The swing of things: Contributions to archaeological research in Alberta, 2018

ARCHAEOLOGICAL SURVEY OF ALBERTA

OCCASIONAL PAPER NO. 38. EDITED BY ERIC R. DAMKJAR

Testing debitage typologies with statistical analysis: Experimental inferences upon archaeological material from FaPx-1, a sub-alpine hunting camp in the Alberta Rockies

Timothy E. Allan[a*]

[a] Department of Anthropology, University of British Columbia, 6303 NW Marine Drive, Vancouver, British Columbia, Canada, V6T 1Z1
*contact: t.allan@alumni.ubc.ca

ABSTRACT

Stone production debris (debitage) is the most common artifact type found at archaeological sites in North America. A significant time investment is required to catalogue debitage from large assemblages. Conventional thought holds that, because lithic tool manufacture is reductive, the attributes of flake size and cortex amount will decrease throughout production while dorsal flake scars increase. Dorsal scar count is an attribute commonly used to infer trends in an assemblage; however, the statistical significance of dorsal scars as a measure of the stage of lithic tool production has not been addressed adequately. Cortex amount is also used to deduce lithic reduction stages; however, I argue that this may not represent behavioral patterns as meaningfully as platform morphology. Alternative approaches distinguish flake types based on platform morphology, with an argument that hammer types leave behind diagnostic flake platforms. In this paper, I statistically analyze an experimental assemblage of flakes from three different hammer types (hard hammer, soft hammer, and pressure flakes) to test if platform dimensions are diagnostic of hammer types and, therefore, are a useful attribute for debitage analysis. I then compare platform dimensions of the experimentally controlled groups with those of an archaeological assemblage from Hummingbird Creek in sub-alpine western Alberta, Canada. I test if dorsal scar counts of complete flakes are statistically different between hammer types in the experimental assemblage. Results indicate that hammer types produce different platform dimensions and that platform types can be used to differentiate flakes and reduction strategies in an archaeological sample where cortex amount does not.

KEYWORDS

Lithic analysis, cortex, dorsal scars, flake platform, Precontact Period, statistics, archaeology

1. Introduction

In this paper I evaluate different methods of stone tool debitage analysis in order to more effectively separate assemblages into reduction behaviors and infer preferences in the modes of lithic reduction. Experimental results are applied to the Hummingbird Creek archaeological site, FaPx-1, located in a sub-alpine region of west central Alberta. I argue that using platform dimensions and platform type are statistically viable alternatives for inferring reduction behaviors occurring at a site, and may be more interpretively powerful than previously established methods based largely on cortex amount and dorsal scar count.

Stone production debris (debitage) is the most common artifact type found at precontact archaeological sites in North America. There is a staggering amount of literature on debitage analysis and many published methods on how to address questions in precontact behavior based on data derived from debitage assemblages. Andrefsky (2005) synthesizes much of the published literature into common approaches to infer production stages of debitage using flake attributes of cortex amount, size class, and dorsal scars (see Sullivan and Rozen 1985; Ahler 1989; Magne 1989; Scott 1991; Bradbury and Carr 2004). The use of these attributes is based on the premise that lithic production is a reductive process, where cortex amount and size class will decrease and dorsal scars will increase as the parent piece is worked. Cortex amount is often used to distinguish between primary, secondary, and tertiary flakes, and is called the triple cortex method (Andrefsky 2005). Fish (1978) notes that there can be great discrepancies between observers when evaluating cortex amount. In addition, the range of cortex amount corresponding to certain flake types differs in the literature, making it difficult to compare assemblages catalogued by different researchers. Furthermore, it is not altogether clear if tertiary flakes are in fact produced after secondary flakes or if it is merely the cortex amount on these two classes that differs. Hence, a behaviorally meaningful relevance of the triple cortex method is lacking.

Analyses of load typologies attempt to determine the application or mode of force to produce flakes based on platform attributes and some subjective assessments (Hayden and Hutchings 1989), which can reveal behavioral differences of high interpretive value (Andrefsky 2005). The key purpose here is to detect discrete behaviors that occurred at a site: distinguishing behavioral preferences in tool production can assist in the classification of site function and, in turn, help infer precontact land-use and logistical mobility. In this paper, I propose that platform dimensions are indicative of hard hammer, soft hammer, and pressure flake reduction that can represent distinct behavioral decisions of knappers that are more reliable and informative than inferences of stages of reduction. I test if platform dimensions and dorsal scars are significantly different between hammer types (hard hammer, soft hammer, and pressure flakes), based on flakes produced experimentally. I then assess debitage from archaeological site FaPx-1, where the proportions of flake types inform reconstructions of ancient behavior.

2. Background: The Hummingbird Creek site

FaPx-1, discovered in 2009 by members of the Archaeological Survey of Alberta, is located on a high terrace above the confluence of the South Ram River and Hummingbird Creek, in the central Rockies of Alberta. A total of 10 square metres of excavations, conducted in 2011, 2012 and 2017, yielded approximately 1,400 lithic artifacts, faunal remains, and several hearth features from stratigraphically separated occupations (see Table 1). Stratified precontact sites are rare in alpine and subalpine regions, so FaPx-1 presents an opportunity to make inferences of precontact hunter-gatherer behaviour with excellent chronological control.

Table 1. Dates and flake proportions of FaPx-1 from the initial cataloguing.

Level (total lithics)	AMS ^{14}C age (BP)	Calibrated Age (μ) BP[b]	Lab No.
D (771)	1010 ±20	935	UCIAMS 101904 (charcoal)
E	2,355 ±20	2,360	UCIAMS 101868 (charcoal)
(44)	2,390 ±15	2,400	UCIAMS 101875 (charcoal)
Bridge River tephra[a]		2,360	UA 1555-13
G (153)	2,425 ±15	2,450	UCIAMS 67158 (charcoal)

[a] Clague et al. 1995.

[b] Calibrated using Intcal13 (Reimer et al. 2013) and Oxcal 4.3 (Bronk 2009).

The lower occupations, levels E and G, are separated by a thick deposit of Bridge River tephra, dated to 2,360 BP (Clague et al. 1995). Tephra was collected during excavation and identified at the University of Alberta, Department of Earth Sciences (UA 1555-13). Much of the material culture from level G resides in a slight depression near the southern edge of a terrace. The debitage, tools, faunal remains, and hearth features were deposited in fine silts overlaid on fluvially deposited gravel and rounded cobbles. These fine silts follow a 2-metre wide, north-south depression along the site. Given the stratigraphy, this depression is likely a remnant streambed from the Early Holocene, when the South Ram River level was much higher. The river has since incised down to its present level, abandoning the channel high on the terrace. Indigenous people likely selected this location for a hunting camp around 2,500 years ago (represented in level G) where the remnant streambed would have provided cover for hunters observing the South Ram valley below (Figure 1). After the deposition of Bridge River tephra, this channel was partially filled, and perhaps the cover it provided previously was diminished. This change in micro-topography, and possibly the associated vegetation, may have caused the site to be less desirable for a hunting camp; a possible change in function as represented by a change in proportion of flake types before and after the tephra deposit is investigated below.

3. Methods

3.1. Platform assignment

Load typologies attempt to identify flakes based on the size and shape of their platform (Hayden and Hutchings 1989). “Flake” is defined here as a single unit of debitage with an identifiable platform (or point of hammer impact),

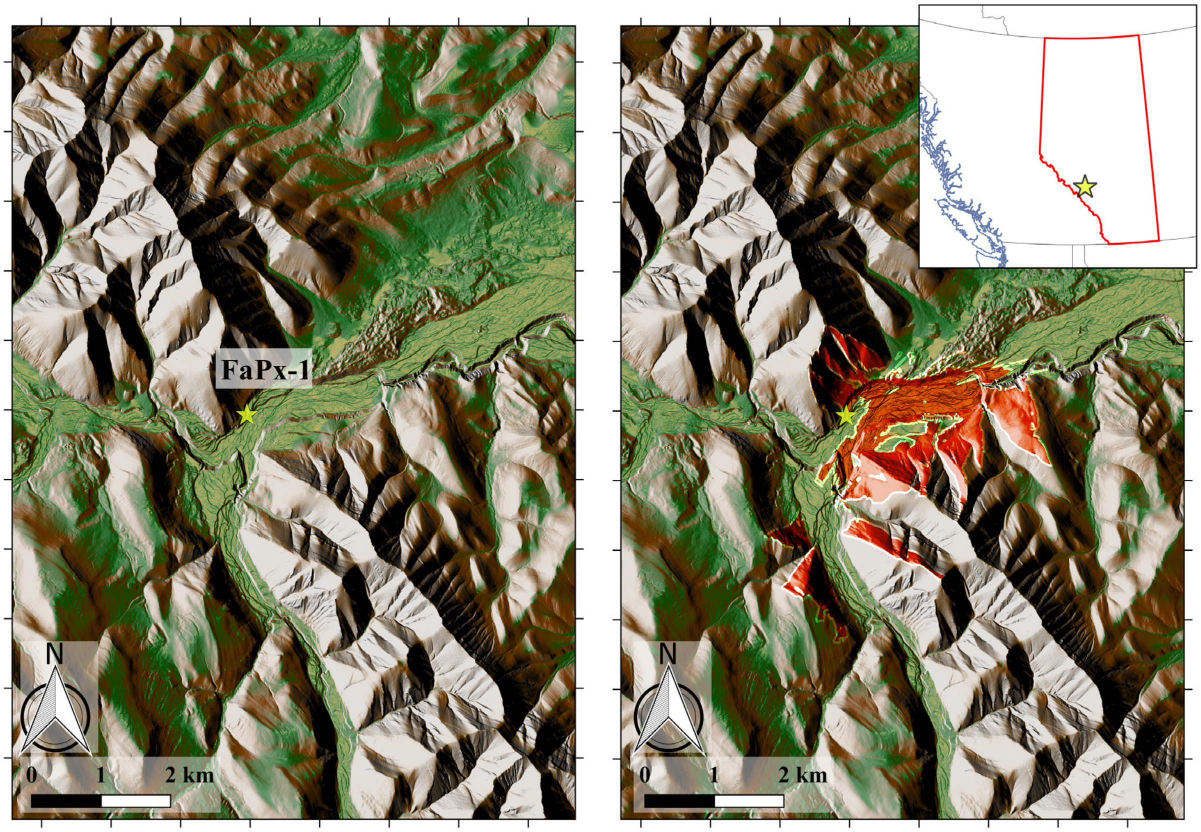

Figure 1. Location of FaPx-1 (left). Visible area from FaPx-1 (right) based on QGIS view shed analyses using 5-metre LiDAR digital elevation data. The areas visible from FaPx-1 are in red.

while debitage without platforms is described here as shatter. Hard hammer flakes can be identified by their wide and flat platform, and a platform angle at roughly 90 degrees to the overall flake profile. Hard hammer flakes typically have distinctive bulbs and display eraillure scars more often than other types. Soft hammer flakes have a narrow platform, typically with a jagged or uneven platform surface, and with a platform angle at 45 degrees relative to the flake profile. Soft hammer flakes sometimes have a 'platform lip' representative of the antler billet absorbing some of the shock of the blow. Pressure flakes have similar characteristics of soft hammer flakes, just at a much smaller scale. I differentiate pressure flakes from soft hammer flakes at FaPx-1 on the basis of size: complete flakes smaller than 10 millimetres with soft hammer platforms are classified as pressure flakes. Shatter is defined as undiagnostic pieces of debitage that do not exhibit platforms. I separate shatter into two categories: blocky shatter and flake shatter. Blocky shatter is typically cubical or angular, has virtually no characteristics of flaking, and is likely produced from the over-application of force on raw nodules. However, blocky shatter can also be produced from natural forces, such as frost-spalling, fire, and erosion, where pieces can break preferentially along planes of weakness leaving blocky debris. Flake shatter includes medial and terminal portions of flakes. Flake shatter is likely produced throughout the manufacturing process, but also is a product of taphonomic processes on debris. Separating debitage in this way can quickly discriminate between diagnostic flakes and shatter to reduce time that is spent on debitage with low interpretive value. Flakes from FaPx-1 were classified according to platform morphology and I also recorded number of dorsal scars, cortex amount, and weight.

3.2. Flint-knapping experiment

Forty-three hard hammer flakes, 45 soft hammer flakes, and 30 pressure flakes from experimental flint-knapping were analyzed. I collected all debris from an experienced flint-knapper (Nick Waber) who was producing dart-sized projectile points, as well as more expedient tools and bifaces. A quartzite hammerstone was used for initial core reduction, an antler billet was used for thinning flake blanks into bifaces, and an antler tine was used to finish edges and to produce notches. Obsidian, siltstone, and basalt cores were used in this experiment. During the experiment, the knapper

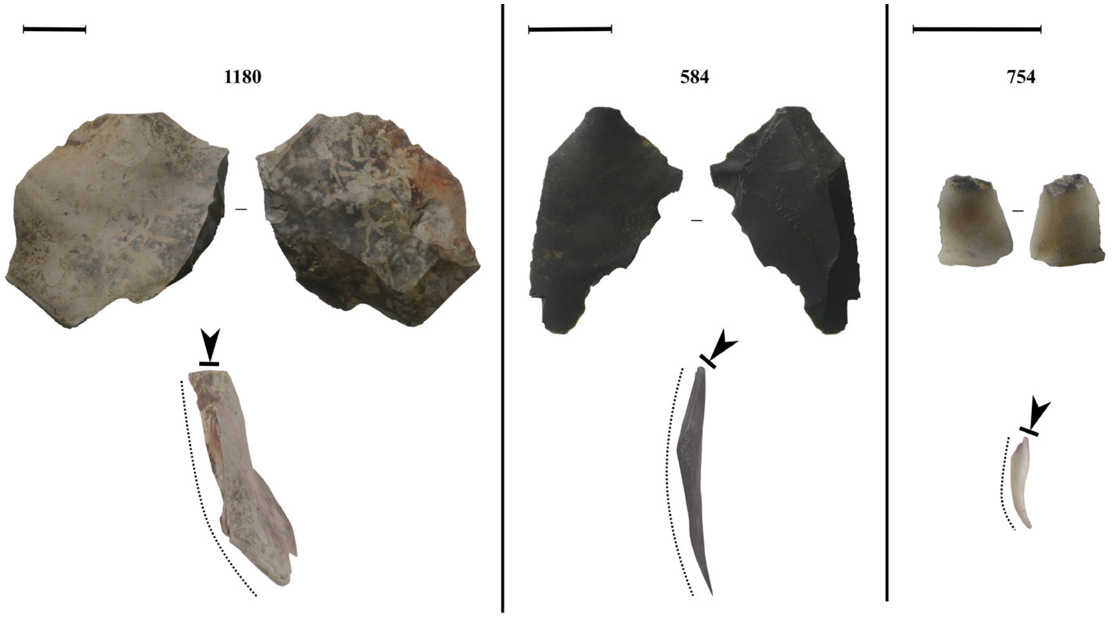

Figure 2. Examples of complete flake types from the FaPx-1 assemblage. Hard hammer flake at left (catalogue number 1180); soft hammer flake at center (584); and pressure flake at right (754). Arrows point to the platform of the flake. Scale bar is 1 centimetre.

used each hammer type during lithic production; when the knapper was about to transition to another hammer type, production was stopped and debris from that hammer type was collected. I attempted here to replicate a flintknapper leaving behind debris at an archaeological site, where each application of force type (hard hammer, soft hammer, antler tine) corresponds with an activity in the lithic reduction process.

Platforms were measured to the nearest hundredth of a millimetre with digital calipers. Statistical analysis was done using IBM-SPSS including Shapiro-Wilk tests of normality and non-parametric Kruskal-Wallis tests of statistical difference on platform length, platform thickness, and dorsal scar counts between flake types. Results of these analyses are used to determine if the flake attributes are truly reflective of being derived from different hammer types and can be used to discriminate flake types.

3.3 Triple cortex method

Lastly, I apply the triple cortex method to the experimental assemblage and FaPx-1 and compare results with those of the load typology (platform assignment). Cortex is determined via visual inspection of an artifact, over the total surface area of the flake. Primary flakes are generally identified as having greater than 50% cortex, secondary flakes 1-49%, and tertiary flakes as 0% cortex. These designations all generally refer to early (primary), middle (secondary), and late (tertiary) stage reduction events.

4. Results

4.1. Statistical analysis

Boxplots of metric data from the experimental samples indicate that the center and spread of flake groups differs using platform length and platform thickness; however, the center and spread of dorsal scars appears very similar between all groups (Figure 3). Dorsal scars of soft hammer flakes and pressure flakes are nearly identical in center and spread (mean=2.67; first quartile=2; third quartile=3).

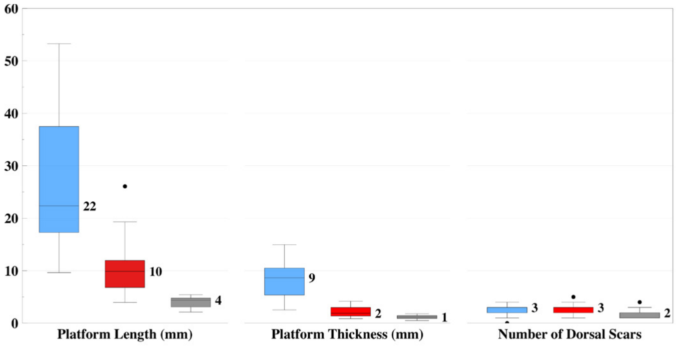

Figure 3. Boxplots of complete flake attributes in experimental sample. Black = pressure flakes, red = soft hammer flakes, blue = hard hammer flakes.

4.1.1. Test for normality

To determine if parametric or non-parametric tests are needed for assessments of statistically significant differences between the experimental flakes, it must be determined if all groups are normally distributed. Shapiro-Wilk tests for normality were conducted on flake types by platform length, platform thickness, and dorsal scars. The null hypothesis for the Shapiro-Wilk test of normality (H0) is that the values are normally distributed, and the alternative hypothesis (H1) is that the values are not normally distributed. For the Shapiro-Wilk test of platform length, all groups rejected the null hypothesis, indicating that all attribute groups are not normally distributed, therefore statistical difference must be determined with a non-parametric test (Table 2). For platform thickness (Table 3), hard hammer flakes and pressure flakes are normally distributed but soft hammer flakes are not; therefore, a non-parametric test is still needed to test statistical difference of flake types with this attribute. For dorsal scars, all flake groups were not normally distributed (Table 4), so non-parametric tests of difference will be used for these attributes as well.

Table 2. Test for normality results for platform length.

Flake Type	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Hard hammer	.154	43	.012	.823	43	.000
Soft hammer	.185	45	.001	.846	45	.000
Pressure flake	.283	30	.000	.796	30	.000

Table 3. Test for normality results for platform thickness.

Flake Type	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Hard hammer	.116	43	.166	.965	43	.212
Soft hammer	.140	45	.028	.912	45	.002
Pressure flake	.099	30	.200	.957	30	.265

Table 4. Test for normality results for dorsal scars.

Flake Type	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Hard hammer	.248	43	.000	.904	43	.002
Soft hammer	.232	45	.000	.885	45	.000
Pressure flakes	.270	30	.000	.808	30	.000

4.1.2. Tests of statistical difference

I use a Kruskal-Wallis test of statistical difference on the experimental assemblage, where the null hypothesis (H0) is that there is no difference between all flake groups of a single attribute, and the alternative hypothesis (H1) is that the flake groups are significantly different, and as a result are likely derived from different populations. The results of the Kruskal-Wallis test for platform length was 98.245 (with df=2; and p=.000) rejecting the null hypothesis; platform thickness was 87.966 (with df=2; and p=.000) rejecting the null hypothesis; and dorsal scars was .395 (with df=1; and p=.530) retaining the null hypothesis (Table 5). The results of the Kruskal-Wallis tests indicate that the flake groups are statistically different using platform length and thickness attributes; however, I did not find statistical differences in the number of dorsal scars between the experimental activities (hard hammer, soft hammer and pressure flaking).

Table 5. Results of the Kruskal-Wallis test

	Length	Thickness	Dorsal Scars
Chi-Square	98.245	87.966	1.005
df	2	2	2
Asymp. Sig.	.000	.000	.605

4.1.3. Linear relationship

I explore the relationship between dorsal scars and flake weight, to test if higher counts of dorsal scars are reflective of later reduction stages. A simple linear regression on a scatterplot of dorsal scars versus weight indicates that R2 = 0.0153 (Figure 4); there is no relationship between dorsal scars and flake weight. If higher counts of dorsal scars are representative of later stages of reductive lithic production (Magne 1989), a negative relationship would be expected where larger (in this case heavier) flakes would be more likely to have fewer dorsal scars. The regression results are not strong enough to make any definitive conclusion; however, I consider the results reflective of a counteracting principle: although smaller flakes are likely to be from a later stage of reduction (and have more dorsal scars) only so many scars can fit on such small flakes.

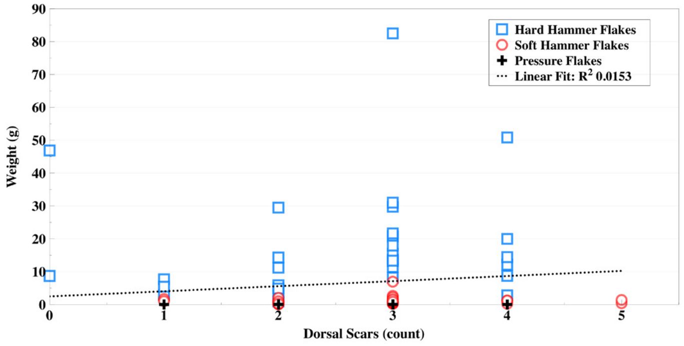

Figure 4. Scatterplot of complete flakes dorsal scars (count) vs. weight (g). R2 value (0.0153) across all flake groups.

Results of tests of statistical difference indicate that platform length and thickness are different between flake types while results of the Kruskal-Wallis test indicate that dorsal scars are not statistically different between flake groups. This result promotes the premise that platform dimensions are diagnostic of flake hammer type. I plot platform dimensions below using a scatterplot and 90% confidence ellipses to assess the catalogued debitage from FaPx-1.

4.2 Application to the FaPx-1 assemblage

The results of the Mann-Whitney U tests indicate that platform length and platform thickness of the three flake groups in the experimental study are all statistically different. Since the experimental flake groups can be distinguished with statistical significance via the use of platform metrics, I use platform morphology to differentiate flake types in an archaeological assemblage. The complete flakes from FaPx-1 were catalogued according to the general morphologies of hard hammer, soft hammer, and pressure flake platforms. An intriguing trend occurs in both levels D and E (Table 6), where pressure flakes are by far the most common flake type in these levels and soft hammer flakes are the most common in level G. In all three levels, hard hammer flakes are the least common flake type. I compare the catalogued flake platform dimensions here from the three distinct occupations of FaPx-1; Level D (Figure 5), Level E (Figure 6), and Level G (Figure 7). Comparing each of the levels with the experimental assemblage data, it is clear that the morphological assignment generally fits well with the ranges of experimental platform dimensions. However, especially within the hard hammer group, platform dimensions of the morphologically assigned flakes fall outside the ranges of experimental flakes.

Table 6. Observed flake proportions from FaPx-1 (percent of diagnostic flakes in level are in brackets)

Level (n of diagnostic flakes)	Hard hammer	Soft hammer	Pressure flake	Flake shatter	Blocky shatter
D (241)	31 (12.9)	84 (34.9)	126 (52.2)	404	189
E (26)	1 (3.8)	6 (23.0)	19 (73.0)	4	5
G (56)	6 (10.7)	34 (60.7)	16 (28.6)	47	23

If the triple cortex method is used, the debitage types from occupations of FaPx-1 occur in similar proportions. Since the vast majority of flakes have 0 percent cortex (78 percent level D; 80 percent level E; 82 percent level G) these would traditionally be classified as tertiary flakes (Figure 8). The proportions of secondary flakes are also very similar between the levels (14 percent level D; 16 percent level E; 14.6 percent level G). Finally, if cortex amount is used to differentiate flake types, primary flakes also occur in very similar proportions (2.56 percent level D; 4 percent level E; 3.6 percent level G). The triple cortex method also highlights how few flakes represent primary production (flakes with greater than 50 percent cortex). Since the proportions of cortex amount are so similar between the levels within the primary, secondary and tertiary flake classes, little if any anomalous trends between the levels can be identified. The triple cortex method highlights that predominantly late-stage production took place in all three occupations.

5. Discussion

The results of the Kruskal-Wallis tests indicate that platform length and platform thickness measurements are different between flakes of three hammer types, hard hammer (hammerstone), soft hammer (antler billet) and pressure flakes (antler tine). I suspect that the differences are caused by the transfer of kinetic energy from the hammer to the parent piece, establishing a threshold of size for a particular hammer type. The cause of the size differences in flake types must be further explored, but the statistical tests here demonstrate that hammerstones, antler billets, and tines all produce statistically differently sized platforms in the experimental sample. Dorsal scars are not statistically different between flake types, and there is no linear relationship between dorsal scars and flake weight. The dorsal scar attribute when measured at many archaeological sites in Alberta does not appear to be reflective of stages of lithic reduction. I also found that identifying flakes using the triple cortex method fails to reveal differences between the three occupation levels in the FaPx-1 assemblage, whereas identifying flakes via platform morphology did.

Identifying flakes by platform type informs reconstructions of flint-knapping activities at FaPx-1. The flakes of level D and E display a clear preference for pressure flaking, with moderate amounts of soft hammer flaking, and relatively low proportions of hard hammer flaking. Alternatively, the flake proportions from level G indicate a clear preference for soft hammer flaking, with moderate amounts of pressure flaking, and very low amounts of hard hammer flakes. It is important to note that this change occurs after a thick deposit of Bridge River tephra. This indicates that the inhabitants of FaPx-1 may have focused their activities on thinning worked pieces with some light retouch during the level G occupation; then, after tephra deposition, there was more emphasis on simply retouching edges and only moderate occurrences of thinning using a soft hammer (antler billet). I interpret the focus on soft hammer and pressure flaking throughout the site's occupation as indicative of a small hunting camp, where hunter-gathers would refurbish and refine tools in preparation for upcoming hunting activities. It is also important to note that this distinction occurring in level G would not have been highlighted if the triple cortex method was used, since virtually all three flake classes occurred in similar proportions in the three respective levels. I consider primary flakes to be synonymous with hard hammer flakes: this category would be under-represented if the triple cortex method is used alone.

I interpret the change in flake proportions from Levels D and E to Level G to reflect a change in site function. The

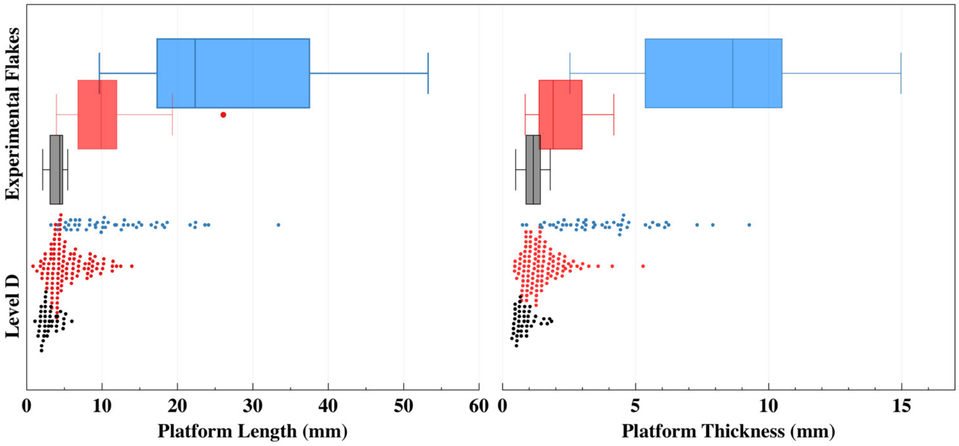

Figure 5. Platform metrics from FaPx-1 assemblage, Level D. Black = pressure flakes, red = soft hammer flakes, blue = hard hammer flakes.

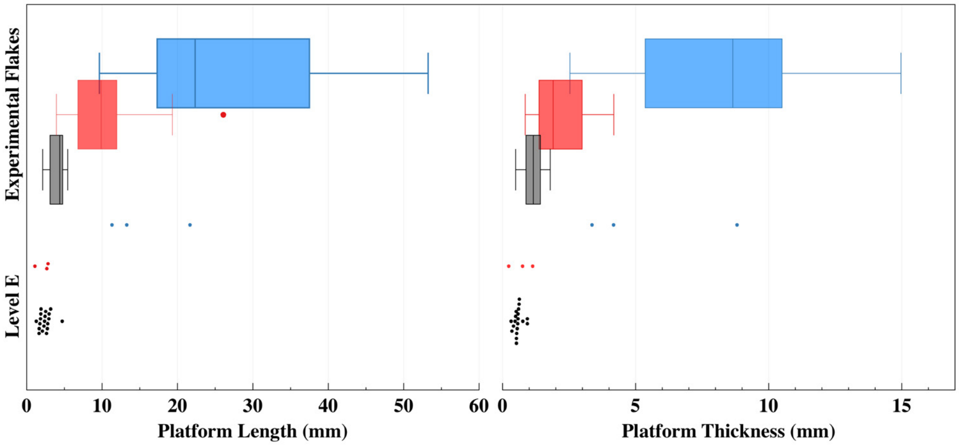

Figure 6. Platform metrics from FaPx-1 assemblage, Level E. Black = pressure flakes, red = soft hammer flakes, blue = hard hammer flakes.

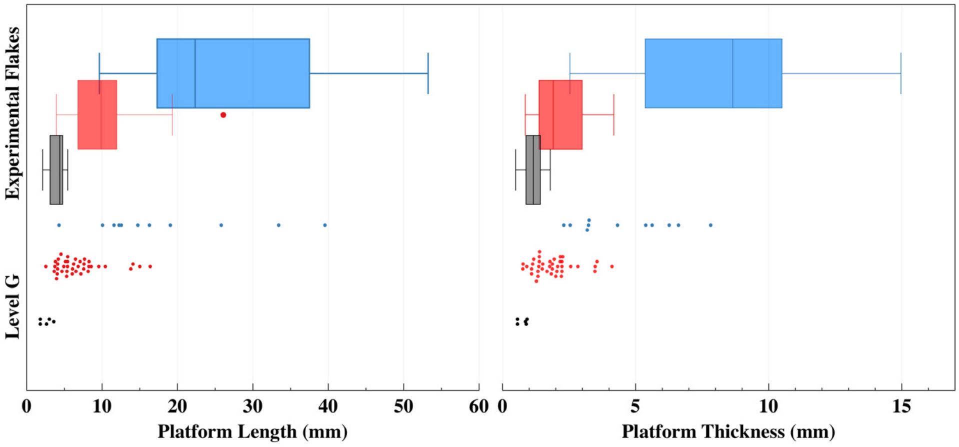

Figure 7. Platform metrics from FaPx-1 assemblage, Level G. Black = pressure flakes, red = soft hammer flakes, blue = hard hammer flakes.

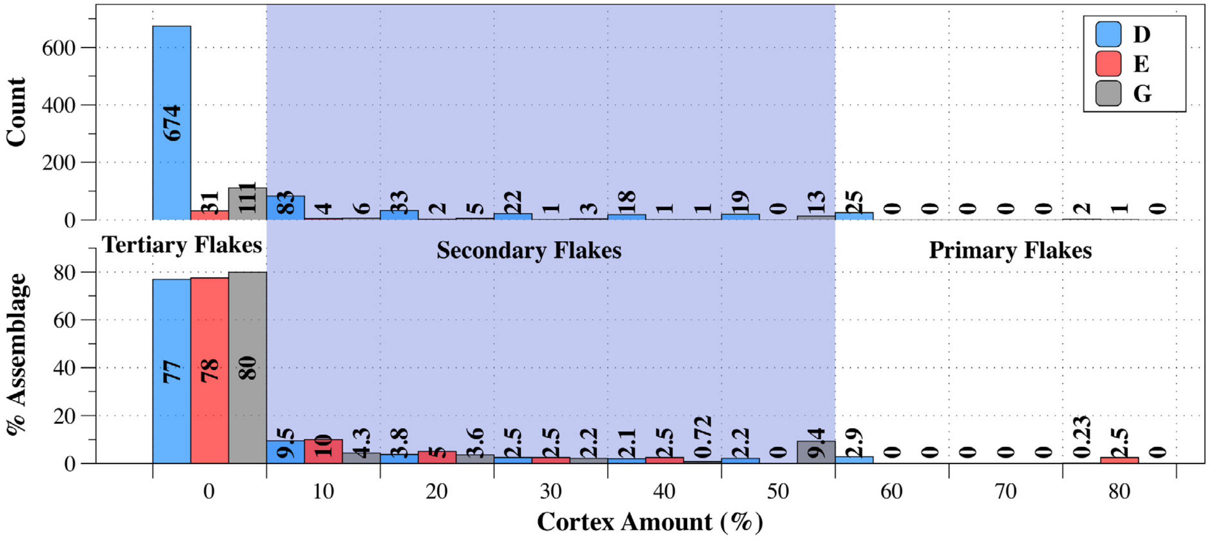

Figure 8. Cortex amount of complete flakes from FaPx-1.

proportions of diagnostic flakes (hard hammer, soft hammer, pressure flakes) represent distinct decisions made by the inhabitants of FaPx-1. The tephra deposition was unusually thick (roughly 10 centimetres) considering that tephra deposits in lakes in central and eastern B.C. are no more than a few centimetres (Mathewes and Westgate 1980; Reasoner and Healy 1986). Given this significant depth, tephra likely accumulated in the remnant streambed after a rapid snow melt, however confirmation requires further analysis. The change in lithic reduction practices after this deposition could reflect regional effects on human populations of the Bridge River tephra fall or local effects of an ash bed on the habitability of a landform. Significant tephra deposits in Alberta are known to cause increase fire susceptibility, alter habitats, and stimulate changes in human land use patterns (Oetelaar and Beaudoin 2016). Perhaps the differences in the proportions of flake types indicated here are a result of adapting to new ecological conditions after the Bridge River tephra deposition or altering land use because the ash bed made the landform less suitable for longer term occupation. The radiocarbon dates of level E indicate that FaPx-1 was occupied immediately after tephra deposition (Table 1) but the inferred changes in reduction practices may imply a change in site function.

Analyses indicate that platform dimension of flakes produced experimentally are statistically different. However, I found that there is overlap of platform dimensions of each hammer type in the experimental assemblage, and flake types from the archaeological assemblage do not conform to these experimental assemblage dimensions exactly. However, identifying flakes by platform morphology, i.e., also considering relative platform to flake angle, presence of a platform lip, and platform size relative to flake size, is productive. These attributes ought to be tested in similar ways to the analyses of platform dimensions here. Despite overlap between the platform types, identifying flakes by platform morphology highlighted a detectable difference in behaviours between occupations at FaPx-1 where identifications via cortex and scar count did not.

6. Conclusion

An analysis of flakes produced by hammerstone, antler billet and antler tine indicates that these technologies produce platforms of statistically different dimensions. I use platform morphology to differentiate flakes from an archaeological site (FaPx-1) in west central Alberta. Analysis of debitage from FaPx-1 indicates that a change in flake type proportions occurs before and after deposition of Bridge River tephra (2,360 BP), which may have affected the microtopography and/or local plant and animal populations and thus potentially the function of the site for ancient people. The effects of Bridge River tephra on ecology and human activity represented at archaeological sites in this region require further study. Before the tephra deposit, soft hammer flakes are the most common flake category, while after the tephra, pressure flakes are most common. I infer here that before the tephra, the site was used mostly as a hunting camp, where tools were lightly refurbished and retouched before and after harvesting game. After the ash, the site was used on a shorter-term basis to sharpen tools, leaving behind much higher proportions of pressure flakes. Identifying flakes by platform type is key to inferring the activities occurring at FaPx-1.

Time is often a limiting factor in the analysis of large assemblages from archaeological sites. I present here a method of quickly differentiating flakes based on platform dimensions. This method, supported here by statistical differences between flake types, may be more valuable and time-effective than previously established procedures that rely on cortex amount and dorsal scar count. Statistical analysis is a powerful tool in archaeological research and this study indicates that platform dimensions are a useful attribute in making inferences about stone tool manufacture and site use. Precontact archaeological assemblages are often dominated by lithic debris; frequently, debris is the only artifact type found at precontact sites. Improving methods of lithic debris analysis can save time in cataloguing large assemblages (by sorting pieces bearing diagnostic platforms from shatter) and focus on attributes with more interpretive value for inferring behavior, rather than infer stages of lithic manufacture based on attributes that may not be reflective of reduction events or human behavior.

7. Acknowledgements

The Hummingbird Creek site (FaPx-1) resides on Treaty 7 Territory; artifact recovery and analysis for the 2017 work were done so with consent from the Stoney Nation after a blessing by Elders from Big Horn Reserve community. I would like to thank Barry Wesley, Seona Abraham, and Bill Snow of the Stoney Nation; and Laura Golebiowski, Aboriginal Heritage Section, for making the Elders' visit and consultation possible. I would like to thank Darryl Bereziuk, Archaeological Survey of Alberta, Alberta Culture and Tourism, for providing fieldwork funding, loaning equipment, and guidance during the excavation. Thank you to Thomas Brown and David Pokotylo of University of British Columbia and Todd Kristensen of the Archaeological Survey of Alberta for insight, edits, and support. Lastly, thanks to Doug and Jane Shaw, Amy and Tate Kristensen for coming out to the site and helping excavate; Kathrine Vit, Devon Tremain, and Brynn Gilles for their assistance cataloguing.

8. Literature cited

Ahler, S.A. 1989. Mass analysis of flaking debris: studying the forest rather than the tree. *Archaeological papers of the American Anthropological Association* 1:85-118.

Andrefsky, W. Jr. 2005. *Lithics: Macroscopic Approaches to Analysis*. 2nd Ed. Cambridge University Press, Cambridge, UK.

Bradbury, A.P., and P.J. Carr. 2004. Combining aggregate and individual methods of flake debris analysis: aggregate trend analysis. *North American Archaeologist* 25: 65-90.

Bronk, Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1): 337-360.

Clague, J. J., Evans, S. G., Rampton, V. N. and G. J. Woodsworth. 1995. Improved age estimates for the White River and Bridge River tephras, western Canada. *Canadian Journal of Earth Sciences* 32: 1172-1179.

Fish, P.R. 1978. Consistency in archaeological measurement and classification: A pilot study. *American Antiquity* 43: 86-89.

Hayden, B., and K. Hutchings. 1989. Whither the billet flake? In: *Experiments in Lithic Technology*, edited by D.S. Amick and R.P. Mauldin, pp. 235-258. BAR International Series 528, Oxford, U.K.

Magne, M.P.R. 1989. Lithic reduction stages and assemblage formation processes. In: *Experiments in Lithic Technology*, edited by D.S. Amick and R.P. Mauldin, pp. 15-31. BAR International Series 528, Oxford, U.K.

Mathewes, R.W., and J.A. Westgate. 1980. Bridge River tephra: Revised distribution and significance for detecting old carbon errors in radiocarbon dates of limnic sediments in southern British Columbia. *Canadian Journal of Earth Sciences* 17:1454-1461.

Oetelaar, G.A., and A.B. Beaudoin. 2016. Evidence of cultural responses to the impact of Mazama ash fall from deeply stratified archaeological sites in southern Alberta, Canada. *Quaternary International* 394: 17-36.

Prentiss, W.C. 1998. The reliability and validity of a lithic debitage typology: Implications for archaeological interpretation. *American Antiquity* 63:635-650.

Reasoner, M.A., and R.E. Healy. 1986. Identification and significance of tephras encountered in a core from Mary Lake, Yoho National Park, British Columbia. *Canadian Journal of Earth Sciences* 23:1991-1999.

Reimer, P.J., E. Bard, A. Bayliss, J.W. Beck, P.G. Blackwell, C. Bronk Ramsey, P.M. Grootes, T.P. Guilderson, H. Haflidason, I. Hajdas, C. Hatt, T.J. Heaton, D.L. Hoffmann, A.G. Hogg, K.A. Hughen, K.F. Kaiser, B. Kromer, S.W. Manning, M. Niu, R.W. Reimer, D.A. Richards, E.M. Scott, J.R. Southon, R.A. Staff, C.S.M Turney, and J. van der Plicht. 2013. IntCal13 and marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55(4)1869–1887.

Scott, S.A. 1991. Problems with the use of flake size in inferring stages of lithic reduction. *Journal of California and Great Basin Anthropology* 13:172-179.

Sullivan, A.P., and K.C. Rozen. 1985. Debitage analysis and archaeological interpretation. *American Antiquity* 50:755-779.

OCCASIONAL PAPER NO. 38 (2018) ISBN: 978-1-4601-3817-5