argued by Close (2006).

1.3 The Dionisio Point Locality

The Dionisio Point locality is situated on the northern tip of Galiano Island in the southern Gulf Island group. Galiano Island is part of the sedimentary formations of the Nanaimo Group, which consists of alternating beds of conglomerates, sandstones, and shale that date to the Upper Cretaceous (Green et al., 1989). Like several other of the southern Gulf Islands, Galiano Island is long and narrow, and reflects the northwest-southeast aspect of its underlying sedimentary rock (Johnstone, 2006). The sandstone and shale substrate is the parent material for most of the regolith, and served as toolstone for the local ground stone industry (Grier, 2001).

Volcanic rock is absent, except in sediments that contain transported material. The sediments of Galiano Island are the result of the Fraser Glaciation. Melting and retreating glaciers deposited glacial tills, which have been eroded, reworked and redeposited over the Holocene. These glacial tills form the parent materials for Gulf Island soils (Eis and Craigdallie, 1980; Green et al., 1989). Cobbles contained in these glacial deposits are present in modern beaches and in erosion exposures. Whether these cobbles were used for toolstone in the chipped stone industry is the focus of

our study.

Post glacial sea level change in the southern Gulf Islands was more gradual than punctuated. Following rapid changes in the late Pleistocene and early Holocene, over the past 5,000 years sea levels have risen between 0.8-1.5m (Grier et al., 2009; Clague et al., 1982; Clague and James, 2002; Fedje et al., 2009; Mitchell, 1971b). Overall the environment at the Dionisio Point locality during its prehistoric occupation appears to be broadly similar to that of recent times (Grier, 2001).

Archaeologically, the Dionisio Point locality includes two major sites: the Dionisio Point site (DgRv-3), a Marpole Period Coast Salish village occupied between 1500 and 1300 cal BP (Grier, 2001, 2006) and DgRv-6, a Late Period plank house and associated midden inhabited from 1000 to 600 cal BP (Grier and McLay, 2007). DgRv-6 also contains a Marpole Period midden component along the shores of Parry Lagoon (Figure 2).

The earliest excavations at the Dionisio Point locality were by Mitchell at the Dionisio Point site (DgRv-3) in 1964 as part of his analysis of the Gulf of Georgia regional sequence (Mitchell, 1971a). Mitchell's excavations included several test units, and analyses emphasized the lithic assemblage (1971b). The site was revisited during 1997 and 1998 for the Dionisio Point Household Archaeology Project (DPHAP) by Grier (2001, 2003, 2006). These excavations yielded a relatively large artifact and faunal assemblage. Since then, additional excavations have occurred at the DgRv-3 village and the Late Period structure (House 1) and adjacent Parry Lagoon midden at DgRv-6. These projects, completed over a span of more than 50 years, have documented two important, substantial and well-preserved village occupations that extended over a millennia (Grier 2014). As such, Dionisio Point provides an ideal archaeological locality

for examining regional and local patterns of exchange and resource acquisition.

Figure 2 Parry's Lagoon natural control sampling locations. Note samples were collected at low tide, image shows high tide. (Base image from Google Earth).

3. MATERIALS AND METHODS

Lithic materials recovered from the house deposits and Parry Lagoon midden at DgRv-6 form the cultural samples in this study (DGRV6), along with several lithic artifacts surface collected from the beaches along Coon Bay and Parry Lagoon (DBF). Natural samples were collected from the beach surface (BEA) and a wave cut bank (WCB) at Parry Lagoon. Samples were assigned to three groups for comparison: natural controls (BEA, WCB), beach finds (DBF), and materials from the excavations at DgRv-6 (DGRV6).

3.1 Natural Sample Sets

During the 2010 field season, surface cobbles were selected from a total of six 5 x 5 m grids (Analytic Units 1-6) spaced 20 m apart to cover the extent of the northwest portion of Parry Lagoon, which had the highest concentration of surface cobbles (Figure 2). GPS coordinates were obtained for the southwest corner of each grid so that each grid could be re-located. Within each 5x5 m grid, all cobbles greater than 15 cm in diameter with flat cortical surfaces that could potentially be used as platforms for hard hammer percussion were examined (Figure 3). A sample of cobbles from the lower (glacial) deposits of the wave cut bank west of the beach surface was also collected (Glacial Units 1-3). Only cobbles on the exposed surface of the glacial till deposits of the wave cut bank were taken to minimize contributing to the erosion of the bank. The same criteria used to select the surface cobbles were also used to select materials from glacial till. Cobbles from glacial till were marked and placed in a separate large sample bag. In total 193 cobbles fit the initial collection criteria.

Figure 3 Cobble selection criteria flow chart.

After the initial cobble selection process, cobbles were evaluated on several criteria that have been noted as affecting toolstone quality, include fracture mechanics, grain, shape and size (e.g., Crabtree, 1972; Doelman, et al. 2008; Rorabaugh and McNabb, 2014; Whittaker, 1994; Wilson, 2007). This ensured our analyzed sample included materials that were more likely to have been selected for lithic reduction by the communities at the Dionisio Point locality. 25.3% (N=49) of all examined cobbles of sufficient size (>15cm diameter) met these criteria and were analyzed.

Cobbles were tested using hard hammer percussion with a local quartzite cobblestone. Cobbles that did not flake

when using the hammer stone were removed from the sample. As cobble cortex is a poor indicator of material quality, the exposed interior of each cobble was examined for whether or not it was macroscopically fine grained and for the absence of major inclusions that would negatively impact conchoidal fracture. All debitage from testing and tested cobbles were collected to prevent these tests from contributing to the “archaeological” record of the area. Cobbles not selected for analysis were placed in the backfill of the excavation units at DgRv-6.

3.2 Cultural Sample Sets

Cultural sample sets were collected from three different contexts: (1) the Coon Bay and Parry Lagoon beaches, (2) the DgRv-6 structure, and (3) the DgRv-6 midden along the Parry Lagoon shoreline. The cultural sample from the beaches consists of isolated lithic artifacts (N=7) randomly encountered and collected during the 2009 to 2011 field seasons. These artifacts had likely eroded out of site contexts from various areas of the tombolo and beaches on the Parry Lagoon and Coon Bay sides. These artifacts include reduced cores, utilized flakes, and bifaces. Debitage selected from the DgRv-6 house structure and midden for analysis was recovered during excavations at DgRv-6 in 2010 and 2012.

Debitage for analysis were selected using criteria from Sullivan and Rozen's (1985) typological approach. Lithic debris over 10 g in mass but where no single interior surface or point of applied force was discernible were selected for destructive analysis to minimize potential data loss for future debitage analyses. In total, 16 pieces of debitage from the house structure and midden met these criteria, and well represent the house and midden both spatially and temporally.

3.3 Methods

We employed Wave Dispersive X-Ray Fluorescence (WDXRF), despite its destructive nature, to overcome the analytical constraints in detecting light elements with nondestructive field methods, such as portable X-Ray

Fluorescence (pXRF) (e.g. Conrey et al., 2014). Identification of crystalline volcanic rocks is based on SiO₂ content, which is a compound too light to be detected reliably by pXRF. Samples were prepared for analysis by double-fusion homogenization (Johnson et al., 1999) in the Peter Hooper Geoanalytical Lab, Washington State University. Larger samples were reduced to 100-150 g using a hydraulic press to break the CVR cobbles into smaller pieces, samples were chipped and then ground in a tungsten carbide swing mill to prepare a homogeneous powder. Ground samples were prepared in a 2:1 ratio from 2 g sample and 4 g spec pure dilithium tetraborate (flux). The sample/flux mixture was then loaded into graphite crucibles and fused for 10 minutes at 1000° C. Cooled samples were reground, re-fused, and polished before analysis. We determined total carbon by loss-on-ignition (Ball, 1964; Heiri et al., 2001) to corroborate instrument calculations of carbon loss used to normalize major and trace elements.

WDXRF analyses were performed on a ThermoARL Advant'XP + sequential x-ray fluorescence spectrometer for 28 elements and compounds: major elements and compounds SiO₂, TiO₂, Al₂O₃, FeO (total Fe as FeO), MnO, MgO, Na₂O, K₂O, CaO and P₂O₅ and trace elements Ni, Cr, Sc, V, Ba, Rb, Sr, Zr, Y, Nb, Ga, Cu, Zn, Pb, La, Ce, Th, and Nd. Instrument performance was regularly assessed with drift monitors and 105 international certified reference materials. Replicates were analyzed every 20 samples. Limits of determination (LOD), with uncertainties expressed as 2-sigma limits, and are available from the Peter Hooper GeoAnalytical Lab at the web address (<http://www.sees.wsu.edu/Geolab/note/xrfprecision.html>). All elements used for this analysis fall within the limits of detection outlined by the lab.

4. RESULTS

All analyzed major (Table 1) and minor (Table 2) elements and compounds were present at concentrations above the analytical uncertainties determined by our instrument in each sample. Samples were identified as basalt, andesite, dacite, or rhyolite based on the silica content (Table 3) and total alkali and silica (Figure 4). Although the TAS classification includes some finer material identifications (Picrebasalt, Basanite/Tephrite, Tachybasalt, Trachyandesite, Trachyte) we emphasize the classification based on SiO₂ to remain consistent with the terminology and classifications used other researchers working in the region. Samples classified as having low SiO₂ content

(basalts) have 55% or less SiO₂. High SiO₂ samples (andesite, dacite, and rhyolite) have a SiO₂ content above 55%.

Sample	Major Elements (Wt. %)								
	SiO ₂	TiO ₂	Al ₂ O ₄	FeO*	MnO	MgO	CaO	Na ₂ O	K ₂ O
BEA1	49.42	1.927	14.34	12.44	0.240	7.08	11.30	2.72	0.36
BEA2	49.40	1.949	15.07	12.02	0.213	7.40	10.64	2.89	0.25
BEA3	69.29	0.434	16.63	2.30	0.023	1.19	2.20	5.02	2.78
BEA4	50.04	1.922	16.97	12.26	0.263	4.95	8.79	3.33	0.93
BEA5	49.68	2.060	13.19	14.16	0.190	7.26	8.97	4.00	0.32
BEA6	53.51	0.541	15.63	7.28	0.152	8.26	10.82	3.01	0.72
BEA7	58.69	0.907	18.69	8.14	0.116	3.32	5.43	2.39	2.10
BEA8	50.70	1.722	15.66	10.76	0.174	7.24	9.36	3.60	0.62
BEA9	49.89	1.904	14.25	12.51	0.228	6.58	12.31	2.00	0.16
BEA10	50.77	1.767	15.39	10.78	0.192	7.29	9.59	3.85	0.24
BEA11	70.01	0.725	14.72	6.22	0.071	3.19	0.79	1.46	2.71
BEA12	53.29	1.633	13.74	10.05	0.210	7.18	9.28	4.15	0.31
BEA13	68.33	0.825	15.05	6.19	0.063	2.55	1.51	2.39	2.99
BEA14	54.06	1.101	16.99	9.98	0.186	6.50	8.60	2.05	0.37
BEA15	50.32	1.465	14.91	10.83	0.182	7.80	11.33	2.91	0.14
BEA16	49.88	1.968	14.44	13.07	0.219	6.01	11.30	2.73	0.17
BEA17	49.87	1.484	15.97	10.86	0.196	7.44	11.23	2.62	0.18
BEA18	49.85	1.461	14.35	11.94	0.192	7.54	12.52	1.84	0.19
BEA19	45.09	2.358	15.11	14.73	0.235	7.03	14.05	0.97	0.21
BEA20	49.11	1.648	15.04	11.36	0.201	7.68	12.40	2.26	0.16
WCB1	49.85	1.783	14.20	12.29	0.201	7.01	12.55	1.77	0.20
WCB2	48.03	1.823	14.57	12.28	0.186	8.43	11.60	2.79	0.13
WCB3	50.30	1.707	14.03	11.49	0.189	7.21	12.92	1.90	0.12
WCB4	50.05	1.452	15.11	11.10	0.180	7.79	11.01	3.00	0.18
WCB5	50.02	1.407	14.31	11.50	0.188	7.60	11.47	2.94	0.45
WCB6	49.75	1.835	14.40	12.57	0.200	7.54	10.71	2.68	0.18
WCB7	49.30	1.544	15.20	11.04	0.187	7.57	12.81	1.99	0.21
WCB8	50.94	1.379	14.27	11.85	0.151	7.21	9.87	4.04	0.15
WCB9	49.23	1.849	14.15	12.44	0.207	7.42	12.12	2.17	0.25
WCB10	49.85	0.674	16.56	9.20	0.174	8.42	12.70	2.01	0.32
WCB11	48.82	2.351	15.46	12.28	0.198	5.97	12.47	2.12	0.11
WCB12	57.39	1.684	17.08	8.71	0.234	3.55	8.29	2.53	0.38
WCB13	50.29	2.537	14.10	12.60	0.191	6.28	11.04	2.48	0.25
WCB14	49.24	1.968	14.39	12.60	0.166	6.76	10.49	4.01	0.20
WCB15	49.85	1.866	14.60	12.40	0.193	6.36	12.29	2.16	0.11
WCB16	49.37	1.722	12.89	12.79	0.199	8.89	11.82	2.00	0.18
WCB17	49.84	1.749	14.76	12.02	0.213	7.60	10.74	2.74	0.19
WCB18	48.83	2.306	15.49	11.64	0.183	6.01	12.55	2.49	0.29
WCB19	52.09	1.215	18.69	10.78	0.189	4.76	7.22	3.42	1.37
WCB20	49.35	1.429	15.08	11.28	0.212	8.04	11.28	2.66	0.55
WCB21	50.03	1.979	15.73	12.77	0.198	7.20	9.06	2.65	0.21
WCB22	61.28	0.496	17.66	5.96	0.095	2.34	4.48	4.88	2.55
WCB23	52.21	1.813	13.47	10.74	0.196	5.17	13.10	3.12	0.02
WCB24	66.05	0.714	16.52	4.75	0.075	1.24	3.65	5.02	1.73

WCB25	50.03	1.548	15.15	10.82	0.184	7.27	12.11	2.51	0.24
WCB26	65.80	0.794	16.65	6.23	0.145	2.42	2.77	2.50	2.46
WCB27	49.94	2.086	16.02	11.24	0.153	4.82	11.79	3.71	0.04
WCB28	50.40	1.576	15.43	11.13	0.233	7.02	9.90	3.41	0.78
WCB29	50.16	2.488	13.92	12.94	0.201	6.29	11.78	1.90	0.09
DBF1	48.66	1.714	16.18	11.64	0.178	7.62	11.82	1.86	0.16

Sample	Major Elements (Wt. %)								
	SiO ₂	TiO ₂	Al ₂ O ₃	FeO*	MnO	MgO	CaO	Na ₂ O	K ₂ O
DBF2	66.04	0.466	16.18	3.90	0.080	2.46	4.73	4.22	1.77
DBF3	48.80	1.928	15.39	10.99	0.190	7.34	12.96	1.99	0.27
DBF4	50.10	1.865	14.46	11.83	0.179	6.88	11.74	2.44	0.34
DBF5	65.85	0.476	16.30	3.90	0.080	2.44	4.80	4.26	1.74
DBF6	57.99	1.266	20.45	8.21	0.134	3.02	2.27	3.88	2.51
DBF7	60.81	1.079	23.20	3.39	0.081	2.48	4.14	3.18	1.19
5DBF1	49.52	1.574	15.26	11.00	0.173	6.87	13.23	2.10	0.14
5DBF2	53.72	1.542	14.15	9.90	0.141	4.25	14.89	1.18	0.09
5DBF3	49.40	1.586	17.31	11.04	0.184	5.46	12.35	2.23	0.30
5DBF4	49.08	1.851	14.86	12.07	0.226	7.10	11.41	3.01	0.23
6DBF1	80.08	0.423	9.06	3.81	0.062	1.30	1.79	2.40	1.01
6DBF2	50.56	0.779	17.56	10.35	0.186	7.40	8.30	3.80	0.92
6DBF3	50.71	1.961	17.18	15.30	0.307	5.18	5.53	3.41	0.24
6DBF4	49.78	1.211	15.20	8.60	0.212	9.54	11.68	1.20	2.09
6DBF5	75.80	0.489	12.26	4.85	0.024	2.03	0.80	1.73	1.95
6DBF6	50.37	1.527	15.17	10.53	0.177	6.92	12.97	2.09	0.11
DGRV6-111	50.16	1.590	15.05	11.49	0.186	7.29	11.43	2.41	0.24
DGRV6-162	49.94	1.849	15.37	12.04	0.131	6.88	9.85	2.90	0.85
DGRV6-194	68.28	0.560	15.88	5.60	0.078	2.10	1.85	3.30	2.16
DGRV6-262	60.71	0.896	22.88	6.79	0.091	2.08	0.49	1.39	4.45
DGRV6-273A	49.31	1.601	14.93	11.14	0.186	7.25	12.93	2.23	0.22
DGRV6-273B	72.06	0.510	15.00	3.52	0.038	1.49	1.38	3.68	2.10
DGRV6-276	66.49	0.812	14.23	8.02	0.100	3.15	2.37	3.19	1.08
DGRV6-292	49.90	1.753	14.13	12.09	0.202	7.02	12.79	1.65	0.30
DGRV6-293	74.45	0.345	13.14	2.91	0.096	0.62	2.66	4.63	0.97
DGRV6-298	49.21	2.158	15.28	11.97	0.179	5.83	12.53	2.12	0.39
DGRV6-301	49.29	1.705	15.24	12.01	0.196	7.46	10.99	2.35	0.57
DGRV6-316	62.80	0.625	17.07	4.80	0.098	2.91	5.31	4.61	1.49
DGRV6-355	49.40	2.209	15.19	11.92	0.184	5.91	12.38	2.29	0.30
DGRV6-384	49.91	1.837	14.17	12.27	0.200	7.22	11.95	1.97	0.29
DGRV6-428A	64.93	0.732	16.69	6.40	0.384	2.44	3.23	1.94	2.91
DGRV6-428B	60.99	0.814	17.68	4.68	0.085	2.90	6.99	4.11	1.45
DGRV6-428C	65.67	0.472	16.37	3.78	0.079	2.56	4.84	4.36	1.69

Table 1 WDXRF determinations of CVR composition for ten major elements presented as oxides (n=83). Total Fe is expressed as FeO. LOI is carbon plus volatile loss as determined by loss-on-ignition.

Samples	Trace Elements (ppm)																
	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th
BEA1	78	99	42	365	95	3	224	110	27	10.6	16	91	82	1	9	27	1
BEA2	102	153	43	387	68	4	221	113	30	10.0	18	134	75	0	4	21	0
BEA3	11	16	5	42	922	75	388	124	5	3.1	21	9	55	15	18	27	7
BEA4	24	10	38	339	337	27	398	224	58	9.1	21	122	121	9	19	50	2
BEA5	70	73	43	387	81	8	383	114	29	9.9	15	71	61	0	8	22	1
BEA6	60	285	42	234	568	17	149	24	15	0.7	13	4	77	2	2	8	0
BEA7	11	17	25	171	694	49	644	106	24	4.1	18	48	94	5	7	24	3
BEA8	85	253	37	319	178	9	243	100	25	9.1	17	378	84	2	8	19	0
BEA9	76	95	40	359	86	3	178	107	26	9.4	19	159	101	1	7	24	2
BEA10	91	272	40	326	57	5	153	106	21	9.1	17	24	94	2	8	13	0
BEA11	17	42	20	160	1357	56	108	113	20	6.0	16	62	73	8	15	30	4
BEA12	90	198	42	341	91	9	379	92	25	8.1	14	102	62	0	8	18	1
BEA13	32	41	20	178	1150	59	284	95	16	5.0	16	65	96	16	10	21	4
BEA14	39	127	33	280	192	8	426	67	17	3.4	18	78	109	5	8	17	2
BEA15	100	316	41	323	35	2	207	83	23	7.6	15	131	87	2	9	19	2
BEA16	62	81	44	404	66	2	375	115	32	8.7	21	87	104	0	8	19	1
BEA17	93	257	36	318	64	3	230	86	23	7.5	17	38	81	2	7	17	1
BEA18	95	170	44	322	50	4	164	80	22	7.0	16	29	87	1	7	13	0
BEA19	108	122	51	447	31	1	91	138	33	12.0	25	51	120	1	18	33	1
BEA20	100	260	42	341	46	4	180	93	25	9.2	19	179	87	2	9	20	0
WCB1	86	130	42	358	98	2	188	102	26	8.9	17	122	94	1	9	19	1
WCB2	92	253	43	356	30	1	115	108	27	9.9	19	84	76	0	10	21	1
WCB3	95	262	44	354	33	2	163	97	26	9.3	17	164	79	2	9	17	0
WCB4	99	309	42	317	38	2	229	84	23	8.1	16	144	84	0	6	18	0
WCB5	97	192	44	327	76	9	322	75	21	6.0	16	56	91	2	6	15	1
WCB6	85	127	42	361	109	5	226	101	26	9.8	16	117	98	0	8	17	1
WCB7	105	308	41	329	44	5	176	87	24	7.7	16	156	81	1	8	17	0
WCB8	81	223	41	288	60	4	245	77	21	6.6	15	3	73	3	4	6	1
WCB9	92	137	42	369	65	2	193	107	27	9.6	20	170	100	2	8	21	0
WCB10	57	243	48	285	100	6	274	34	16	1.3	16	125	74	1	5	8	1
WCB11	75	140	38	395	43	1	241	144	31	12.7	22	228	108	3	10	29	1
WCB12	63	181	44	324	142	10	245	94	26	8.5	17	52	39	1	4	16	1
WCB13	82	151	40	409	95	6	286	150	31	14.6	23	230	112	1	12	31	1

Samples	Trace Elements (ppm)																
	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th
WCB14	80	144	44	383	51	2	127	112	30	11.0	19	25	55	0	8	23	1
WCB15	79	105	40	374	35	2	188	107	28	9.0	18	182	95	1	8	24	1
WCB16	133	181	45	362	64	3	170	93	25	8.2	18	64	94	0	4	19	0
WCB17	81	95	41	355	54	3	207	99	26	8.9	20	130	98	3	7	23	0
WCB18	71	144	38	392	61	4	217	137	31	12.8	21	552	63	0	11	27	1
WCB19	12	9	31	297	273	28	338	65	29	3.1	19	82	89	1	10	23	1
WCB20	100	176	43	323	132	11	268	75	21	6.5	15	34	82	0	3	17	1
WCB21	101	179	43	381	51	5	265	111	31	9.6	17	187	101	2	8	20	2
WCB22	6	3	11	96	875	36	601	91	17	4.7	17	2	64	4	13	27	2
WCB23	68	90	37	366	18	1	323	103	26	8.5	21	436	73	3	8	19	1
WCB24	2	3	15	42	944	38	308	212	42	7.0	18	2	38	5	15	43	2
WCB25	104	306	42	331	51	6	179	86	25	8.0	17	169	72	0	6	19	1
WCB26	15	32	23	154	1213	46	529	93	28	4.7	16	48	81	3	15	28	2
WCB27	70	166	35	366	28	2	93	124	29	12.0	22	121	74	0	10	29	1
WCB28	107	310	42	327	101	39	356	87	25	8.1	18	17	72	1	4	15	0
WCB29	82	140	39	406	47	2	219	146	31	14.3	21	230	109	1	9	30	1
DBF1	100	269	42	338	35	2	158	104	26	9.7	20	100	87	1	8	25	1
DBF2	46	46	10	76	681	28	670	122	15	3.7	18	26	57	8	14	27	2
DBF3	110	245	42	370	80	5	249	110	29	9.8	20	20	79	1	7	23	1
DBF4	111	253	40	364	87	6	204	106	26	9.2	18	19	93	1	8	17	0
DBF5	42	43	9	80	666	27	682	123	14	4.7	18	26	57	8	15	29	3
DBF6	9	21	29	166	1221	47	405	157	29	5.8	20	34	109	6	14	35	2
DBF7	2	45	32	286	449	25	317	108	27	3.5	20	13	71	7	4	13	2
5DBF1	105	312	42	332	41	3	179	90	25	7.7	18	166	78	0	7	21	1
5DBF2	81	248	35	306	54	3	88	91	23	8.7	22	156	52	1	9	22	0
5DBF3	63	82	35	326	90	6	250	88	23	7.2	20	136	82	1	8	19	1
5DBF4	87	180	42	344	78	2	187	106	28	10.1	19	73	113	0	10	24	3
6DBF1	7	20	13	90	314	21	129	66	16	3.2	11	43	64	4	8	13	2
6DBF2	40	120	40	285	810	11	467	27	16	1.6	14	81	75	1	4	9	0
6DBF3	98	180	39	351	169	7	228	110	26	9.7	21	138	100	0	8	22	1
6DBF4	108	356	36	318	3413	98	684	65	20	11.2	17	199	84	2	21	45	3
6DBF5	22	35	14	115	576	40	222	80	14	4.3	14	38	87	7	13	21	2
6DBF6	104	306	42	324	40	2	168	87	24	9.0	18	158	79	0	8	16	1
DGRV6-111	94	170	41	331	59	2	276	92	25	8.5	17	43	89	1	6	16	1
DGRV6-162	79	149	39	335	190	20	394	104	25	9.1	16	2	63	1	4	15	1
DGRV6-194	30	53	10	83	747	72	319	146	20	10.0	17	18	84	12	20	46	8

Samples		Trace Elements (ppm)															
	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th
DGRV6-262	27	64	18	178	2002	135	115	144	20	10.8	26	31	83	16	30	57	11
DGRV6-273A	102	283	43	338	59	4	199	92	26	8.9	17	132	88	2	9	18	2
DGRV6-273B	17	45	8	56	585	63	252	189	20	10.2	16	8	58	11	22	41	7
DGRV6-276	8	9	16	108	570	43	392	101	33	4.9	15	10	106	5	13	25	3
DGRV6-292	86	132	41	353	79	5	176	101	27	9.0	18	111	92	2	4	18	1
DGRV6-293	3	4	15	26	535	18	224	116	36	3.6	12	64	153	58	10	25	3
DGRV6-298	72	176	38	366	166	10	240	131	30	13.4	21	153	105	0	8	28	2
DGRV6-301	94	222	41	343	240	11	272	99	24	9.1	17	438	93	1	7	13	0
DGRV6-316	44	55	10	92	611	19	788	153	18	6.3	19	26	73	7	18	39	3
DGRV6-355	73	176	38	373	93	6	269	131	29	11.7	20	119	91	1	15	29	1
DGRV6-384	87	132	44	370	186	6	189	100	26	9.4	19	52	94	1	8	21	1
DGRV6-428A	13	22	24	165	2256	64	321	113	34	4.1	17	44	78	7	18	39	3
DGRV6-428B	25	20	11	114	445	15	1944	135	12	3.6	22	40	63	5	24	59	3
DGRV6-428C	44	46	9	79	610	25	719	115	14	3.9	17	25	55	8	16	30	1

Table 2 WDXRF determinations of CVR composition for 18 trace elements (n=83)

Natural Samples (n=49)		Cultural Samples (n=34)	
Basalt	41	Basalt	19
Andesite	3	Andesite	5
Dacite	3	Dacite	6
Rhyolite	2	Rhyolite	4
Low SiO ₂		Low SiO ₂	19
High SiO ₂		High SiO ₂	15
Percent (Low/High)		Percent (Low/High)	56/44

Table 3 Material types comprising natural control and cultural sample groups. Based on silica content.

Figure 4 Total Alkali Silica (TAS) Classification LeMaitre Plot

Bivariate plots were generated comparing the major and trace elements for all samples in order to show groupings of

high SiO₂ materials and low SiO₂ materials across sample sets and to identify elements to be used in statistical analyses. The major elements, excluding SiO₂, that were determined to be the most effective for discriminating between the two material type groups include: TiO₂, MnO, MgO, Na₂O, CaO, and K₂O. Trace elements with the clearest distinctions are Ni, Cr, Sc, and V.

The natural control samples (n=49) were mostly basalt (n=41), but also included a small number of andesite (n=3), dacite (n=3), and rhyolite (n=2) samples (Table 3). The low SiO₂ samples account for 84% of the samples in the natural control sample group, while high SiO₂ samples comprised the remaining 16%. The cultural samples (n=34), which include the beach finds (DBF) and DGRV6 sample groups, also contain basalt (n=19), andesite (n=5), dacite (n=6), and rhyolite (n=4). However, the ratio of low SiO₂ samples to high SiO₂ samples is much different, with low SiO₂ samples accounting for 56% of the cultural samples and high SiO₂ samples making up the other 44%.

Differences in the frequency of high and low SiO₂ CVR in the natural and control samples are highly significant at a 0.01 level based on a Fisher's Exact test (p=0.0012).

Elements other than SiO₂ were also found to be useful to distinguish between CVR classes. MgO was found to be the best element for discriminating CVR classes. The bivariate plots in Figure 5 show the distinction between samples in the low SiO₂ material group and the high SiO₂ using the elements MnO and MgO. These plots also reveal that there are samples from both the natural control and cultural sample sets in both of the material groups.

As SiO₂ content increases MgO content decreases as a result of magmatic differentiation (Jaupert and Tait 2012). All low SiO₂ samples have an MgO content above 4 percent, while the high SiO₂ samples have MgO content below 4 percent. This element can be reliably detected on pXRF machines and would be a good field proxy for silica content for these materials but not all CVR. As there is a complex relationship between SiO₂ and MgO content due to magmatic differentiation processes, using pXRF one would only be able to distinguish between low and high silica material groups, not specific SiO₂ content. The trace elements that were identified to be the most important for discriminating the two material type groups include: Ni, Cr, Sc, and V. Figure 6 shows that the distinction between

the high quality and low quality tool stone is also evident in these trace elements.

Figure 5 Bivariate plots comparing SiO₂ vs MnO (top) and SiO₂ vs MgO (bottom) for all sample groups.

Figure 6 Bivariate plots comparing Ni vs Sc (top) and Cr vs V (bottom) for all sample groups.

To verify that the samples were forming two distinct material quality groups a Linear Discriminant Analysis (LDA) was performed on all samples using the major and trace elements, excluding SiO₂ (Table 4). The results of our LDA were highly significant at a 0.01 level (Wilks' Lambda=0.073, $\chi^2=200.39$, df=9, p=0.001). This demonstrates that

the samples from the Dionisio Point locality form two distinct groups, a low percentage SiO₂ material type (Material Group 1) and a high percentage SiO₂ material type (Material Group 2) with membership predicted by their constituent major and trace elements. Using major elements 100% of the samples were correctly classified into the high and low SiO₂ content groups. The analysis using trace elements correctly classified samples into the high and low SiO₂ content groups with one exception.

Classified			
True Material	1	2 Total	
1	60	0	
	100	0	100
2	0	23	
	0	100	100
Total	60	23	83
	72.29	27.71	100
Priors	0.5	0.5	
Classified			
True Material	1	2 Total	
1	60	0	
	100	0	100
2	1	22	
	4.35	95.65	100
Total	61	22	83
	73.49	26.51	100
Priors	0.5	0.5	

Table 4 Linear discriminant analysis of low (Material group 1) and high (Material group 2) SiO₂ content materials using all major (top) and trace (bottom) elements.

5. CONCLUSIONS

With this study we set out to answer two core questions. First, was high quality toolstone available at the Dionisio Point locality? By directly measuring SiO₂ content, we were able to assess the quality of toolstone readily available at the Dionisio Point locality. Our analyses show that basalt was the dominant material type for cobbles locally available at Parry's Lagoon. However, higher quality (higher SiO₂ content) CVR toolstone including andesite, dacite, and rhyolite were also present in the natural samples. Although low quality toolstone was prevalent, high quality

toolstone was clearly accessible and locally utilized at Dionisio Point.

Our second question concerned whether there is evidence of selection for higher quality materials. The presence of basalt, andesite, dacite, and rhyolite samples in the cultural data sets reveals that precontact communities in the Dionisio Point locality were utilizing the full range of locally available lithic source materials, but with a preference for high SiO₂ content materials. As the range of toolstone locally available at Parry's Lagoon includes basalt, dacite, andesite, and rhyolite, it is entirely possible that primarily local cobbles were utilized as toolstone at DgRv-6. In contrast to previous interpretations of toolstone acquisition (eg., Close, 2006), for Dionisio Point there is no evidence to support that the majority of raw toolstone was acquired through direct lithic procurement at distant locations such as Watts Point, British Columbia. However, very high quality toolstone as indicated by unusually high SiO₂ content was present in the debitage from the artifact assemblages (specifically samples DGRV6-273B and DGRV6-293) but absent from the natural controls. This may indicate some use of extralocal lithic sources, whether the result of down the line trade or directed lithic procurement (Rorabaugh and McNabb, 2014). It is clear that Coast Salish peoples engaged in directed lithic procurement of exotic toolstone for reasons including ideology (e.g. Reimer, 2012), but complex trade relations, kin networks, and pilgrimages do not have to be invoked to account for the toolstone procured for many daily practices.

Although WDXRF is destructive, which may limit its applicability to many archaeological assemblages, our findings suggest that other elements can act as proxies for silica content. MgO, MnO, and trace elements can be used with pXRF and EDXRF to distinguish between high and low silica material groups in the absence of actual SiO₂ data. Although WDXRF provides more accurate and precise results, we suggest that these elements can be used as a proxy for SiO₂ content. This means that non-destructive analyses to examine relative toolstone material quality are feasible in the Salish Sea and other regions where CVR toolstones are prevalent. This is important for contexts where destructive methods may not be permitted due to heritage purposes but researchers have considerable questions relating to lithic technological organization. However, we argue that researchers should still use WDXRF if their research questions require the identification of specific CVR material types.

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