The Late Holocene White River Ash East Eruption and Pre-contact Culture Change in Northwest North America

by

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ABSTRACT

The White River Ash East eruption of A.D. 846-848 blanketed portions of Subarctic Yukon and Northwest Territories, Canada in volcanic ash. This dissertation examines impacts of the eruption on pre-contact hunter-gatherer social relationships. The main bodies of data on which interpretations are based are previously published palaeoenvironmental records, historic records of Indigenous practices, and previously unpublished provenance studies of obsidian (generated through portable X-ray fluorescence, instrumental neutron activation analysis, and laser ablation-inductively coupled plasma-mass spectrometry) and Tertiary Hills Clinker (generated through portable X-ray fluorescence), both of which were used to make pre-contact stone tools. Obsidian and Tertiary Hills Clinker distributions reveal expansive social relationships in the Yukon and Mackenzie river basins that span the Holocene. Changes in raw material distributions after the White River Ash East eruption suggest that some residents in the tephra footprint in the Yukon Basin temporarily abandoned their territories and returned up to a century later with strengthened networks involving kin from southeast Alaska. Residents of the eastern extent of the tephra footprint in Northwest Territories also experienced a disruption to social relationships that may relate to a temporary reliance on kin from the barren grounds east of Mackenzie River. The utilization of hunter-gatherer kinship networks to weather an ecological disturbance promoted new modes of economic exchange and the transfer of technologies, including the spread of the bow and arrow and the intensification of copper use.

PREFACE

Chapter 2 of this thesis has been accepted for publication as "Kristensen, T.J., Beaudoin, A.B., and Ives, J.W. In Press. Environmental and hunter-gatherer responses to the White River Ash east volcanic eruption in the late Holocene Canadian Subarctic. *Arctic* 73(2)." I was responsible for literature review, data collection, analysis, and interpretation, and lead authorship of the manuscript. A.B. Beaudoin and J.W. Ives contributed to manuscript composition and assisted with data analysis and interpretation.

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Chapter 5 of this thesis is in preparation for publication in *Arctic Anthropology* as "Kristensen, T.J., Supernant, K., and Ives, J.W. Power, security, and exchange: Impacts of a late Holocene volcanic eruption in Subarctic North America". I was responsible for literature review, data interpretation, and manuscript composition. K. Supernant assisted with data interpretation and manuscript composition. J.W. Ives was the supervisory author and assisted with manuscript composition.

The introductory material in Chapter 1 is my own original work.

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CHAPTER 1: INTRODUCTION

1.1 Dissertation Summary

This dissertation focuses on impacts of a volcanic eruption at A.D. 846-848 on hunter-gatherers in northwest North America (Figure 1.1). I provide syntheses of published palaeoenvironmental studies and new archaeometric data contextualized by ethnohistoric records to elucidate human responses to tephra dispersal in Subarctic Yukon and Northwest Territories (N.W.T.). Lithic provenance studies of Tertiary Hills Clinker (THC) enable a reconstruction of pre-contact social networks before and after the White River Ash east (WRAe) eruption in the Mackenzie Basin of N.W.T., while obsidian analyses provide a means to infer social networks between people of the Yukon Basin and those from coastal southeast Alaska and northwest British Columbia.

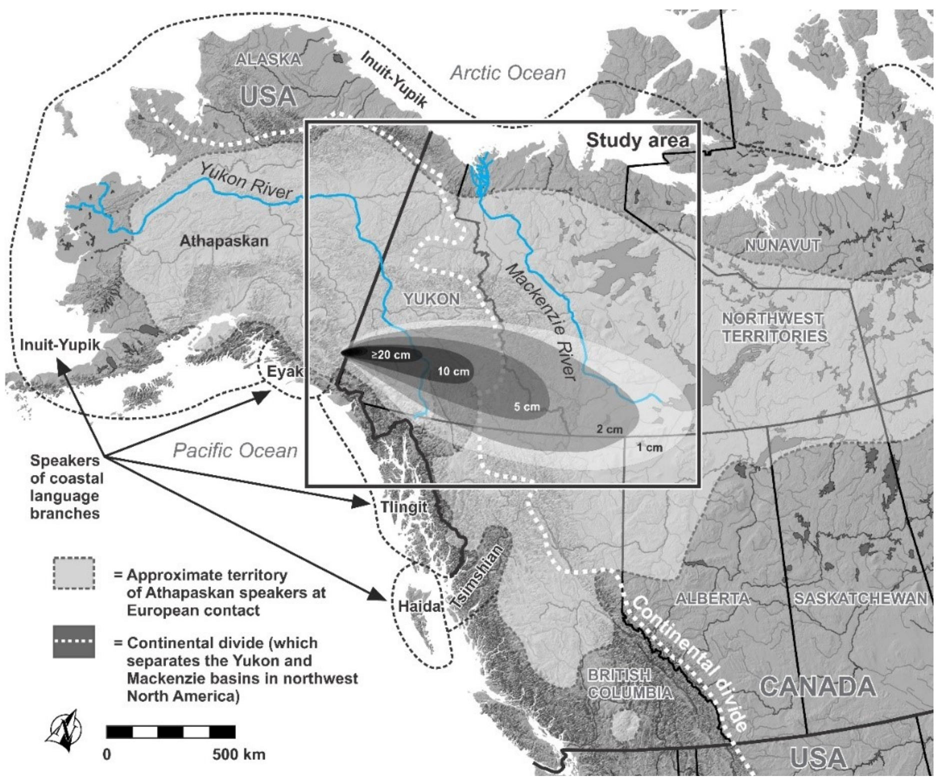

Figure 1.1 Study area and WRAe tephra isopachs (adapted from Lerbekmo, 2008).

Social networks are here conceived of as connections between groups through which information and resources are channeled (Wetherell et al., 1994). Emphases in this dissertation are directed towards the importance of those connections or relationships as structural regularities in a group or society that influenced individual actions (Otte and Rousseau, 2002), particularly actions in response to an ecological event. I explore resiliency in a context of network-mediated migration (Butterworth, 1962; Kemper, 1977; Kearney, 1986; Massey et al., 1987; Wilson, 1994), whereby social relationships or networks, in conjunction with economic variables, shape and sustain population movements (Brettell, 2000), both away from, and back to, ancestral homelands. Resilience here refers to both the capacity to recover and the shape of the resulting adaptations. Resilience among groups of people can therefore involve completely different behaviors or relationships than those that existed prior to a disturbance. A major volcanic eruption in the past, like many ecological events, was a dynamic force both destructive and creative. In complex socio-political landscapes, certain groups capitalized on opportunities afforded by the destabilizing force of a large-scale event to further their interests, which re-organized relationships and stimulated new forms of resilience (Holling, 2001; Gunderson and Holling, 2002; Redman, 2005).

The dissertation builds on the academic work of geologists who have studied the WRAe event (Capps, 1915; Lerbekmo and Campbell, 1969; Lerbekmo et al., 1975; McGimsey et al., 1992; Richter et al., 1995; Robinson, 2001; Jensen et al., 2014; Preece et al., 2014) and that of the archaeologists and linguistic anthropologists who have debated links between the ecological disturbance and major cultural events in pre-contact North America (Workman, 1974, 1979; Derry, 1975; Ives, 1990, 2003, 2010, 2014; Clark, 1991; Hare et al., 2012; Magne, 2012, Magne and Matson, 2010; Moodie et al., 1992; Mullen, 2012; cf. Gordon, 2012a). WRAe has been both proposed and rejected in the literature as an important trigger for local technological changes and for the migration of Dene ancestors from northern Canada into the U.S. Southwest and southern Plains. This dissertation presents empirically-driven hypotheses about the impacts of the eruption on pre-contact people in Subarctic Canada.

I argue that hunter-gatherer resilience to disturbance was shaped in large part by networks of kinship and economic exchange that differed between the Yukon and Mackenzie basins, which respectively related to exertions of power over contested resources versus affordances of security to intercept coveted resources. The means that pre-contact hunter-gatherers maintained or redressed ecological imbalances through kinship and the modes of economic exchange with their neighbours shaped respective trajectories of resilience to disturbance events. Adaptive responses to the WRAe eruption appear to have influenced the ensuing movement of bow and arrow technology from coastal Alaska into Yukon and the proliferation of copper utilisation in northwest North America.

The dissertation consists of four related manuscripts submitted to peer-reviewed journals. Chapters two, three, and four present distinct bodies of data and interpretations regarding the WRAe eruption. Chapter 5 synthesises the previous chapters and extends their implications to provide a unified narrative of the impact of a Late Holocene volcanic eruption on pre-contact people in N.W.T. and Yukon.

Chapter 2, *Environmental and hunter-gatherer responses to the White River Ash east volcanic eruption in the late Holocene Canadian Subarctic*, presents published palaeoenvironmental data (primarily pollen and charcoal records) alongside studies of modern ash fall ecology and human health to infer effects of WRAe on hunter-gatherer subsistence. Using trophic links, I argue that negative biological effects of the ash temporarily pushed hunter-gatherer populations to neighbouring and less affected kin groups for up to a century. A version of this chapter was accepted in the journal *Arctic* (Kristensen et al., in press).

Chapter 3, *The movement of obsidian in Subarctic Canada: Holocene social relationships and human responses to a large-scale volcanic eruption*, presents previously unpublished obsidian provenance data from 462 archaeological sites in Yukon and N.W.T. I argue that social mechanisms explain overlapping occurrences of exotic and local obsidians and that the volcanic ash fall associated with WRAe triggered changes to obsidian exchange patterns. Following the volcanic event, obsidian from British Columbia moved north into Yukon with higher frequency than it previously had while local obsidian use remained largely consistent. This suggests that the ash did not cause population replacement but rather a temporary abandonment. Yukon hunter-gatherers sought refuge to the southwest where they strengthened networks of exchange that were retained upon their return. A version of this chapter was published in the *Journal of Anthropological Archaeology* (Kristensen et al., 2019b).

Chapter 4, *Identifying and sourcing pyrometamorphic artifacts: Clinker in Subarctic North America and the hunter-gatherer response to a late Holocene volcanic eruption*, presents previously unpublished X-ray diffraction, thin section analyses, and electron probe microanalyses to identify and characterise a pyrometamorphic rock used for stone tool manufacture in the Mackenzie Basin. THC is then geochemically compared to other pyrometamorphic rocks used by pre-contact people across North America to demonstrate that it can be sourced using portable X-ray fluorescence. A comparison of pre- and post-WRAe distribution patterns of THC suggest that the eruption fragmented modes of lithic exchange and associated social networks. A version of this chapter was published in the *Journal of Archaeological Science: Reports* (Kristensen et al., 2019a).

Chapter 5, *Power, security, and exchange: Impacts of a late Holocene volcanic eruption in Subarctic North America*, synthesises elements of the previous chapters regarding environmental and cultural change following WRAe to demonstrate that social networks shaped responses to natural disasters. The adaptations of people in the Yukon and Mackenzie river basins are contrasted. Local impacts of the eruption on pre-contact people in both Subarctic basins are then extended to illuminate broader impacts on technological change. A version of this chapter is intended for submission to *Arctic Anthropology* for publication consideration (Kristensen et al., in preparation).

This research demonstrates that social and political landscapes were complex among pre-contact Subarctic hunter-gatherers and their responses to ecological events can be reconstructed through syntheses of palaeoenvironmental, archaeological, and ethnohistoric records. Ecological and social conditions influenced resilience to a large-scale volcanic eruption that presented opportunities for the transmission of technologies, new modes of economic exchange, and the socio-political rise of opportunistic groups of hunter-gatherers. Disturbance events ushered profound cultural change by triggering new patterns of human contact and stimulating the fluorescence of ideas.

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CHAPTER 2: ENVIRONMENTAL AND HUNTER-GATHERER RESPONSES TO THE WHITE RIVER ASH EAST VOLCANIC ERUPTION IN THE LATE HOLOCENE CANADIAN SUBARCTIC

Abstract

The eastern lobe of the Alaskan White River Ash volcanic event of A.D. 846-848 blanketed portions of Yukon and Northwest Territories, Canada, in 5 to 50 cm of tephra. The eruption has been linked to concurrent changes among hunter-gatherers, including the spread of new technologies and the continent-wide migration of a group of Dene ancestors from Subarctic Canada to the U.S. We use published palaeoenvironmental data (primarily pollen and charcoal profiles) as well as studies of modern ash fall ecology and human health hazards associated with eruptions to reconstruct effects of the White River Ash east event on northern hunter-gatherer subsistence. While many components of local ecosystems appear to have rebounded quickly from ash deposition, we deduce a more pronounced impact on the important game species of caribou and salmon, the seasonal migration paths of which were intersected by thick deposits of ash. A trophic model informed by palaeoenvironmental data and ethnohistoric records suggests that negative biological effects of the ash temporarily pushed hunter-gatherer populations to neighbouring and less affected kin groups for up to 100 years. This synthesis contextualises archaeological theories of human responses to ecological disturbance events in circumpolar landscapes.

2.1 Introduction

Large-scale natural disturbances in the past have garnered archaeological interest as catalysts of change. Volcanic eruptions, earthquakes, and tsunamis have been portrayed as stimuli of new modes of cultural resilience (Jacoby et al., 1999; Losey, 2005; Williams, 2002; Elson et al., 2007; Sheets, 2007; Begét et al., 2008; Fitzhugh, 2012; Torrence, 2016; Mohlenhoff and Butler,

2017) and as instigators of unrest, conflict, and forced relocation (Mackie, 1961; Black, 1975; Dumond, 1979; Sheets et al., 1991; Cronin and Cashman, 2007; Riede, 2016). Studies of past disasters are best supported by accurate reconstructions of an event's ecological parameters including magnitude, duration, impact on flora/fauna, and implications for human access to food, water, and shelter (Grattan, 2006; VanderHoek, 2009; Riede, 2014; Mulliken, 2016). This paper investigates a hypothesis that a late Holocene volcanic eruption in Subarctic Canada spurred human population displacement and technological change (Hare et al., 2012; Kristensen et al., 2019a). We examine impacts of the eruption on hunter-gatherers and their trophic pyramid including flora (based on pollen and charcoal records) and fauna (fish and ungulates based on ancient DNA and studies of modern ash falls), as well as human health (based on records of pre-contact physiology and modern disaster studies). This research helps contextualise a large-scale disturbance event that has been implicated in archaeological theories without thorough investigation of its biological effects.

The White River Ash east (WRAe) volcanic eruption originated in the Wrangell volcanic field (Figure 2.1) near Mount Churchill in Alaska (Lerbekmo and Campbell, 1969; Lerbekmo et al., 1975; McGimsey et al., 1992; Richter et al., 1995; Robinson, 2001; Preece et al., 2014). The Plinian eruption (Volcanic Explosivity Index or VEI of 6.0) produced an estimated 47 km^3 of bulk ejecta (22.5 km^3 dense rock equivalent (DRE)) that spread east across southern Yukon and the Northwest Territories (N.W.T.) (Lerbekmo, 2008). The WRAe event is dated to A.D. 846-848 or 1104-1102 cal yrs BP based on preserved cryptotephra horizons in European bogs and Greenlandic ice cores (Jensen et al., 2014). It is thought that the eruption occurred in late fall or early winter because of: 1) the typically westerly wind patterns during that season (Hanson, 1965; West and Donaldson, 2002); 2) the preservation of ash on steep slopes that would only occur if covered by snow (Hanson, 1965; Lerbekmo and Campbell, 1969); and 3) the preservation of fractured clasts of ash/pumice in floodplain deposits that implies relatively rapid freezing of ash sediment in some areas immediately prior to snowfall (West, 2007).

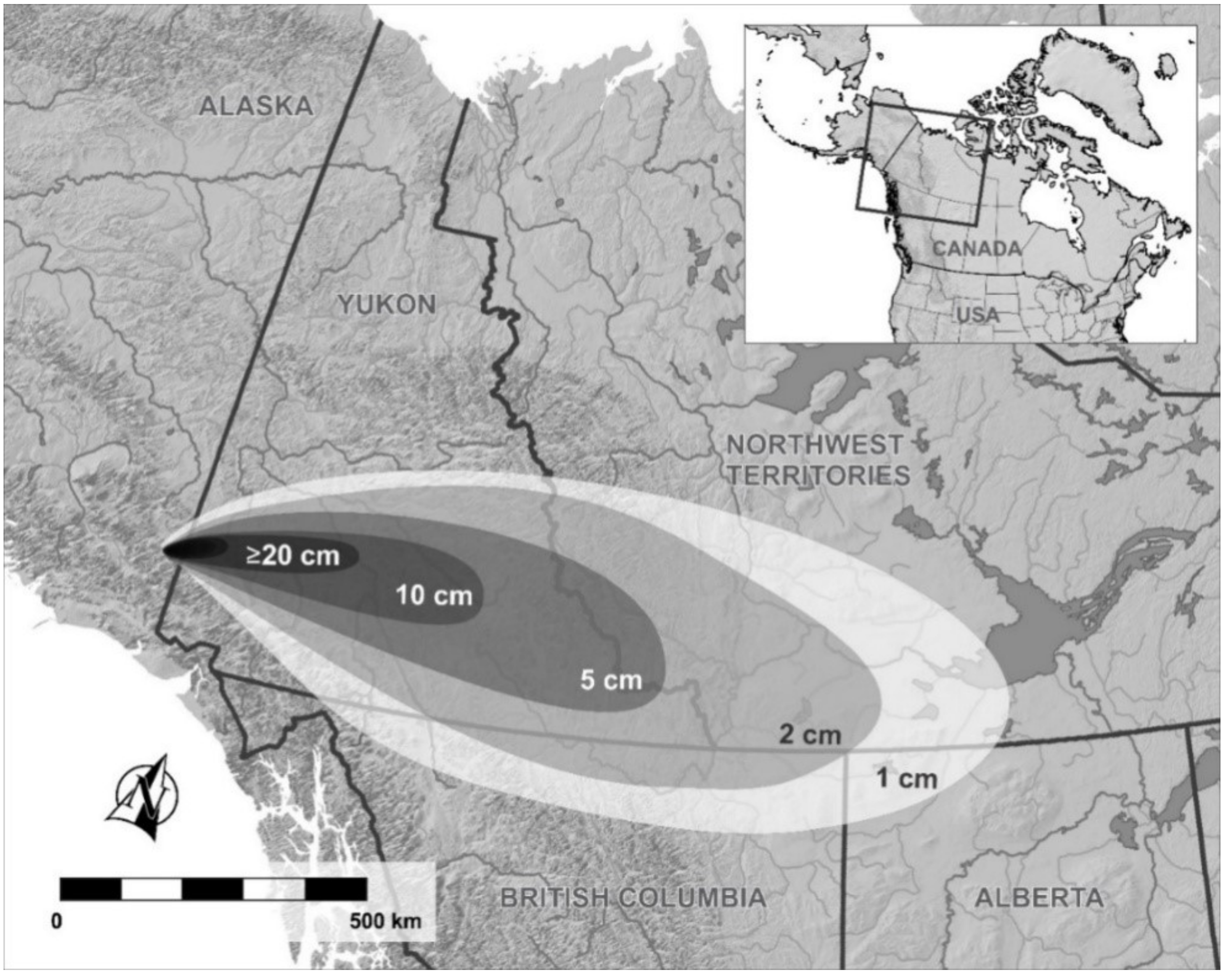

Figure 2.1 Study area and inferred WRAe tephra isopachs (adapted from Lerbekmo, 2008). Isopachs are lines joining a common thickness of ash, here based on terrestrial sediment records. These isopachs are post-compression: tephra compresses up to 50% in the decades following deposition (Aramaki, 1956; Gorshkov and Dubik, 1970:283; Riehle, 1973; Hildreth and Drake, 1992; Guichard et al., 1993; Larsen and Eiríksson, 2008; Blong and Enright, 2011; Engwell et al., 2013) although the compression ratio of WRAe is unknown. The isopachs mark occurrences of visible tephra. It is likely that the ashfall extent is much greater, but would only be detectable by cryptotephra occurrence. Delineation of the ashfall through mapping cryptotephra occurrence remains to be done in this region.

The WRAe event ranks among the five largest eruptions in North America during the past 10,000 years (VanderHoek and Nelson, 2007). In a comparison of ejecta volume, WRAe lies between the Mount Mazama (U.S.) eruption at 7630 cal yrs BP (VEI = 7.0, >180 km^3 of bulk ejecta, 50 km^3 DRE) (Lidstrom, 1971; Bacon, 1983; Zdanowicz et al., 199; Egan, 2016) and the A.D. 1883 eruption of Krakatau in Indonesia (VEI = 6.0, 19 km^3 of bulk ejecta, 12 km^3 DRE) (Rampino and Self, 1982; Mandeville et al., 1996). Five to fifty cm of WRAe tephra fell across a Yukon landscape (Figure 2.1) in which archaeologists have uncovered a long history of hunter-gatherer occupation extending from 13,000 yrs BP to European contact at roughly 150 yrs BP (Workman, 1978; Hare, 1995; Thomas, 2003; Easton, 2007; Easton et al., 2011; Castillo, 2012). Aside from its value as a chronostratigaphic marker (Davis et al., 2016), WRAe has received comparatively little attention from ecologists (Kuhn et al., 2010; Bunbury and Gajewski, 2013; Hutchinson et al., 2019).

Archaeologists have implicated WRAe tephra as a stimulus of cultural change in the Canadian Subarctic (Workman, 1974, 1979; Ives, 1990; Clark, 1991; Hare et al., 2012; Mullen, 2012; cf. Gordon, 2012). The event has assumed a continental importance as a proposed trigger for the migration of Dene ancestors over a linear distance of 3000 km from northern Canada into the U.S. Great Basin and Southwest (Haskell, 1987; Ives, 2003, 2010, 2014; Magne, 2012, Magne and Matson, 2010; Seymour, 2012a; Hill and Trabert, 2018).

Our objective here is to reconstruct biological effects of the WRAe event. We rely principally on published pollen and charcoal records that capture conditions before and after the WRAe event and have been sufficiently studied to warrant a synthesis indicative of trends across the study area. Regional diatom, chironomid, ostracod, and isotope records that span the Holocene epoch (Bradbury and Whiteside, 1980; Anderson et al., 2005; Anderson et al., 2007; Chakraborty et al., 2010; Anderson et al., 2011; Bunbury and Gajewski, 2012, 2013; Rainville, 2015) are not discussed to the same extent as the pollen and charcoal records because their limited geographic distribution prevents an informative regional synthesis. Pollen and charcoal research in the study area has been conducted in a variety of habitats, elevations, and thicknesses of tephra deposition, and reveals diverse impacts of the eruption. Pollen and charcoal syntheses are followed by a discussion of hunter-gatherer subsistence and trophic links between tephra and major game species.

This synthesis contributes to broader theories and international studies of human resilience and adaptability to natural disturbances that are often portrayed as uniformly devastating disasters (Sheets, 1980; Bawden and Reycraft, 2000; Nunn, 2000; Torrence and Gratton, 2002; Williams, 2002; Losey, 2005; Bradtmöller et al., 2017; Fitzhugh et al., 2018; Torrence, 2018). This work highlights temporal gaps in archaeological research of natural disturbances that modern analogues can partially address: the ability to understand palaeoenvironmental impacts on people depends in part on the availability of high resolution records that reveal changes on the order of weeks, months, and years that influenced human survival, as opposed to the scale of decades and centuries that most palaeoenvironmental research targets.

2.2 Palaeoenvironmental records

2.2.1 Pollen

2.2.1.1 Methods and limitations

Published pollen records from lakes, peatlands, and wetlands are the primary sources of data used here to infer vegetation change associated with the WRAe eruption (Figure 2.2). From a total of 55 pollen diagrams in the study area (Table 2.1), we excluded 21 because they lacked temporal resolution (e.g., visible tephra were not detected, they lacked bracketing radiocarbon dates, and/or the cores failed to penetrate through the ash, making it impossible to evaluate changes before and after the event). We input the remaining 34 pollen diagrams into CorelDRAW design software to visually extract the WRAe interval and evaluate relative percentage changes to pollen taxa before and after the tephra.

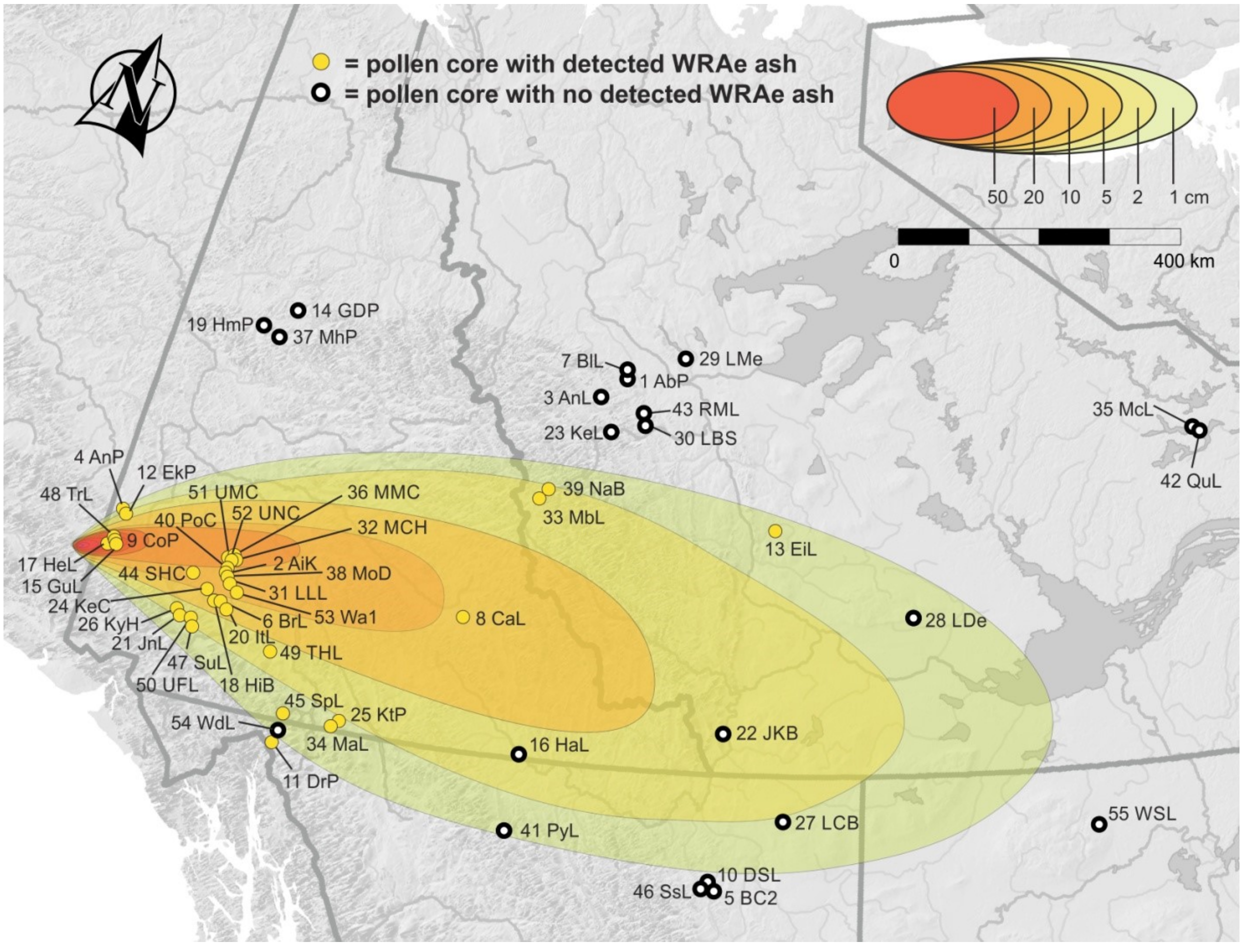

Figure 2.2 Pollen cores utilised in this study. Names and references of core locations are listed in Table 2.1.

Table 2.1 Pollen locales and diagrams evaluated in this study. Grey shaded entries contain enough temporal control to evaluate vegetation changes before and after WRAe.

No.	Abb.	Name	Reference
1	AbP	Abbey Pond, NWT	Szeicz and MacDonald
2	AiK	Aishihik Kettle, YT	Wang 1989
3	AnL	Andy Lake, NWT	Szeicz et al. 1995
4	AnP	Antifreeze Pond, YT	Vermaire and Cwynar
5	BC2	BC2, BC	Pisaric et al. 2003
6	BrL	Bear Lakes, YT	Wang 1989
7	BlL	Bell's Lake, NWT	Szeicz et al. 1995
8	CaL	Candelabra Lake, YT	Cwynar and Spear 1995
9	CoP	Cotton Pond, YT	Birks 1980
10	DSL	Dead Spruce Lake,	Pisaric et al. 2003
11	DrP	Drizzle Pond, BC	Spear and Cwynar 1997
12	EkP	Eikland Pond, YT	Vermaire and Cwynar
13	EiL	Eildun Lake, NWT	Slater 1985
14	GDP	Gray Day Pond, YT	Cwynar and Spear 1991
15	GuL	Gull Lake, YT	Birks 1980
16	HaL	Hail Lake, YT	Cwynar and Spear 1995
17	HeL	Heart Lake YT	Birks 1980
18	HiB	High Bog, YT	Wang 1989
19	HmP	Honeymoon Pond, YT	Cwynar and Spear 1991
20	ItL	Ittlemit Lake, YT	Wang 1989
21	JnL	Jenny Lake, YT	Stuart et al. 1989
22	JKB	John Klondike Bog	Matthews 1980
23	KeL	Keele Lake, NWT	Szeicz and MacDonald
24a	KeC	Kettle Camp, YT	Campbell 1999
24b	KeC	Kettle Camp, YT	Campbell 1999
25	KtP	Kettlehole Pond, YT	Cwynar 1988
26	KyH	Keyhole Pond, YT	Whittmire 2001
27	LCB	Lac Ciel Blanc, BC	Macdonald 1984
28	LDe	Lac Demain, NWT	Macdonald 1987
29	LMe	Lac Meleze NWT	Macdonald 1987
30	LBS	Little Bear River, NWT	Hughes et al. 1993
31	LLL	Long Lost Lake, YT	Keenan and Cwynar
32	MCH	Mackintosh Creek	Beaudet 1986
33	MbL	Marahbodd Lake,	Rainville 2015
34	MaL	Marcella Lake, YT	Anderson et al. 2005
35	McL	McMaster 3, NWT	Moser and Macdonald
36	MMC	Middle Mackintosh	Wang 1989
37	MhP	Monkshood Pond, YT	Cwynar and Spear 1991
38	MoD	Moose Depression,	Wang 1989
39	NaB	Natla Bog, NWT	Macdonald 1983
40	PoC	Polecat Lake, YT	Wang 1989
41	PyL	Pyramid Lake, BC	Mazzucchi 2000
42	QuL	Queens Lake 4, NWT	Moser and Macdonald
43	RML	Rouge Mountain Lake,	Szeicz and MacDonald
44	SHC	Shaky Hand Creek,	Campbell 1987
45	SpL	Spirit Lake, YT	Rainville 2015
46	SsL	Sunset Lake, BC	Pisaric 2001

Table 2.1 continued

47	SuL	Sulphur Lake, YT	Lacourse and Gajewski
48	TrL	Triangle Lake, YT	Birks 1980
49	THL	Two Horseman Pond,	Keenan and Cwynar
50	UFL	Upper Fly Lakes, YT	Bunbury and Gajewski,
51	UMC	Upper Mackintosh	Wang 1989
52	UNC	Upper Nisling Valley,	Wang 1989
53	Wa1	WA01, YT	Rainville and Gajewski
54	WdL	Waterdevil Lake, BC	Cwynar 1993
55	WSL	Wild Spear Lake, AB	Macdonald 1987

Pollen sums were recorded to evaluate comparability but were not standardised across the dataset: they ranged from minimums of 150 grains per sample to 500. Particularly low pollen sums (e.g., <100) might not capture minor elements of pollen assemblages (see Beaudoin and Reasoner, 1992). Pollen sums on diagrams generally included pollen from upland vegetation comprising trees, shrubs, herbs, and grasses, and excluded aquatics and non-pollen palynomorphs (NPP), such as *Sphagnum* spp. spores. Most of the tree and shrub taxa are wind pollinated although typical dispersal distances vary between taxa. This bias towards upland terrestrial taxa is here considered acceptable given that we are interested in trophic links largely based on terrestrial ecosystems. Eleven terrestrial taxa were present in enough diagrams to warrant comparison: *Pinus* spp. (pine), *Picea* spp. (spruce), *Betula* spp. (birch), *Populus* spp. (poplar/aspen), *Alnus* spp. (alder), *Salix* spp. (willow), *Juniperus* spp. (juniper), Ericaceae (heather), Cyperaceae (sedge), Gramineae (grass), and *Artemisia* spp. Note that Gramineae is now referred to as Poaceae but we have used the plant taxon names as given in the publications and have not updated the nomenclature to reflect current taxonomy. *Sphagnum* spp. spores were generally presented in diagrams separate from the taxa above and we include them here as the twelfth taxon in our comparison.

We recorded pollen changes in five broad categories to retain some quantitative value despite disparate datasets: major increase (>20% increase in the pollen of a specific taxon in the core sampling intervals that span the WRAe), minor increase (5 to 20%), no significant change (-5 to 5%), minor decrease (-5 to -20%), and major decrease (<-20%). Note that due to closure on the percentage values, changes in pollen percentages may reflect changes in the input of pollen from other taxa included in the pollen sum, rather than a change in the input of pollen from the taxon under consideration. Figure 2.3 contains two annotated pollen diagrams to illustrate the method. Attempts were made to ensure that the percentage changes in taxa were recorded from before WRAe to immediately after the WRAe tephra (as opposed to changes in relative pollen percentages within tephra bands, which may be more heavily influenced by pollen preservation patterns during deposition as opposed to changes in plant communities). However, the ability to target the precise interval of ash fall is hindered by processes of re-deposition (e.g., re-activation of ash by wind) that can be difficult to distinguish in the stratigraphic record.

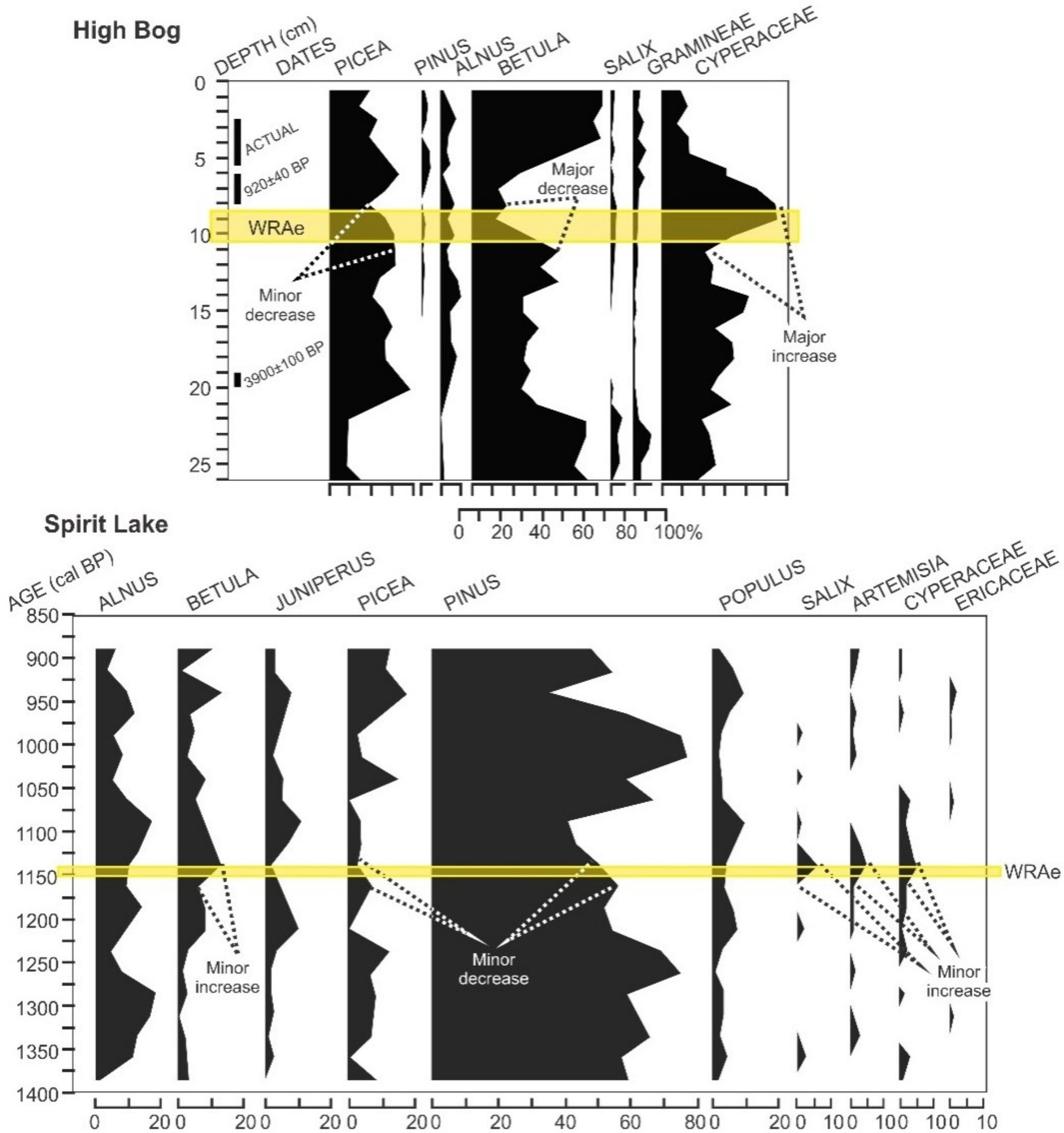

Figure 2.3 Annotated pollen diagrams that illustrate the selection of WRAe intervals based on reported depths of tephra layers and age curve calibrations as reported by authors, in this case, Wang (1989) for High Bog (above) and Rainville (2015) for Spirit Lake (below). The categories of change are based on pollen percentages; some examples of minor and major increases and decreases are annotated. This process was completed for the 34 pollen diagrams highlighted in Table 2.1.

Pollen diagram syntheses are subject to limitations. Researchers sampled cores at different intervals (1 to 10 cm), therefore some diagrams capture plant communities immediately before and after WRAe while others predictably have lags. In the vast majority of studies, researchers investigated broader climate and vegetation changes through the Late Pleistocene and Holocene epochs, and utilised the WRAe tephra as a chronostratigraphic marker, not as a potential catalyst of vegetation change. None of the studies incorporated high-resolution sampling through the WRAe interval, so fine-scale ash-driven change has not been captured. Interpretations of WRAe impacts presented below are largely our own (cf., Birks, 1980; Slater, 1985; Rainville, 2015). Lastly, in six instances when tephra were either very diffuse or not detected, bracketing radiocarbon dates enabled evaluation of the WRAe interval, although these radiocarbon dates and their interpretation are subject to error. Despite these limitations, a regional synthesis offers opportunities to investigate patterns of tephra impacts on vegetation.

2.2.1.2 Pollen results

Vegetation responses to the eruption were variable (Figures 2.4 and 2.5). Of the 337 evaluations of taxa (Table 2.2), the most common response to the WRAe was no significant change (65.8%). Colonizing/pioneer species that would predictably respond well to ash disturbances (e.g., *Salix* and *Alnus* spp.) do not exhibit consistent positive responses to WRAe (Figure 2.4), suggesting that ecological effects of the tephra were neither drastic nor uniform. Pollen records north of the WRAe lobe (Figure 2.2) suggest that some vegetation changes may be either independent from the ash or occurred on regional scales that extended beyond the ash footprint.

Two taxa display informative trends. Within tephra depths of 2 cm or greater, *Picea* spp. pollen predominantly decreases (Figure 2.4) and within tephra zones of 5 cm or greater, Cyperaceae pollen predominantly increases (Figure 2.5). Although it is wind-dispersed, *Picea* spp. pollen tends not to travel long distances and is therefore indicative of local pollen production, as opposed to *Pinus* spp. pollen, which travels long distances (Davis and Goodlett, 1960; Janssen, 1966; Campbell et al., 1999). The relatively consistent decrease in *Picea* spp. pollen indicates either an increase in tree mortality or decrease in tree viability. Cyperaceae includes upland and wetland sedges in the study area, both of which produce pollen that tends not to travel far (Ritchie and Lichti-Federovich, 1967; Sugita et al., 1999).

Table 2.2 Evaluations of plant taxa by category.

Category	# of evaluations	%
Major increase	5	1.4
Minor increase	57	16.6
No significant change	227	65.8
Minor decrease	44	12.8
Major decrease	12	3.5
Total	345	

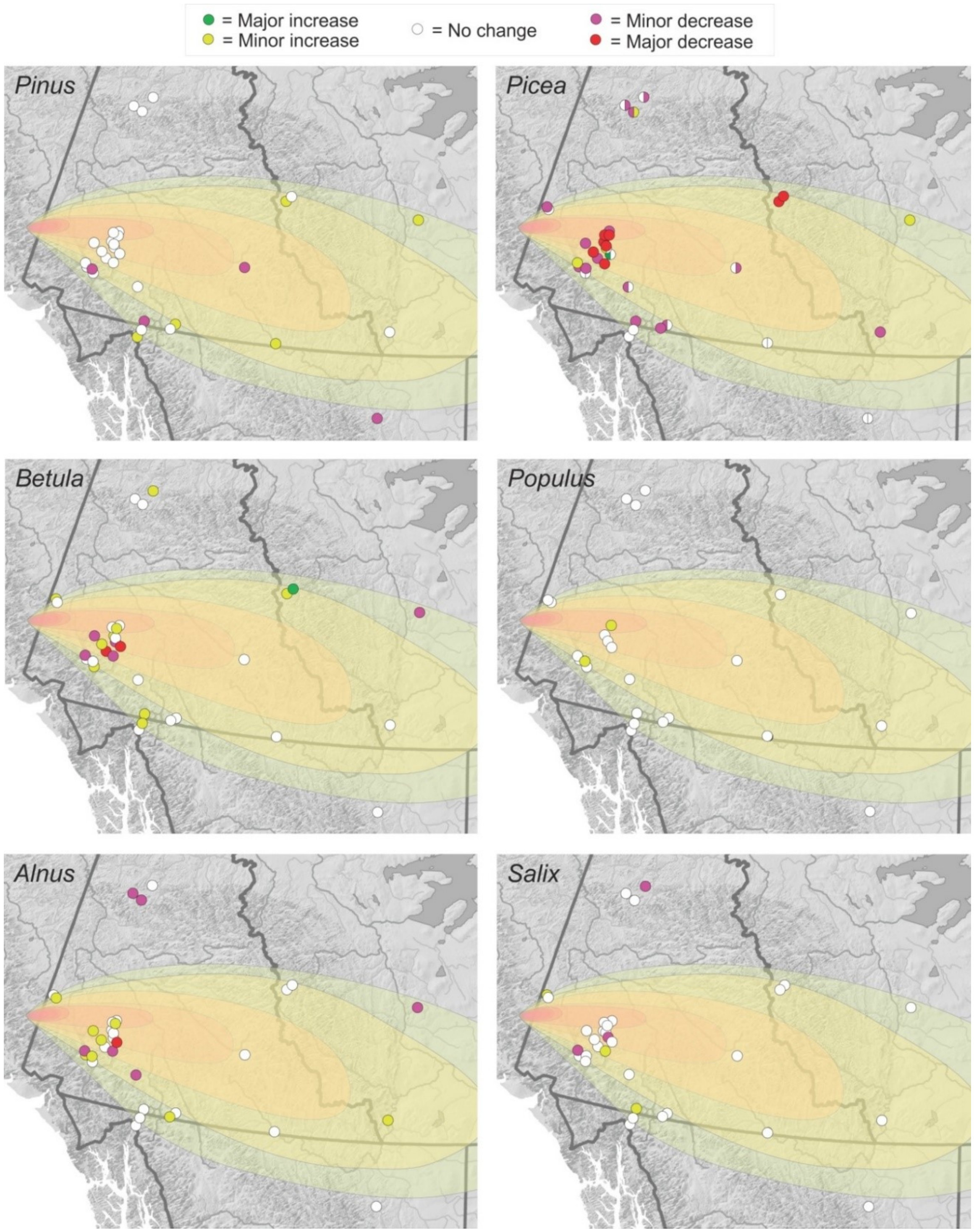

Figure 2.4 Changes in pollen percentages for trees and large shrubs before and after the WRAe. Note that some researchers distinguished *P. glauca* from *P. mariana*, in which case the left portion of a split circle symbol represents *P. mariana* and the right portion represents *P. glauca*.

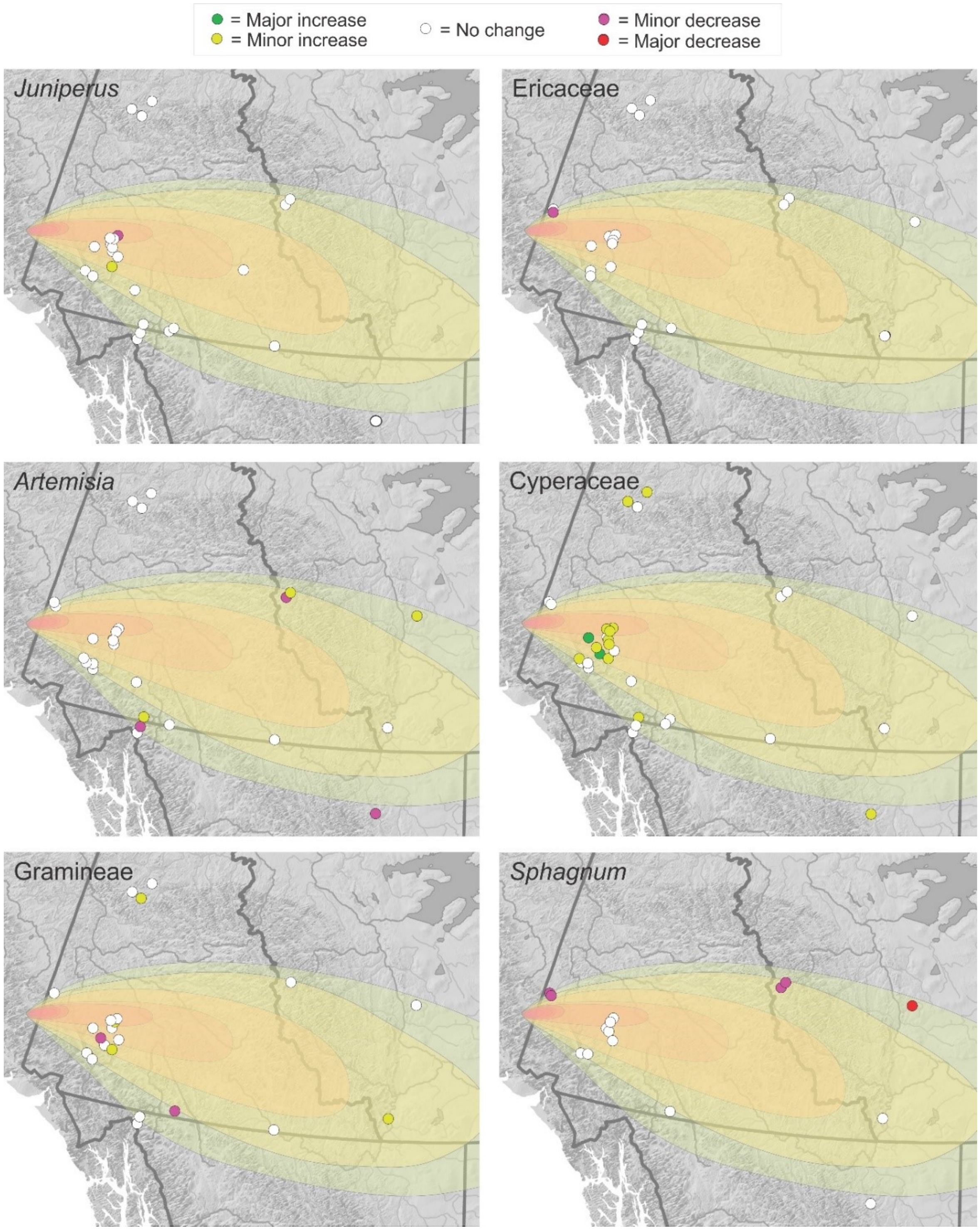

Figure 2.5 Changes in pollen percentages for small shrubs, herbs, grasses, and mosses before and after the WRAe event.

2.2.1.3 Pollen discussion

Research on the impacts of modern eruptions provides analogues for interpretation of WRAe pollen results. Impacts on modern vegetation generally vary depending on the thickness of airborne tephra, grain size, and distance from the vent (tephra tends to be thick, large in grain size, and continuous close to the vent, whereas it becomes thinner, smaller in grain size, and discontinuous farther away). Four to 15 cm of tephra from the 1980 Mount St. Helens eruption in Washington, U.S., killed a large percentage of understory plants and decreased the productivity of conifers and deciduous trees through leaf abscission and photosynthetic disruptions (Black and Mack, 1984; Hinkley et al., 1994; Antos and Zoebel, 2005). Tree mortality was limited to a small percentage of mature conifers in the vicinity of the vent (Segura et al., 1994) although some mature trees of species like Douglas fir can survive over a metre of tephra deposition (Yamaguchi, 1985). Four to five cm of Mount St. Helens tephra killed most mosses but herbs persisted; the response of shrubs and small trees to tephra was diverse and depended on local habitats and distance from the vent.

In a circumpolar environment, 10 cm of ash from the 1907 eruption of Ksudach volcano in Kamchatka eliminated lichen and moss but herbs, shrubs, and trees generally persisted in conditions with less than 30 cm of tephra (Grishin et al., 1996). Grishin (1996) documented an 8% decrease in forest stands under 3 cm of tephra and a 20% decrease in forest stands under 10-12 cm of tephra ten years after the Tolbachik eruption of 1975-76 in Kamchatka. Of Alaska's Novarupta-Katmai eruption in 1912, Griggs (1922) noted a similar widespread destruction and delayed regrowth of low-lying understory species like moss and reindeer lichen (*Cladonia rangiferina*). Long et al. (2014) found that, in areas of 14-50 cm of tephra deposition from Mount Mazama at ca. 7630 BP, arboreal species were minimally affected while the understory took 50-100 years to recover. In an experimental study in Hokkaido, Japan, Hotes et al. (2004) found that mosses had difficulty re-establishing in tephra >6 cm thick but most other mire vegetation taxa were not significantly depressed, particularly when tephra deposition occurred at the end of a growing season.

Environments with more uniform relief, like meadows or clear-cut forests, tend to experience greater damage with more delayed regrowth, while tephra that interacts with snow often develops an impenetrable crust that can delay recovery of plants like mosses for over 40 years (Antos and Zoebel, 2005:56; Ayris and Delmelle, 2012). Modern studies (Magnusson, 1994; Aradóttir et al., 2010) suggest that terrestrial mosses and lichens may have been severely affected after WRAe but this is not detectable in pollen records. Lichens do not have reproductive structures that are detectable in pollen records so they cannot be assessed by this method. Mosses reproduce by spores but most palynologists do not record moss spores to a taxonomic level lower than Bryophyte. A few taxa, such as *Sphagnum* and *Lycopodium*, are, however, readily identifiable to genus level, and these may be tallied in pollen analyses. *Sphagnum* spores are commonly present in peatland samples, especially if the peatland is ombrotrophic because bogs are generally *Sphagnum* dominated. Fluctuations in the abundance of *Sphagnum* spores may be indicators of moisture status of the peatland (i.e., wetter/drier intervals). As such, their abundance is tied to local moisture conditions in the peatland, controlled in part by topography, but which can reflect either increased atmospheric input or changes in run-off. In instances where moss spores are recorded (in the *Sphagnum* spp. examples above), input from terrestrial mosses is generally not recorded, so it remains difficult to assess terrestrial changes associated with tephra (and cascading trophic impacts up to game animals). However, tephra does increase water retention in soils, preventing evaporation and slowing run-off, which presumably favoured a variety of bryophytes.

The Yukon pollen studies fail to indicate widespread, uniform, and marked vegetation changes associated with the WRAe event. Based on studies of modern eruptions, this is likely attributable to the facts that: 1) much of the pollen research has been undertaken in regions distal to the main fall-out zone (with less than 5 cm of tephra) where ash did not significantly impede regrowth of most woody plant species; 2) many of the pollen records are from areas characterised by high topographic relief that would have facilitated erosion of unconsolidated tephra and limited its disturbance on plants; 3) most vegetation appears to have recovered within several decades (conifer tree ring data from Mount St. Helen's, Washington suggest the recovery of surviving trees to normal growth patterns in about a decade (Yamaguchi and Lawrence, 1993)) but disturbance on this time frame is nearly impossible to detect in these pollen records, most of which were sampled at temporal intervals too large to reveal subdecadal perturbations; and 4) low-lying understory like terrestrial mosses and lichens were the most significantly disturbed by tephra but the signals of these vegetation components are not detectable in pollen studies.

However, observable trends in spruce and sedges warrant discussion. Increased forest fires associated with tephra deposition (Long et al., 2014; Egan et al., 2016) may have decreased spruce populations. It is possible that tephra converted some landscapes (e.g., black spruce muskeg) into habitats more favourable to non-spruce species. If WRAe tephra was deposited in late fall or early winter (Hanson, 1965; Lerbekmo and Campbell, 1969; West and Donaldson, 2002; West, 2007), spruce may have experienced increased mortality associated with snow breakage (tephra is denser than snow and would significantly increase the weight of snow burdens). Because of branch growth patterns, pine trees are often more susceptible to snow damage than spruce (Elfving et al., 2001; Quine and Gardiner, 2007) so predictably, both spruce and pine pollen would decrease after WRAe if snow burdens had a significant effect on mortality and stand composition. Two variables may explain why only spruce appears to decrease following WRAe; 1) pine pollen travels greater distances so it does not reflect local conditions to the extent that spruce pollen does; and 2) pines thrive following fires, which may explain a quicker regional recovery than spruce, and result in difficulty detecting a shorter term decrease in pine. Regardless, if WRAe fell in winter, snow loading, especially in areas exceeding 10 cm of tephra, would likely cause notable conifer damage (see Pruitt, 1958; Päätalo et al., 1999; Hanewinkel et al., 2008; Teste and Lieffers, 2011, for studies of the importance of snow damage in boreal forest ecology). In addition, black spruce have shallow, adventitious roots compared to pine and may have experienced more notable disruptions to growth processes following the deposition of a tephra layer that altered permeability and the near-surface movement of ground water. The cumulative effects of fire, snow/tephra loading, and the alteration of soil permeability may explain a drop in spruce pollen.

An increase in sedges (Cyperaceae) at some localities in central and southern Yukon may relate to deposition of a poorly permeable horizon that reduced infiltration, increased water retention, and/or increased nutrient loading (including phosphorous) that favoured sedges (Major and Yamakoshi, 2005; Hughes et al., 2013; Egan et al., 2016). Sedges are perennials that experience strong re-growth following annual die back so a different ecological response than spruce is expected. The decrease in spruce and increase in sedge appear directly related at several localities (Figures 2.4 and 2.5). Birks (1980) documented the colonization of thick WRAe pumice and ash layers by Cyperaceae-dominated assemblages and it appears that this occurred at a number of regions across Yukon (Figure 2.5). Increases in sedges and grasses have been linked to tephra deposition and an inferred increase in soil wetness in other northern forest habitats by Mehringer et al. (1977b), Mack et al. (1983), Heinrichs et al. (1999), Lotter and Birks (1993), and Egan (2016). Payne and Egan (2019) noted an increase in Cyperaceae pollen in Washington following the Mazama tephra fall. The pollen diagrams of Mehringer et al. (1977a) and Blinman et al. (1979) at separate locales in Montana suggest that pine, *Artemisia* spp., and grass (Poaceae) pollen may have increased following Mazama ash deposition. Snow breakage, forest fires, and increased saturation of sediments associated with tephra may have led to a decrease in coniferous species (spruce and pine) followed by a rapid increase in sedges and pine in some habitats.

Keller-Pirklbauer et al. (2007) found that tephra accumulation led to permafrost aggradation in Iceland and it is likely that similar conditions prevailed following WRAe deposition in Yukon and N.W.T., which are high latitude areas characterised by permafrost. The expansion of permafrost layers and ground ice in wetlands may have also favoured sedge growth and hindered spruce re-growth. This pattern would be predictably more exaggerated in colder, high altitude regions. Alpine areas, including those of the Mackenzie Mountains, may have been more susceptible to long-term vegetation change because of slower ecological succession in response to tephra (Arnalds, 2013), permafrost aggradation, as well as a lower and more uniform vegetation canopy (alpine meadows vs. lower valley forests) that was more consistently smothered by tephra (see Kershaw and Gill, 1979 for a discussion of the impact of WRAe tephra on permafrost aggradation and palsa formation in an alpine region of western N.W.T. in the current study area).

In summary, pollen data demonstrate that most taxa were not significantly influenced over long time periods by the WRAe event. Where changes were noted, responses were quite variable even within tens of kilometres, which is indicative of diverse impacts that were likely dependent on different local ash thicknesses, basin sizes, elevations, erosion patterns, and forest canopy. Patches of biota that persisted probably served as nuclei of revegetation. Within the 5 cm tephra isopach in particular, sedge pollen increases while spruce decreases at some localities - plant community canopies appear to have opened up, particularly within 300 km of the WRAe origin. The WRAe-related pollen fluctuations are unlike those that occurred during other narrow Holocene time intervals (e.g., a 100-year time span): there do not appear to be similar patterns of spruce decrease and sedge increase over such a large area. Relatively small and frequent ecological events like forest fires may have pre-adapted local biota to disturbances but modern studies and the current regional pollen review point to the WRAe event as a disturbance factor that created mosaic environments on a much larger spatial extent than wildfires.

2.2.2 Charcoal

2.2.2.1 Methods and limitations

Charcoal generated by forest fires is introduced to lakes and bogs through run-off and aerial transport, and can serve as a proxy indicator of climate, anthropogenic burning, and large-scale disturbances such as fires associated with tephra deposition (Patterson et al., 1987; Gardner and Whitlock, 2001). Researchers have linked fires to tephra in palaeoenvironmental studies due to intense lightning associated with ash clouds during the eruptive event (Wilcox, 1959; Thorarinsson, 1979; Hoblitt, 1994; Beierle and Smith, 1998; Hallett and Walker, 2000; McNutt and Davis, 2000) and plant desiccation in the following months or years (Wilmshurst and McGlone, 1996; Long et al., 2014). Needle fall, dead standing timber, and the desiccation of shrubs and herbs increase fuel loads (Long et al., 2011).

Microcharcoal (<100 µm) can be transported large distances by winds and run-off (Clark, 1987) and tends to indicate larger regional trends associated with fire activity (Patterson et al., 1987). Macroscopic charcoal (>100 µm) provides more local indications of forest fires (Gardner and Whitlock, 2001). Both micro- and macrocharcoal data from cores were amassed from publications and dissertations (Table 2.3) and input into design software to extract the WRAe interval and evaluate fire frequency and regional trends during and shortly after the tephra. Charcoal levels (as measured in particles/cm²/year or particles/gram dry weight/year) were classified in five broad categories within or immediately above tephra for comparative purposes: major increase (>50% increase in the charcoal particles), minor increase (20 to 50%), no significant change (-20 to 20%), minor decrease (-20 to -50%), and major decrease (<-50%). As in the synthesis of pollen studies, researchers sampled cores at different intervals (1 to 5 cm), so some diagrams capture immediate changes while others have lags. In the majority of studies, researchers were investigating broader Holocene climate and vegetation changes and therefore did not discuss direct associations of charcoal and tephra.

Table 2.3 Charcoal extraction locales and diagrams evaluated in this study.

No.	Abb.	Name	Reference
26	KyH	Keyhole Pond, YT	Gajewski et al., 2014
33	MbL	Marahbodd Lake,	Rainville, 2015
34	MaL	Marcella Lake, YT	Edwards et al., 2015
45	SpL	Spirit Lake, YT	Rainville, 2015
47	SuL	Sulphur Lake, YT	Lacourse and Gajewski,
50	UFL	Upper Fly Lakes,	Bunbury and Gajewski,
53	Wa1	WA01, YT	Rainville and Gajewski,
57	BbL	Burnt Bowl Lake,	Marcantonio, 2007
58	SmL	Salmo Lake, YT	Edwards et al., 2015
59	DfL	Dragonfly Lake,	Edwards et al., 2015
60	HcL	Haircut Lake, YT	Edwards et al., 2015
61	YK1	YK1	Pellow, 2016
62	YK3	YK3	Pellow, 2016
63	YK5	YK5	Pellow, 2016
64	SyL	Spindly Pine Lake	Prince et al., 2018

2.2.2.2 Charcoal results

Charcoal records, like the pollen studies, are variable across the study area (Figure 2.6) although most micro- and macrocharcoal studies demonstrate minor or major increases following the WRAe event. This suggests increases in both local and regional fire regimes. However, some habitats (e.g., those at high altitudes and/or with relatively small catchment basins like Upper Fly Lake, Sulphur Lake, and YK3) appear to have undergone no visible change in fire dynamics. In virtually all cases, the abundance of charcoal following WRAe is not unique in the Holocene fire history of each study site, but no other narrow time interval across the whole study area occurs in which fires appear to have been as common as that following the WRAe event.

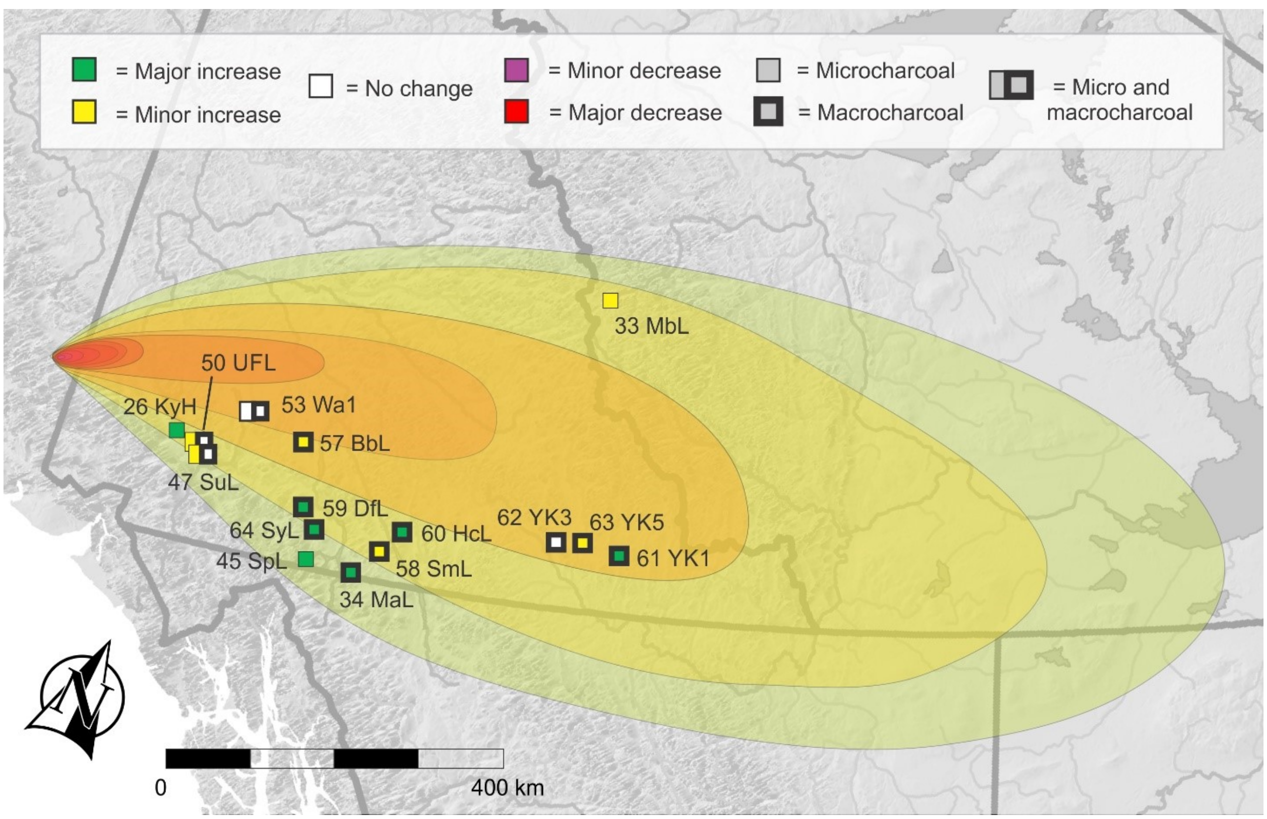

Figure 2.6 Charcoal locations and results.

2.2.2.3 Charcoal discussion

Long et al. (2014) and Egan et al. (2016) linked Mount Mazama tephra deposition to local and regional fires that were presumed to have been promoted by increased fuel loads associated with plant mortality or stress. However, their results were not uniform, with some localities displaying little or no connection between tephra deposition and ensuing fires. Studies of links between modern eruptions and fires are rare and would perhaps be less informative as analogues because of modern fire suppression (wildfire fighting efforts) and a host of other factors that limit the extent of recent forest fires (e.g., transportation networks and commercial logging). However, charcoal results from Yukon (though biased toward the southern portion of the study area) do demonstrate a consistent increase in forest fires following deposition of WRAe tephra (Figure 2.6).

When combined with pollen syntheses, the charcoal results suggest that landscapes immediately following the WRAe eruption were not uniformly altered although some experienced a decrease in forest cover and an increase in sedge meadows. Some habitats do not appear to have experienced much change (e.g., small and isolated catchment areas where the probability of fires remained low). The tephra, like other natural large-scale disturbances, probably enhanced environmental patchiness with more local diversity of habitats. Long et al. (2014) view volcanic disturbances as additive through the creation of new habitats and the re-initiation of ecological succession across landscapes, which the current pollen and charcoal studies support. However, the spatial extent of landscape disturbance may have presented challenges up the trophic pyramid to fauna and people.

2.3 Human subsistence following WRAe

We here bridge palaeoenvironmental studies and archaeology through trophic links from vegetation to game animals and hunter-gatherers. This bridge extends over a temporal gap from palaeoenvironmental studies (that reveal century-scale changes) to meaningful time frames for humans and animals (weeks, month, years, and decades). We begin with a summary of human subsistence based on ethnohistoric and archaeological records to focus the ensuing discussion of ecological impacts on important prey species. While climatic records do illustrate some changes in the study area in late Holocene-times (Chakraborty et al., 2010; Anderson et al., 2011; Bunbury and Gajweski, 2012; Gajweski et al., 2014), it is not expected that these changes would have significantly altered animal distributions (e.g., migratory paths of caribou or salmon) from the time of the WRAe eruption to the interval represented by ethnohistoric records (from A.D. 846-848 to the A.D. 1700-1800s). The WRAe event occurred during the global Medieval Warm Period (MWP), which may have involved increased summer and winter temperatures in the study area (Bunbury and Gajewski, 2009) that caused more frequent winter thawing, increased snowfall, and elevated stresses on cold-adapted species in the Yukon (Kuhn et al., 2010). Archaeological records generally fail to illustrate major changes in distributions of important food animals over the past 1000 years but it is worth a cautionary note that the MWP and ensuing phases of regional Little Ice Age advances between A.D. 900 and 1900 may limit the extension of ethnohistoric records to the time of the WRAe event.

2.3.1 Ethnohistoric records and subsistence

The WRAe tephra dispersed across the territories of what were probably several different hunter-gatherer groups based on contact-era distributions (Figure 2.7). Figure 2.8 compares subsistence models of those groups and the neighbours with whom they may have interacted. Models of hunter-gatherer seasonal rounds (the shift from one resource and resource extraction area to another throughout the year) are built from ethnographic records/oral histories (Dawson, 1889; Pike, 1896; Emmons, 1911, 1991; Osgood, 1936; McClellan, 1953, 1975; Honigmann, 1954; Krause, 1956; Teit, 1956; de Laguna, 1972; Gillespie, 1981; Albright, 1982; Grinev, 2005; Legros, 2007; Andrews et al., 2012a) and archaeological records (MacNeish, 1951, 1954, 1960, 1964; Workman, 1978; Shinkwin, 1979; Ives and Sinopoli, 1980; Clark, 1982; Clark and Morlan, 1982; Morrison, 1984, 1987; Hanks and Winter, 1991; Hare, 1995; Gordon, 1996; Holmes, 2001; Thomas, 2003; Farnell et al., 2004; Hare et al., 2004; Dixon et al., 2005; Easton

2007; Richards et al., 2007; Corr et al., 2008; Potter, 2008; Andrews et al., 2012b; Hare et al. 2012).

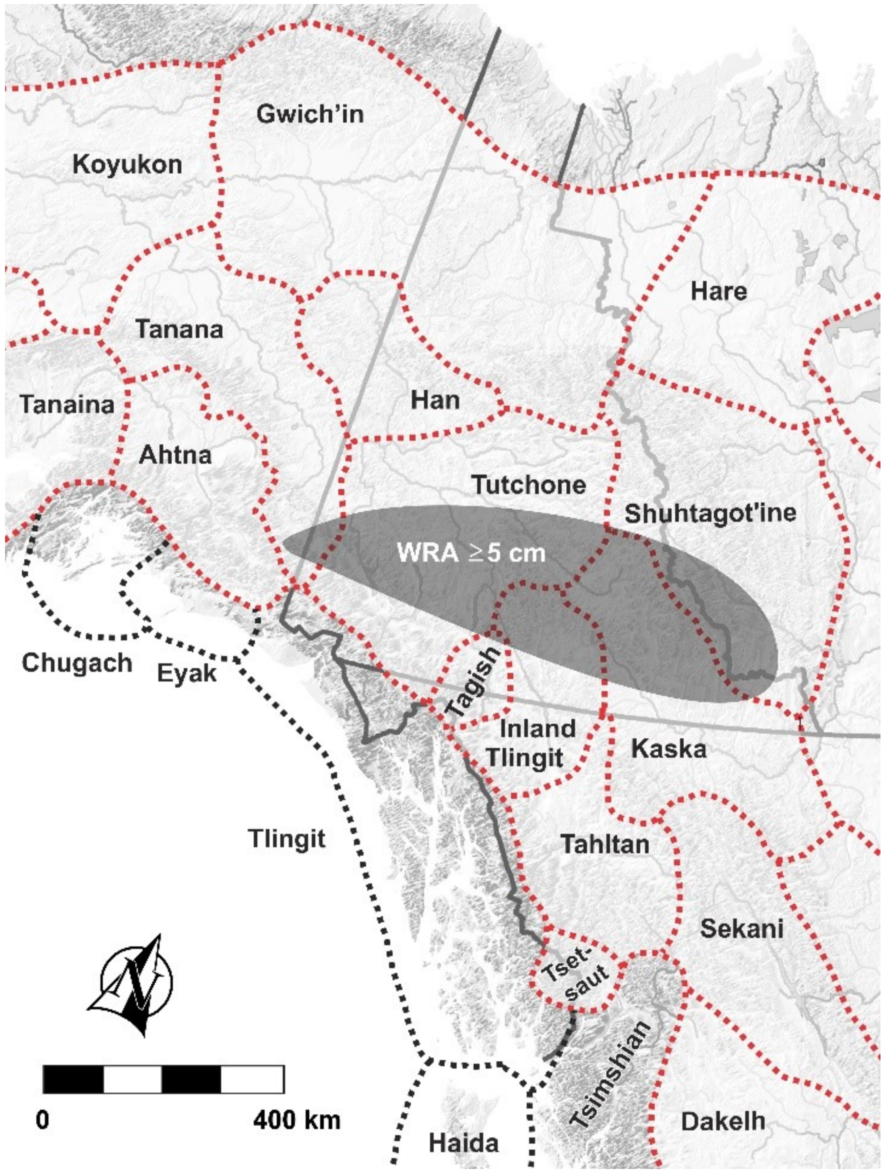

Figure 2.7 Approximate First Nations territories at European contact (adapted from Ives, 1990 and de Laguna, 1972) and the WRAe tephra footprint equal to or greater than 5 cm in thickness (based on Lerbekmo, 2008). Botanical and faunal studies of recent eruptions indicate that the most significant impacts of ash are in tephra zones of 5 cm depth or greater (Capps, 1915; Kurenkov, 1966; Mack, 1981; Seymour et al., 1983; Black and Mack, 1984; Hinckley et al., 1984; Martin et al., 1984; Antos and Zobel, 1985; Tsuyuzaki, 1995; Grishin et al., 1996; Dale et al., 2005; Talbot et al., 2010; Flueck, 2016). Athapaskan (Dene) territories are bordered by red.

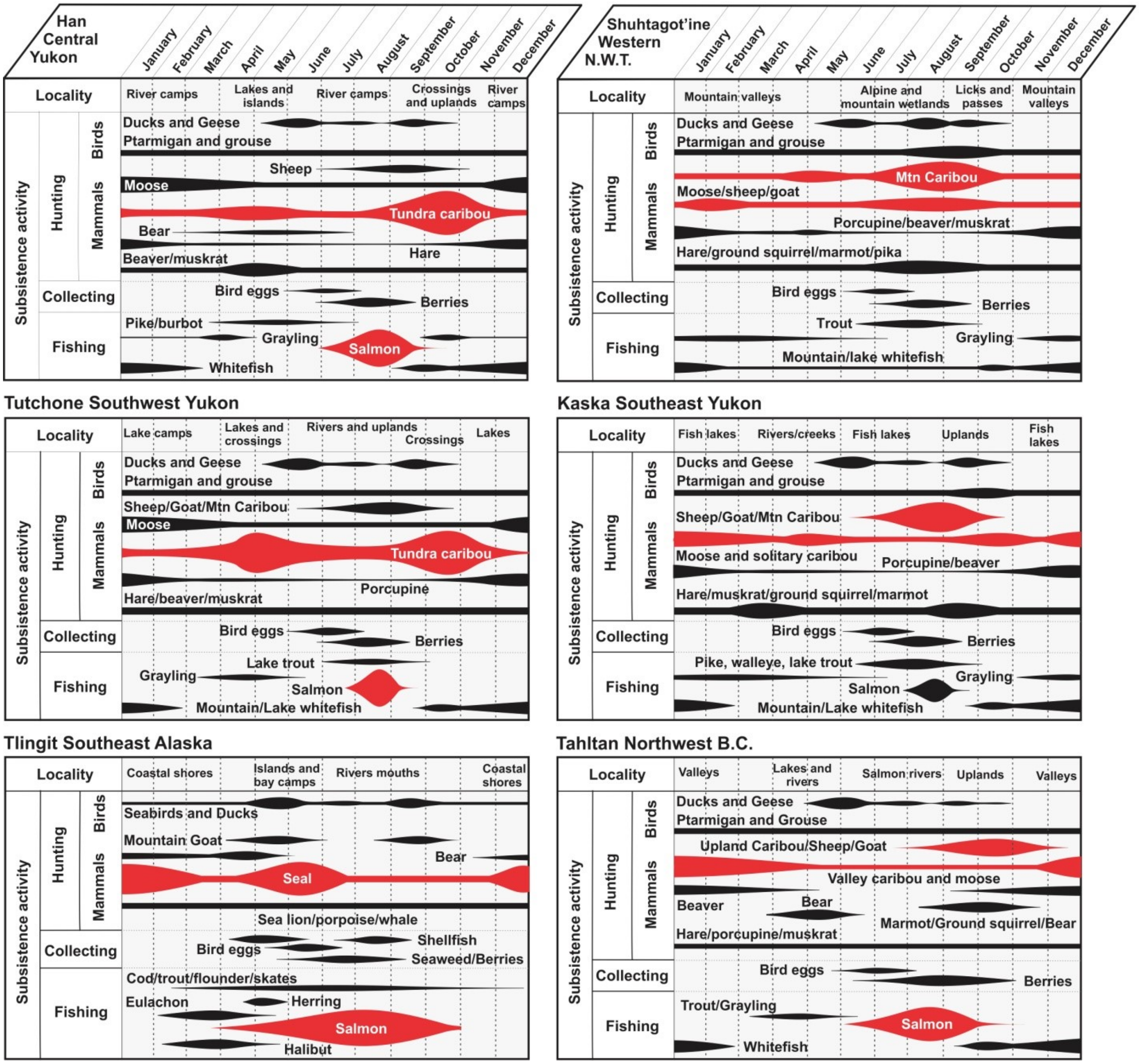

Figure 2.8 Generalized human seasonal rounds in the study area shortly before European contact. Major or key resources are in red. We accounted for contact-era increases in attention to small fur-bearing mammals and the utilization of fisheries to support dogs (both of which assumed greater importance during the fur trade) and for early ethnographic biases towards subsistence pursuits with complex socio-political dimensions (e.g., ungulate hunting tended to receive more early ethnographic attention

than snaring birds although both pursuits seasonally sustained populations). Archaeological data informed these models with acknowledgement that preservation biases may exaggerate the importance of large animals.

In what is now southern and central Yukon, people relied on seasonal migrations of caribou and salmon, both of which have roughly north-south migratory paths that would have been intersected by WRAe tephra (Figure 2.9). Barren ground caribou herds that exceeded 500,000 animals historically migrated from calving grounds in the north each fall to feed in sheltered forests of central and southern Yukon over winter (Valkenburg et al., 1994; Boertje and Gardner, 2000). Scattered herds gathered together in spring to return to northern tundras to calve. Woodland caribou live throughout southern and central Yukon and northern B.C. and have much smaller geographic territories but still migrate seasonally from forested valleys in winter to alpine meadows in summer. Both barren ground and woodland caribou rely on lichens and sedges as principal food sources. Salmon enter the Yukon from the Pacific Ocean primarily via the Yukon and Alsek rivers (Figure 2.9). Several species (chinook, chum, and coho) spawn along Yukon river beds from June until mid-October (Scribner et al., 1998; Brown et al., 2017; Cunningham et al. 2018). Major salmon fisheries also occur along the Stikine River in northern B.C.

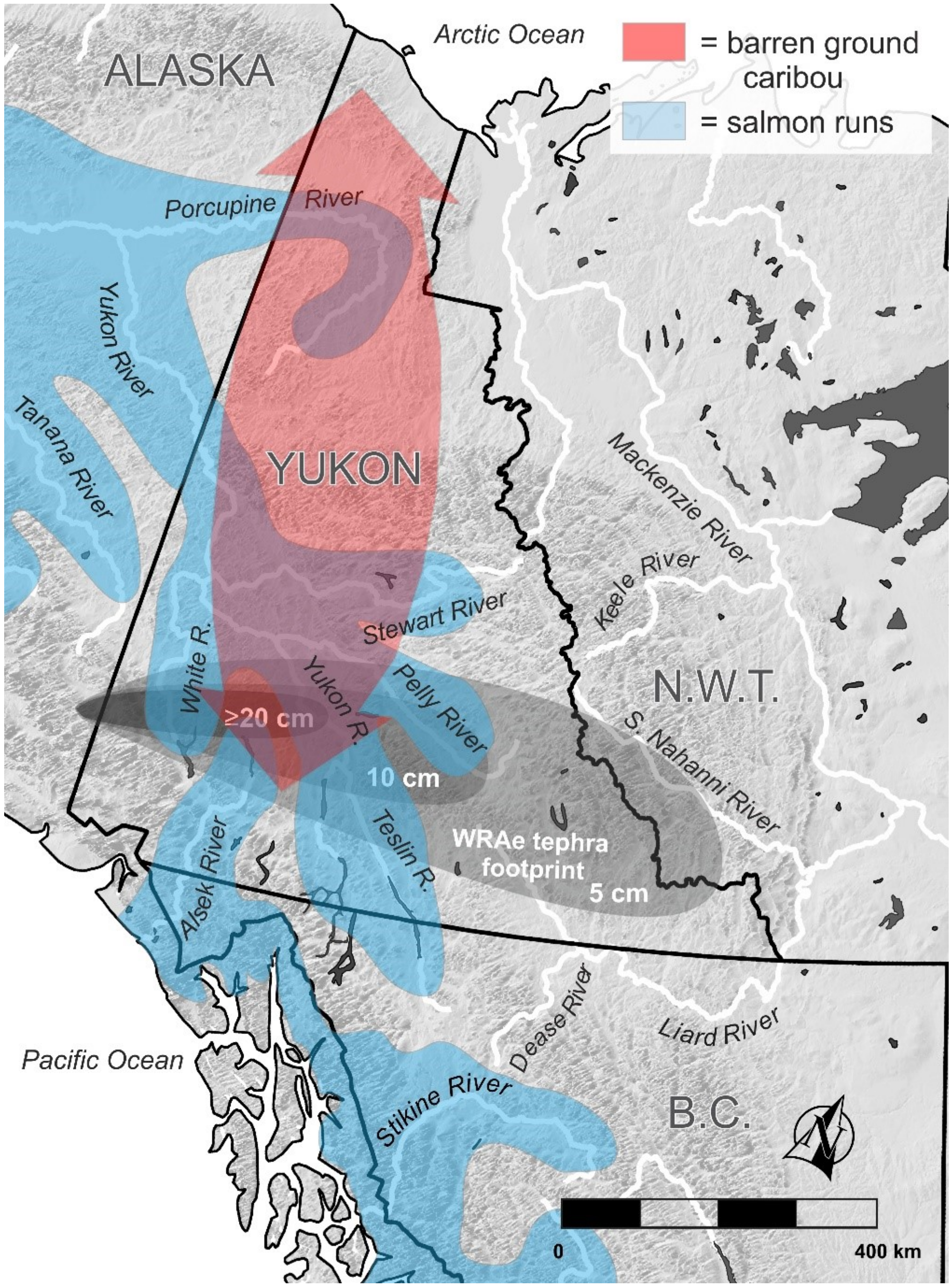

Figure 2.9 Rivers mentioned in text and generalised outlines of the barren ground caribou migration path and the most productive salmon spawning areas in Yukon and northwest B.C.

The diet of neighbours of people impacted by WRAe tephra differed. In the absence of large barren ground caribou herds, the Tahltan and Kaska hunted isolated moose and caribou in valleys, and upland populations of bighorn sheep, mountain goat, woodland/mountain caribou, and marmot (Figure 2.8). Salmon do not spawn in the Mackenzie River Basin where the Shuhtagot'ine and others relied more heavily on upland ungulates and small game (marmot, ground squirrel, and hares), beaver and muskrat in rivers and wetlands, birds, and freshwater fish such as whitefish, pike, lake trout, inconnu, walleye, and burbot (Gillespie, 1981; Andrews et al., 2012b). The coastal Tlingit people exploited seasonal availabilities of sea mammals and a variety of marine fish species (Figure 2.8) (de Laguna, 1972). In virtually all of the study area, small to medium mammals and a variety of birds were hunted or snared throughout the year. Beaver and whitefish were important sources of fat in winter across the Subarctic, which factored heavily into hunter-gatherer attraction to valleys and fish lakes during this season.

2.3.2 Discussion of fish, game, and WRAe

The effects of WRAe ash on populations of fish and game in southern and central Yukon have not been well addressed (cf. Mulliken, 2016). The data sources utilized below to assess impacts of the ash are from Yukon caribou ancient DNA (aDNA) and studies of modern eruptions and their impacts on wild animals and livestock.

2.3.2.1 Ungulates

Kuhn et al. (2010) concluded, on the basis of aDNA from Holocene caribou remains, that populations in southwest Yukon were partially replaced by new caribou populations following the WRAe event, although this may be attributable to concurrent climatic changes (i.e., the Medieval Warm Period). WRAe may have induced caribou mortality by hindering access to their principal food supply (reindeer lichen) when migratory herds wintered in southern forests. If the ash fell in winter, immediate impacts on the lichen food supply may have been delayed until the following winter when lichen abundance was reduced (although ash may have made lichen harder to access immediately after deposition). In studies of modern ash falls, Alaskan caribou have been found to undergo drastic tooth wear from grit that led to mortality (Hubbard, 1938:57) while in Kamchatka, reindeer deaths in ash-covered ranges were attributed to the ingestion of coarse ash while feeding (VanderHoek, 2009:166). Ash ingestion leads to rumen blockage and inanition (exhaustion from lack of nourishment) in addition to depressed fur production, chronic bronchitis, pneumoconiosis, silicosis, and corneal abrasion (blindness) (Gregory and Neall, 1996). Griggs (1922) argued that the destruction of reindeer lichen by tephra from Katmai 1912 eruption in Alaska led to widespread caribou mortality. Eruptions in Kamchatka in 1953 and 1975 similarly caused widespread caribou malnutrition because of lack of access to meadows, in some cases involving over 70% mortality in a herd (VanderHoek, 2009:166).

Caribou mobility drops in winter when their biological response to a disturbance event may be more akin to livestock, which have been studied more extensively following modern eruptions. Fluorine released during volcanic events is captured by plants and transmitted to herbivores, often leading to rapid fluoride contamination and osteofluorosis or dental fluorosis (Óskarsson, 1980; Araya et al., 1993; Cronin et al., 2003; Flueck, 2016). The abundance of fluorine released is related to specific magma compositions and it is not currently known if WRAe was associated with high levels of fluorine that could have caused fluoride contamination. Toxic levels of fluoride cause bone deformation and wear on articular surfaces (erosion of bone joints). Mortality linked to dental fluorosis (pathological tooth wear and severe ablation leading to malnutrition) has been noted in wild deer populations in Chile following eruptions (Flueck, 2014) while osteofluorosis has been implicated in livestock mortality after ash falls in Chile (Araya et al., 1993) and New Zealand (Cronin et al., 2003). Records of tephra-induced livestock mortality from around the world (often in areas subjected to less than 5 cm of tephra before compression) (Table 2.4) indicate that a variety of large herbivore species can be affected. Following the 1970 Hekla eruption in Iceland, adult sheep mortality due to fluorosis under 1 mm of tephra was 3% while that of lambs was 8-9% (Thorarinsson, 1979:146). Thorarinsson (1979) noted that fluorosis is more severe with distance from the eruption because fine particles are more likely to adhere to vegetation and bind to water. These conditions can persist for over a decade but ash mobilization events (e.g., windstorms) can re-introduce tephra effects for centuries (Wilson et al., 2011a).

Table 2.4 Examples of recorded livestock mortality due to tephra following volcanic eruptions.

Eruption	Year	Livestock loss	Reference
Paricutin, Mexico	1943-52	~4500 cattle, 500 horses	Rees 1970
Mt Hudson, Chile	1991	~1 million sheep	Wilson et al. 2011b
Laki, Iceland	1783	10,263 cattle, 186,638 sheep, 27,256 horses	Thorarinsson, 1979
Hekla, Iceland	1970	15,600 sheep	Thorarinsson, 1970
Chaitén, Chile	2008	25,000 sheep	Craig et al., 2016

Fluorosis, and the biological impacts of tephra in general, are difficult to reconstruct for pre-contact eruptions because they are related to compositions specific to each tephra fall and local soil characteristics (Ayris and Delmelle, 2012). However, agricultural studies and DNA research suggest that wintering barren ground caribou and resident woodland caribou (as well as moose, bighorn sheep, and mountain goat) exposed to over 1 cm of tephra were negatively affected through inescapable ash ingestion. Presumably, lichen feeders and grazers were more negatively affected than browsers. Prolonged exposure by caribou and other ungulates to volcanic ash would have led to malnutrition (e.g., related to fluorosis, rumen blockage, or tooth wear), depressed breeding success, and/or mortality. Summer erosion in high relief areas would have exposed lichens and sedges in some habitats, which may have altered caribou ecology without significantly depressing nutrition. Ancestral migration paths would have seasonally brought caribou into the WRAe footprint (Figure 2.9) and introduced biological challenges, particularly to pregnant females prior to spring calving.

To extend up the trophic chain from our pollen synthesis, decreased spruce and increased sedge (Figures 2.4 and 2.5) following the WRAe may have produced habitats that favoured the recovery of summer ungulate food supplies within several decades. However, lichen communities can take over 100 years to become established after disturbance events in Subarctic environments (Rupp et al., 2006; Payette and Delwaide, 2018); for example, in Alaska's boreal forest, lichens took over 80 years after forest fires to return to sufficient abundance to attract grazing caribou (Collins et al., 2011). Woodland caribou favour old-growth forest where lichen is abundant so disturbance events like ash deposition and associated forest fires would reset stages of ecological succession with prolonged impacts on caribou. Caribou adapted to alpine habitats in Yukon and western N.W.T. (e.g., the Mackenzie Mountains) may have also experienced delayed recovery because of their reliance on meadows that were susceptible to more uniform impacts of tephra and permafrost aggradation that altered plant communities. Letts et al. (2012) noted no significant change in aDNA of woodland caribou in western N.W.T. following WRAe, which indicates genetic continuity although their ecology may have been disrupted. We estimate that it minimally took several human generations (50-100 years) for caribou to return to pre-WRAe abundance and to re-establish predictable migratory paths that humans seasonally exploited. This is based on the estimated recovery of moss/lichen communities after the initial tephra fall and re-mobilisation events (Rupp et al., 2006; Collins et al., 2011; Payette and Delwaide, 2018), the general hiatus of over a century in southern Yukon ice patch artifacts and dated faunal remains (a repository of organic hunting artifacts and animal remains preserved at high altitudes) following WRAe (Hare et al., 2012), and other work that estimated the recovery of caribou from circumpolar eruptions (VanderHoek, 2009:289). In the weeks and months after ash deposition, caribou populations were probably stressed because of hindered food access and this would have altered both their daily movement patterns and their once predictable foraging territories through the following winter and summer.

2.3.2.2 Fish

Tephra and ensuing erosion can lead to fish mortality related to suffocation and changes in channel morphology (gravel spawning beds), riparian vegetation, and habitat availability (Lallement et al., 2016). A principal impact on anadromous fish like salmon is through turbidity. Suspended ash coats or abrades gills (Newcombe and Flagg, 1983), impedes homing behaviours used to relocate ancestral spawning beds (Whitman et al., 1982), decreases egg survival, reduces soluble oxygen (Ward et al, 1983), and depresses invertebrate and algae populations, such as amphipods, chironomids, and diatoms, upon which fish directly or indirectly rely (Kurenkov, 1966; Abella, 1988; Hutchinson et al., 2019). Acidity associated with volcanic emissions and tephra can also alter pH and aluminum toxicity that harms invertebrates and fish (Birchall et al., 1989; Birks and Lotter, 1994; Telford et al., 2004; Schaefer et al., 2008; Wall-Palmer et al., 2011), although WRAe is from a volcanic vent and eruption type - high-silica adakitic vent producing a water-rich phreatomagmatic eruption (Lerbekmo, 2008; Preece et al., 2014) - that is not typically associated with high levels of sulphur dioxide (see Jensen et al., 2014), a major contributor to acid rain (Ayris and Delmelle, 2012). Decreased riparian vegetation is one factor that led to high water temperatures and elevated mortality of juvenile salmon after the Mount St. Helens 1980 eruption (Martin et al., 1986). However, nutrient- and iron-rich ash deposition has been linked to phytoplankton blooms (Olgun et al., 2013) and zooplankton productivity (Bisson et al., 2005), which in turn promote the rapid recovery of fish communities (Parsons and Whitney, 2012), although some tephra may lead to anoxic events from over-nutrification (Bisson et al., 2005; Ayris and Delmelle, 2012).

Eicher and Rounsefell (1957) and Kurenkov (1966) noted sharp declines in salmon populations in Alaska and Kamchatka due to suffocation following tephra deposition but recovery within three years, in some cases leading to salmon populations larger than pre-ash times. Ball (in Evermann, 1914) reported the suffocation of 4000 salmon in one stream in 1913 following the Katmai eruption in 1912 (due to turbid waters) while Evermann (1914) noted the destruction of salmon spawning beds by tephra, both observations made in water bodies over 100 km from the volcano (these areas were exposed to between 3 and 20 cm of tephra based on isopachs from Hildreth and Fierstein, 2012:10). Bisson et al. (1988) noted immediate declines followed by sharp increases in fish productivity attributed to an abundance of food resources for salmon after the Mount St. Helens 1980 eruption. In general, fish populations in mountain waterways decrease but rebound quickly to pre-eruption levels (Bisson et al., 2005), possibly because of high spring and summer meltwater levels that flush ash downstream and out of fluvial systems.

Extrapolating modern fish studies to the WRAe event is difficult because salmon ecology in the upper Yukon River is quite different from systems analysed after modern eruptions. Of direct relevance, Bunbury and Gajewski (2013) studied impacts of WRAe on aquatic environments in southwest Yukon and concluded that, in systems with moderate to large catchment basins, chironomid communities often displayed significant reductions, indicative of negative WRAe impacts on organisms that support fish. In some cases, chironomid communities took 100 years to recover from the WRAe. Hutchinson et al. (2019) detected distinct changes in diatom communities after the WRAe event in a lake in Northwest Territories over 1200 km from the volcano.

We expect that Yukon salmon populations were reduced in the ≥5 cm tephra isopach because of suspended ash particles, sediment loads, and a loss of riparian vegetation that regulated temperatures of spawning beds and smolt development. The pollen studies are informative because spruce appears to have decreased post-WRAe and plays an important role maintaining fish habitat and water temperatures through the provision of shade, predator refuge, and erosion control. The 20-cm tephra isopach crosses the Yukon River and the 10-cm isopach crosses portions of the Pelly, Teslin, and Alsek Rivers (Figures 2.1 and 2.9). The introduction of this much ash may have raised turbidity to lethal levels for fish in important fishing grounds for people in that region, and downstream from it, although large percentages of ash deposited in winter may have flushed through the Yukon Basin prior to summer salmon runs.

Perhaps more significantly, the timing and location of salmon runs would have been less predictable due to population changes, large-scale erosion events that altered river bed and bank morphology, and straying/homing issues (Whitman et al., 1982; Leider, 1989). Reductions in anadromous fish productivity probably lasted 10 years (due to ash remobilization events). This is based on modern studies of salmonid depression for roughly three to eight years following smaller northern eruptions (Ball in Evermann, 1914; Eicher and Rounsefell, 1957; Kurenkov, 1966), an expected five to ten year episode of ash flushing and stabilisation after WRAe (cf. Wilson et al., 2011a), and the roughly 5-year life cycle of salmon (that is, five years of ash flushing through rivers would influence the population of salmon that return to ancestral spawning beds for an additional five years).

Landlocked (or non-diadromous) fish like whitefish and lake trout may have been locally eradicated for centuries due to turbidity and changes in lake pH, as is inferred to have occurred in New Zealand where lakes still have not been re-colonised by non-diadromous fish more than 1000 years after a major ash fall (McDowall, 1996). Hutchinson et al.'s (2019) high resolution study in N.W.T. indicates that <5 mm of WRAe tephra caused a significant though short-lived change in pH and diatom communities. Lakes in Alaska were also determined to undergo steep decreases in productivity (based on carbon and nitrogen isotopes) due to tephra deposition during Holocene volcanic events (Misarti, 2007). Changes in pH and turbidity due to ash and intensified sediment yields (Kadomura et al., 1983; Major et al., 2000; Waythomas et al., 2010) may have pushed lake fish populations to different habitats, making access to fish unpredictable for people. Species like whitefish and inconnu can migrate long distances from the Mackenzie Mountains across the Mackenzie Basin (Helm, 1981; Stephenson et al., 2005; McPhail, 2007), which would expose them to impacts arising from 1 to over 5 cm of ash fall. Ash deposition in winter (when lakes and many rivers were capped with ice) may have rendered ash impacts negligible until the spring melt, which appears to have lessened the impact of tephra on fish after the 1980 Mount St. Helens eruption (Bisson et al., 2005). However, winter tephra deposition would presumably concentrate ash impacts within the vulnerable spring spawning season of many Mackenzie and Yukon basin fish.

2.3.2.3 Rodents, birds, and plant foods

Aside from fish and ungulates, very few studies have systematically analysed tephra-related changes to species that were valuable to pre-contact people, such as rodents (e.g., porcupine, muskrat, beaver, and marmot), birds (e.g., ptarmigan, grouse, and geese), and berries. Small mammal communities in tephra fall zones appear minimally affected because of the ability to survive in, and quickly re-colonise from, small refugia (Crisafulli et al., 2005). This is partly due to higher reproductive rates than large mammals. For example, hare populations fluctuate widely from year to year in boreal ecosystems, which humans were aware of and adapted to through changes in hunting patterns; we predict a minor disruption to the cyclical rise and drop in hare abundance. Ptarmigan mortality was noted as severe after the Katmai eruption of 1912 (Ball in Evermann 1914:62-63) and Thorarinsson (1979:137) described mass kills of ptarmigan following the 1693 eruption of Hekla Volcano in Iceland. Ash falls may have also disoriented migratory waterfowl if the falls occurred during spring or autumn migration. Changes to lake productivity and water quality (especially in small water bodies) would have also affected some waterfowl species.

Hunn and Horton (1984) documented a sixfold decrease in berry productivity (mountain huckleberry, *Vaccinium membranaceum*) under an average of 32 mm of tephra from Mount St. Helens. This was attributed to significant decreases in insect pollinators (Cook et al., 1981) and may relate to the timing of the 1980 eruption in May, an important season for pollination (Hunn and Horton, 1984). Despite reports of local decreases in ground birds and berries, most small animal and plant food species likely re-colonised tephra-coated landscapes quickly but in spatial patterns that may have taken years for people to re-locate. In summary, animal movements, productive berry grounds, leks (where ground-dwelling birds gather), and the timing of other animal congregations and plant availability were less predictable for weeks, months, and possibly decades following ash deposition.

2.3.3 Human biology

Global studies of eruption impacts on human health enable some extrapolations to hunter-gatherers. Fatalities related to volcanic eruptions are most commonly linked to pyroclastic density currents consisting of ash and hot gas driven by dynamic pressure and gravity (Baxter and Horwell, 2015). The average extent of density currents is not well-known but the comparatively small eruption of Mount St. Helens in 1980 produced a blast zone extending 28 km from the summit (which killed 57 people) and the Merapi eruption in Indonesia in 2010 produced a pyroclastic density current that extended 17 km (causing close to 200 human deaths) (Jenkins et al., 2013). Ash flow deposits from the Aniakchak eruption of 3700 BP (Kaufman et al., 2012) in Alaska extend 80 km from the caldera (Miller and Smith, 1977).

Although the full extent of pyroclastic density currents associated with WRAe are not known, it is reasonable to conclude that pyroclastic flows and associated density currents were small (Lerbekmo and Hughes, 1969; Richter et al., 1995; Lerbekmo, 2008). Associated human fatalities would be minimal unless specific task groups were moving within 10 km of Mount Churchill at the time of the eruption or were camped in neighbouring valleys. Population densities of hunter-gatherers in the vicinity of Mount Churchill and the St. Elias Mountains (the origin of the WRAe event) were predictably low, especially in winter when hunter-gatherers tended to reside at lower altitude fish lakes, rivers, and coastal shores (Figure 2.6). Workman (1974) postulated a population density of 1 person per 100 to 250 km^2 in the general study area (southern and central Yukon) and suggested that virtually no one resided within a danger zone of pyroclastic density currents - dubbed glowing ash clouds by Workman (1974). Modern eruption data support Workman's (1979:348-349) notion that WRAe did not cause human mortality in Yukon and that volcanic impacts on human biology would have most likely been limited to regions that experienced fine-grained tephra falls.

Ash falls are generally not a cause of mortality (Wilson et al., 2015) and, when implicated in human deaths, tend to relate to roof collapse and particle loading exaggerated by rain water (Baxter and Horwell, 2015). Tephra is an unlikely cause of immediate death in pre-contact times given that most structures were small and adequately shed snow burdens. More significant are chronic respiratory and eye issues associated with prolonged exposure to ash (from the initial deposit and during remobilization events). Airborne tephra can lead to potentially fatal silicosis, particularly if tephra contains cristobalite (Baxter et al., 1981; Horwell et al., 2014). Cristobalite has not been noted in WRAe (Preece et al., 2014) and it is unlikely to have been present. Modern studies suggest that respiratory hazards of tephra among healthy people are minimal

(Gudmundsson, 2011; Baxter and Horwell, 2015), but a few variables temper extrapolations of these studies to pre-contact times (prior to European arrival in the 1800s). If WRAe tephra fell in winter, relative air moisture would be low and the amount of dangerous respirable crystalline silica (Horwell et al., 2012) would be high. Secondly, most modern studies are in urban settings where ash is cleared so exposure tends to be short-lived; hunter-gatherers were much more mobile, which may have increased exposure to tephra. Thirdly, respiratory issues associated with tephra are exacerbated among people with pre-existing conditions (Baxter et al., 1981); in urban settings, this is often due to smoking and/or regular exposure to airborne pollutants. In pre-contact times, some hunter-gatherers had respiratory issues associated with regular smoke inhalation in closed settings due to the need for indoor fires much of the year. Studies of pre-contact populations in North America indicate that respiratory illnesses were common and are attributed to poor indoor air quality and airborne pathogens (Keenleyside, 1998; Merrett and Pfeiffer, 2000; Lambert, 2002; Roberts, 2007). For example, Zimmerman and Aufderheide (1984) documented severe anthracosis in the preserved lungs of pre-contact women from ca. A.D. 1500 in northern Alaska that they attribute to prolonged smoke exposure. Constant exposure to indoor wood or turf fires causes pulmonary diseases (e.g., chronic bronchitis) that have been linked to morbidity and mortality in some populations (Cleary and Blackburn, 1968; Rajpandey, 1984; Larson and Koenig, 1994; Bruce et al., 2002).

We suggest that Subarctic people who relied on wood fires for indoor heating in small enclosed spaces for over five months of the year were prone to respiratory diseases. Over 5-10 cm of tephra would aggravate health issues for much of this population. Biological impacts of tephra are influenced by height above ground level so we presume that children and domestic dogs would have been particularly susceptible to respiratory stress associated with thick tephra. We conclude that tephra exceeding 5 cm introduced respiratory issues that would have been actively avoided by pre-contact people for over five years until sufficient ash had been flushed through the ecosystem or stabilised. This conservative estimate is based largely on Wilson et al. (2011a), who documented ash storms that continued for twenty years after an eruption much smaller than WRAe in Chile - the 1991 eruption of Mount Hudson, VEI=5, 4.3 km^3 bulk ejecta, and 2.7 km^3 DRE (Kratzmann et al., 2009). Respiratory issues may have been re-introduced decades later when ash was re-mobilised by wind (Wilson et al., 2011a). The pervasive impacts of finer ash fall and smoke from forest fires may also have been challenging for populations in more distal locations of the WRAe footprint in N.W.T. (cf., Thorarinsson, 1979; Óskarsson, 1980).

Ash falls would have contaminated some water sources but not to the same extent as has been presumed following large-scale eruptions in more arid regions like the Northern Plains of the U.S. (Oetelaar and Beaudoin, 2005). Human fluorosis has been linked to contaminated ground water, which serves as the major route of intake for volcanic fluorine for people, as opposed to cascade effects, i.e., fluorine is not significantly transmitted from prey to predator (D'Alessandro, 2006). However, volcanic fluorine contamination is more commonly linked to rock-water interactions or degassing – fluorine contamination of water supplies from tephra generally does not result in chronic exposure to humans (D'Alessandro, 2006). Human fluorosis was noted among several families following the 1783 Laki eruption in Iceland with some bone and teeth deformation but this occurred among sedentary farmers with diets and water supplies that were much more spatially limited than pre-contact hunter-gatherers. With abundant snow deposits and flowing water, and a mobile lifestyle, it is not anticipated that fluorine water contamination was a significant issue for people following the WRAe eruption. It is likely, though, that ash was regularly ingested from drinking water, which may have had notable, though non-fatal, mechanical impacts on internal organs and teeth (e.g., increased tooth wear). We hypothesise that ash inhalation significantly harmed human populations because of mechanical irritation during tephra deposition and in the following weeks, months, and years.

2.4 General discussion and synthesis

We infer effects of a volcanic eruption on hunter-gatherers in circumpolar landscapes by reconstructing trophic links from plant communities to major prey species and up to people. The severity of disturbance induced by the WRAe tephra fall appears variable across different habitats and in some ways resembles those of severe forest fires. However, the charcoal and pollen records suggest that impacts extended across thousands of square kilometres as opposed to the generally smaller extent of wildfires, and the ash itself had other deleterious consequences. Overall, the diversity of local responses to tephra likely created a mosaic or patchwork environment with different implications for fauna with small vs. large territories and resident vs. migratory species. The effect of the widespread disturbance caused by WRAe is perhaps best illustrated in caribou DNA that suggests partial population replacement following the eruption (Kuhn et al., 2010). Because caribou were a principal prey species across Yukon (Figure 2.8), it is probable that WRAe had a significant negative impact on people for several generations while caribou recovered. An expansion of sedge meadows (as suggested by pollen records) may have facilitated caribou recovery but slow succession of lichen communities (based on studies of modern eruptions) in critical winter habitat may have slowed recovery and elevated winter mortality. An alteration of migratory paths to avoid the ash would have left caribou less predictable to hunter-gatherers. These negative impacts on subsistence were compounded through what we argue was a decrease in salmon populations and the predictability of their migratory runs that may have lasted for a decade due to lethal turbidity, changes in river bank morphology, and homing issues. The WRAe footprint extends across migratory paths of caribou and salmon (Figure 2.9), which would have seasonally re-exposed key prey species to ash and its negative biological consequences. Widespread forest fires may have further lessened the ability of hunter-gatherers to persist in portions of southern and central Yukon (Figure 2.10).

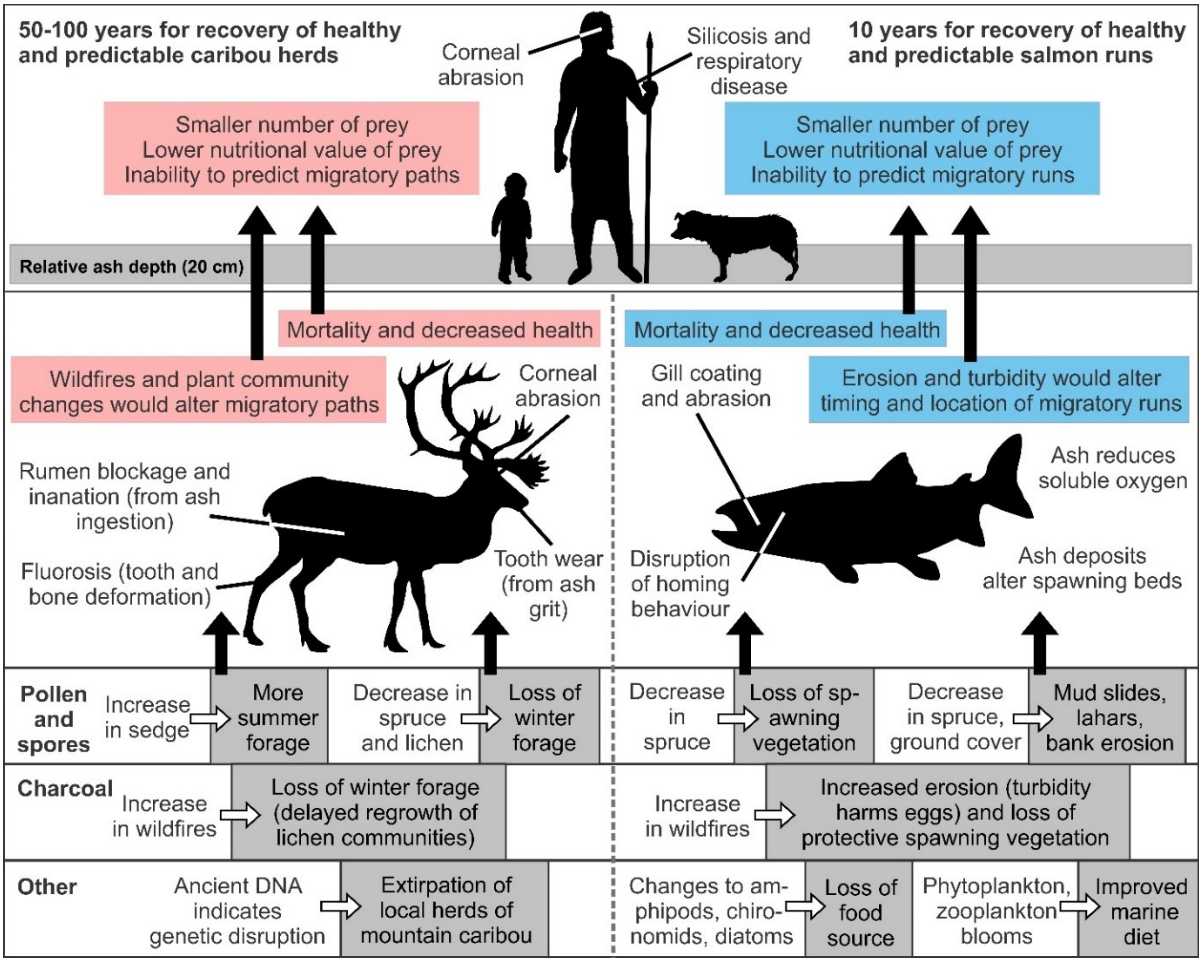

Figure 2.10 Schematic of trophic impacts of the White River Ash east eruption in southern and central Yukon.

WRAe tephra was likely a discontinuous layer that fell on topographically diverse areas with a resultant range of effects (Figure 2.11). High-elevation areas with more continuous permafrost and a more uniform vegetation canopy (e.g., alpine meadows) may have experienced more prolonged impacts than lower elevation areas that hosted more diverse vegetation canopies, discontinuous permafrost, and higher microscale vertical relief (which promoted more rapid erosion and flushing of tephra). High-elevation regions may have experienced more drastic changes to ecological succession than lower elevation areas. However, variables that spatially concentrate tephra (e.g., erosion toward fish-bearing lakes and tributaries) would exacerbate effects. Ecological impacts are also influenced by tephra grain size with evidence that some toxic effects for fish and mammals are linked to smaller tephra particles that are typically deposited farther from the vent (Thorarinsson, 1979; Óskarsson, 1980). Coupled with more continuous permafrost, a more uniform vegetation canopy, and slower succession at high-elevation areas (Arnalds, 2013), such as alpine meadows in the Mackenzie Mountains (see Kershaw and Gill, 1979; Rainville, 2015), the eastern reaches of the WRAe footprint may have experienced more significant impacts on flora and fauna than neighbouring lower elevation areas to the west with thicker deposits (e.g., along Pelly River).

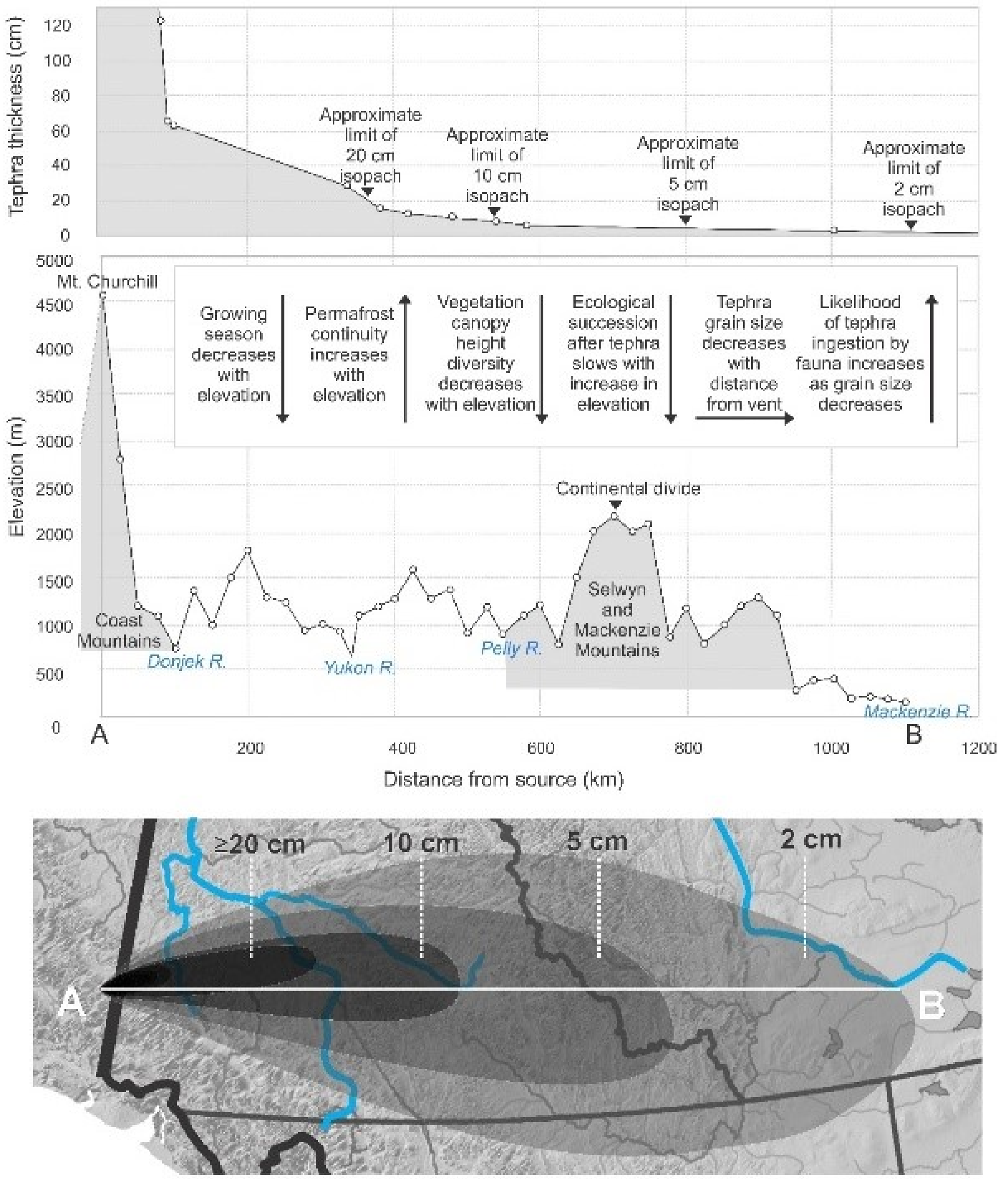

Figure 2.11 Schematic of tephra thickness (top) with distance from the source (from Robinson, 2001) and a general landscape elevation profile (middle) along a transect from the WRAe source to the Mackenzie River (bottom)(the isopachs at bottom are adapted from Lerbekmo, 2008).

WRAe tephra in N.W.T. likely affected vegetation and game animals. Fine-grained ash is more susceptible to intense compaction (Antos and Zobel, 2005), which limits oxygen flow and hinders vegetation re-growth while finer-grained ash has an increased likelihood of adsorbing volatiles that alter pH (Smith et al., 1993; Payne and Blackford, 2008) and adhere to vegetation (Thorarinsson, 1979; Óskarsson, 1980). Based on these studies, eastern reaches of the WRAe tephra footprint (e.g., places with 0.5-1 cm of tephra) may have experienced ecological impacts that rivaled areas closer to the vent. We expect there to have been negative impacts on waterfowl and freshwater fish including inconnu and whitefish, a fall spawner with runs that involve millions of individuals (Bond, 1980), both of which were crucial to people in the Mackenzie Basin (Helm, 1981). Moose and bison in the Mackenzie Basin may have also been affected through their seasonal reliance on aquatic vegetation and/or meadow habitats. Consequently, there are reasons to suspect that Dene populations of N.W.T. were adversely affected.

One element of successful hunter-gatherer food procurement in Subarctic landscapes involved the periodic aggregation of people to seasonal pulses in biological productivity (such as caribou and salmon migration) that sustained large gatherings vital for information sharing about regional resources, marriage arrangements, and ceremonial life. We hypothesise that both caribou and salmon (as well as small mammals and birds) were both scarcer and less predictable in portions of Yukon because of large-scale landscape changes induced by the ash. It may have taken up to a century for human populations to return to the ≥5 cm tephra footprint and resume former patterns of subsistence. This is supported by a roughly century-long hiatus of ice patch artifacts in southern Yukon (Hare et al., 2012) and by Mullen's (2012) work on radiocarbon dates and population history following WRAe. Mullen (2012) concluded that an exodus occurred after WRAe, based on radiocarbon-dated occupations, but because of error ranges in radiocarbon dates, it is not currently possible to say how long an interval of abandonment or population decline lasted. It is probable that smaller local groups, task groups, or scouting parties occasionally entered the tephra fall-out area (perhaps for decades following the eruption) to reconnoitre their homeland and exploit resources that persisted or had re-colonised patchwork landscapes.

The stability of the trophic pyramids of neighbouring hunter-gatherers undoubtedly influenced the directions in which displaced people turned following a natural disturbance. We expect that people who temporarily left the tephra fall-out area would rely on neighbours, as occurred historically in times of need (McClellan, 1975). Derry (1975) suggested that WRAe forced people north into central and northern Yukon. While the movement north of some social units may have taken place, in a purely ecological sense, people would have faced challenges seeking support from neighbouring kin in that direction. Northern neighbours were also experiencing related stresses on their major food supplies of salmon and caribou, which, because of their migratory paths, seasonally entered the WRAe footprint to the south. However, the WRAe event likely had minimal effects on subsistence of hunter-gatherers south and west of the WRAe footprint (Figure 2.8), such as the Tlingit in southeast Alaska and Tahltan in northwest British Columbia. These were logical places to seek refuge from an ecological perspective, as were regions south and southeast of the ash fall zone.

Neighbours in regions southeast of the WRAe zone, historically inhabited by the Sekani, Dene Tha', and Dane-zaa of northeast British Columbia and northwest Alberta, could have harboured groups affected in the more easterly footprint of the ash fall. Apachean ancestors share close, recent ties with the eastern branch of the Dene languages (those of the Peace and Mackenzie basins) (Achilli et al., 2013; Krauss and Golla, 1981; Mahli et al., 2003; Snoek, 2015); microbands of prototypical speech communities of the eastern Dene divisions described by Snoek (2015) may have been among those displaced in the wake of WRAe.

We envision two major alternatives for ancestral populations of Dene (Athapaskan) hunter-gatherers who temporarily left the WRAe footprint: 1) to have sought assistance from communities in which ties of kinship existed, or 2) to have sought support where alliances such as trading partnerships had been previously established. These strategies were not mutually exclusive. Historically, northern Dene communities explored various options in kinship and residence, with marriage practices ranging from endogamy to exogamy (Ridington, 1968, 1969; Asch 1980, 1988; Ives 1990, 1998; Legros, 2007): exogamous strategies promoting external kin ties would have alleviated ecological challenges created by WRAe. Such kin ties were vital in allowing people to gather in larger groups for communal harvesting (i.e., caribou and salmon migrations), or in times of scarcity, when it would be necessary to seek help. Similarly, ties established through trading relationships, often involving real affinal or fictive consanguineal kinship, would provide social avenues along which to move away from areas of severe impact.

Cultural perceptions of large-scale events and the social networks on which people relied to cope with them surely shaped responses (Oetelaar and Beaudoin, 2005; Torrence, 2016). The ash cloud of the WRAe event is thought to have extended over 40 km high (Lerbekmo, 2008) and would have been visible on the horizon over 500 km away. For comparison, Wilcox (1959:421) recorded an ash cloud 18-21 km high and 50 km wide roughly 40 minutes after the Mount Spurr eruption of 1953 in Alaska (lightning flashes were recorded every 3 seconds as the ash cloud dispersed downwind). Based on other models of large-scale eruptions (Oetelaar and Beaudoin, 2005) that accounted for ash cloud dispersal (Hooper et al., 1980), sound emanation (Fairfield, 1982; Simkin and Fiske, 1983), and light transmission (Lamb, 1970; Cook et al., 1981), it may have taken as little as one hour for thunderous booms, and ten hours for the WRAe ash cloud (and accompanying lightning), to descend across Yukon and N.W.T. Ash clouds over southern Yukon would have blocked out the sun with a darkness akin to night time for several days (see Griggs (1922:9-11) for a description of the several days of darkness on Kodiak Island over 100 km from the source of the 1912 Katmai eruption, and Blong (1982) for accounts of the three to four days of darkness reported after the Matapen-Tibito eruption in Papua New Guinea in the 1650s or 1660s). This presumes a single explosive event over a short time frame – Lerbekmo (2008) estimated 70 hours for WRAe. In a landscape where people were accustomed to periods of resource depression (e.g., lean food supplies during portions of the year), they could probably survive on stored food during the days and weeks of out-migration. The event was almost certainly a terrifying spectacle that would be psychologically stressful and confusing, and would have pushed people to fall back on reliable resources and kin networks (cf. Oetelaar, 2015; Riede, 2016, 2017).

The vulnerability of human populations to large-scale disturbances relates to their capacity to anticipate, cope with, and recover from incidents (Blaikie et al., 1994:9; Losey, 2005; Riede, 2018; Torrence, 2018). Regular forest fires pre-adapted Subarctic hunter-gatherers to landscape disturbances but perhaps not at the scale of the WRAe event. Major volcanic eruptions occur infrequently (e.g., every 500 years) in North America's northwest circumpolar region (Davies et al., 2016) such that they may have been preserved in oral history as powerful phenomena (Moodie et al., 1992; Fast, 2008). The White River Ash north eruption of 1605-1805 BP is pertinent because it preceded the WRAe eruption by roughly 600 years and occurred in a partially overlapping territory (Figure 2.12). Oral histories of WRAe (Moodie et al., 1992; Fast, 2008) may have embedded moral codes and prescriptions for ecological responses to widespread disturbance events (e.g., Minc, 1986).

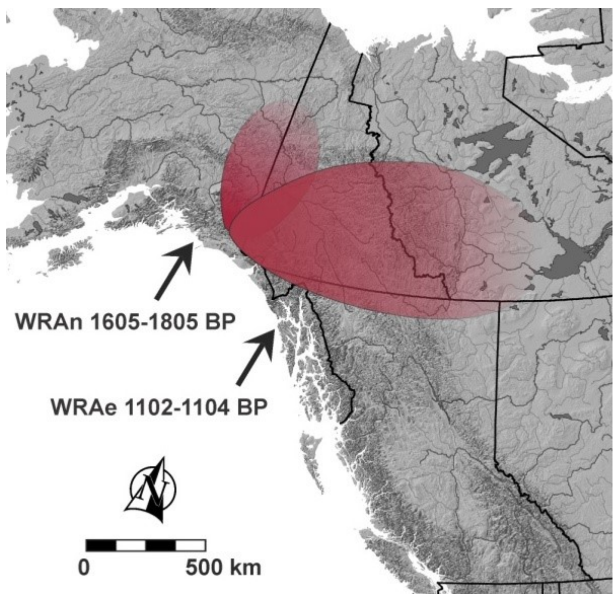

Figure 2.12 Comparative plumes and dates (BP) of the White River Ash north and east eruptions.

The eastward spread of ash, coupled with knowledge of social networks and the habitual ranges of adjacent kin groups would have determined in what direction displaced people spread. This in turn would have shaped longer-term consequences of the eruption on technological transfer and the potentially permanent migration of some social groups of Dene ancestors to other regions (Ives, 1990; Magne, 2012). The Yukon ice patch data point to a distinct change in weaponry (from the atlatl or spearthrower to the bow and arrow) from before to after the WRAe eruption, likely due to coastal influences (Hare et al., 2004; Hare et al., 2012), while obsidian data (Kristensen et al., 2019b) bolsters a vector of movement of temporarily displaced people to the southwest, toward Tlingit communities. Tertiary Hills Clinker data (Kristensen et al., 2019a) suggest that the WRAe eruption and its impacts decreased human contact across the Mackenzie Mountains in the eastern portion of the WRAe tephra footprint while groups in N.W.T. strengthened networks to the east and northeast. It remains possible that some hunter-gatherer social units in the eastern portion of the WRAe footprint moved south and southeast away from tephra impacts. Genetic and linguistic research has affirmed a timing roughly coeval with both WRA eruptions of the southward migration of northern Athapaskan speakers to coastal Washington and California and the Great Basin and Southwest U.S. (e.g., Krauss and Golla, 1981; Mahli et al., 2003, 2008; Achilli, 2013; Monroe et al., 2013; Ives et al., 2014; Billinger and Ives, 2015; Snoek, 2015; Flegontov et al., 2019). On the basis of current palaeoenvironmental and comparative evidence, the suspicion that WRAe triggered human population movements in northwest North America is warranted. The current paper presents ecological studies of the WRAe event and likely vectors of movement to be tested in the future with archaeological and oral history data (see Moodie et al., 1992; Fast, 2008; Edinborough, 2015).

The Hutchinson et al. (2019) diatom study at Pocket Lake, N.W.T., illustrates that precise detection of ecological events and their impacts requires sediment core sampling at millimetre-scale intervals. For the time being, we attempt to bridge the temporal gap between most other palaeoenvironmental studies and human adaptation by linking pollen and charcoal records to major prey species, the seasonal round of hunter-gatherers, and human health. Ultimately, palaeoenvironmental studies, research on modern ash falls, and a trophic approach inform a hypothesis of the ecological parameters of a large-scale disturbance. Future work may reveal human adaptations to this event through social strategies, subsistence, and ideology. This approach complements other studies that have elucidated human responses to eruptions through detailed palaeoclimatogical data, radiocarbon dates and demographic models, and changing settlement patterns (Mullen, 2012; Riede et al., 2017; Tremayne and Brown, 2017; Jørgensen and Riede, 2019).

2.5 Conclusion

We utilise palaeoenvironmental data (principally pollen and charcoal records) supplemented by studies of modern ash fall ecology to infer effects of the WRAe event at 846-848 A.D. upon hunter-gatherers in southern and central Yukon. The WRAe event was capable of triggering the temporary movement of people away from the thickest zones of tephra deposition (≥5 cm) because of expected effects of ash on the physiology and ecology of ungulates, fish, and people. People relied on predictable animal aggregations; we argue that the volcanic event stimulated a disruption to patterns of human subsistence in the ≥5 cm tephra footprint that lasted for up to century, with notable but shorter term impacts in the 1-5 cm tephra isopach zone. However, the intervening period of recovery of that subsistence strategy was likely characterised by frequent visits and the persistence of smaller, dispersed social units across a mosaic landscape that the tephra disturbance fostered. Our synthesis addresses misconceptions of the uniformly cataclysmic nature of disturbances and contextualises archaeological inferences of what this volcanic eruption induced, including previously proposed eradications of local human populations, long-term abandonment of landscapes, the migration of groups of Dene people across the continent, and technological change (Derry 1975; Workman, 1974, 1979; Ives, 1990, 2010; Magne and Matson, 2010; Kristensen et al., 2019a; Kristensen et al., 2019b). By the same token, our synthesis does suggest that ecological impacts associated with this eruption induced changes in human behaviours with a long-lasting cultural legacy. As with eruptions elsewhere, hunter-gatherer communities responded through increased mobility and the activation of social networks, both of which leave archaeological signatures. Palaeoenvironmental data in the context of trophic links, combined with ethnohistoric and archaeological records of subsistence, offer means to understand pre-contact human responses to natural disturbances.

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CHAPTER 3: THE MOVEMENT OF OBSIDIAN IN SUBARCTIC CANADA: HOLOCENE SOCIAL RELATIONSHIPS AND HUMAN RESPONSES TO A LARGE-SCALE VOLCANIC ERUPTION

Abstract

Lithic provenance analyses offer means to reconstruct ancestral social relationships in Subarctic North America. We summarize sourced obsidian data from 462 archaeological sites in the Yukon and Northwest Territories, Canada, and interpret obsidian distribution through the Holocene with particular attention to the volcanic White River Ash East event of A.D. 846-848. We argue that social mechanisms explain overlapping occurrences of exotic and local obsidians and that the volcanic ash fall triggered changes to obsidian exchange patterns. Following the volcanic event, obsidian from British Columbia moved north into the Yukon with higher frequency. Instead of a population replacement, persistent patterns in the distribution of some obsidian source groups suggest that the ash temporarily pushed some Yukon First Nations south where they strengthened networks of exchange that were retained upon their return. The short-term displacement may also have facilitated the movement of bow and arrow technology into the Yukon, which appears concurrent with the volcanic event. The large-scale eruption had the potential to sever connections between a small group of ancestral Dene (Athapaskans) and their homeland, which culminated in a continent-wide migration in the Late Holocene.

3.1 Introduction

Geochemical analyses of archaeological obsidian in Alaska and northern British Columbia have occurred since the 1960s (Griffin et al., 1969; Wheeler and Clark, 1977; Michels, 1981, 1983, 1985; Fladmark, 1984, 1985; Clark and Clark, 1993; Cook, 1995; Lee, 2001; Reuther et al., 2011; Reimer, 2015) but results of obsidian provenance research have rarely been summarized at a regional scale and applied to questions of broader anthropological interest. We use a dataset of

1354 sourced obsidian artifacts from 462 archaeological sites in the Yukon and Northwest Territories (N.W.T.) to explore changes in the movement of obsidian (Figure 3.1). Sourced lithics are proxy indicators of thousands of years of social relationships that are otherwise difficult to discern (Earle and Ericson, 1977; Kelly, 1995; Peterson et al., 1997; Torrence, 2002; Fitzhugh, 2004; Whallon, 2006). Obsidian in the Yukon and N.W.T. is therefore a window to observe past human networks. We employ previously unpublished obsidian provenance analyses to understand relationships and culture contact across a Subarctic region of North America in which archaeological attention has tended to focus more on economic realities of survival (Workman, 1978; Gillespie, 1981; Morrison, 1984, 1987; Gordon, 1996, 2012a; Kuzyk et al., 1999). A chronostratigraphic marker (preserved volcanic tephra), radiocarbon dated occupations, and typologies enable reconstructions of how social relationships have changed through time, including responses to major ecological events such as volcanic eruptions.

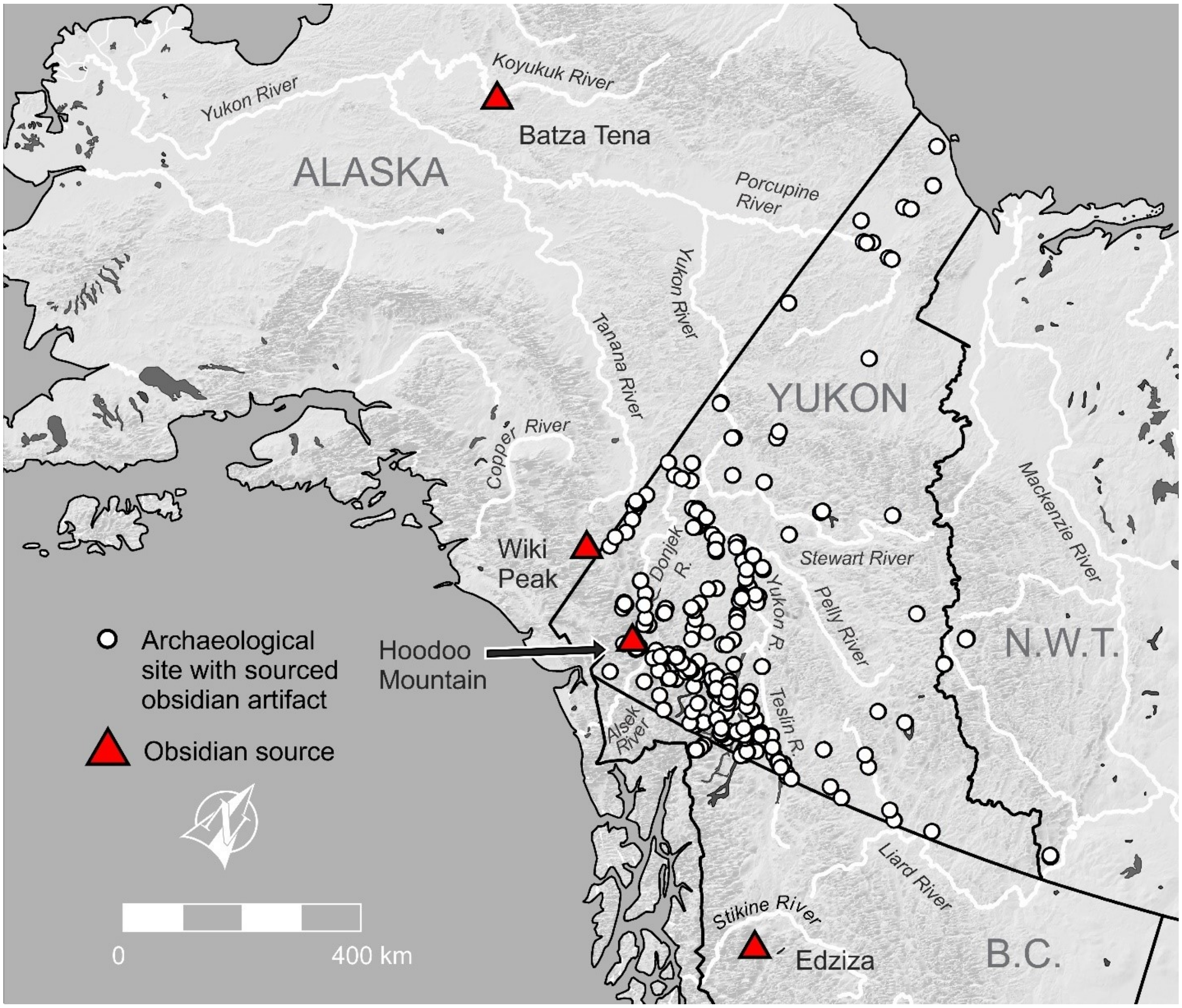

Figure 3.1 Locations of sourced obsidian artifacts in this study and four major known obsidian sources. Note that Suemez Island obsidian (Moss and Erlandson, 2001) from the southern Alaskan panhandle (south of the current figure) has been found in Alaskan archaeological sites (Potter et al., 2017) but has yet to be identified in the Yukon.

Previous attempts to place regional archaeological records into a broader context of Holocene interaction have relied largely on typological comparisons of artifact types (MacNeish, 1964; Workman, 1978; Millar, 1981; Morrison, 1984, 1987; Greer, 1993; Hare, 1995; Clark and Gotthardt, 1999). Provenance analyses offer an alternative method to help elucidate how

Subarctic people navigated through landscapes and employed kinship and exchange patterns with neighbouring people to further economic and socio-political goals. Networks of human contact in the Yukon and N.W.T., and changes to them over millennia, can inform hypotheses about the development of major linguistic groups (Dene, Tlingit, and Eskimo-Aleut) and the nature of interaction between them, including long-standing questions about culture contact across the Coast Mountains that separate the Yukon from the Pacific Ocean and across the Mackenzie Mountains between the N.W.T. and Yukon (Workman, 1978; Krauss and Golla, 1981; Millar, 1981; Morrison, 1987; Ives, 1990, 2010; Hare, 1995; Hare et al., 2012; Berge, 2018; Kristensen et al., 2019).

We track obsidian distribution patterns before and after a large-scale volcanic eruption near Mount Churchill, Alaska at A.D. 846-848 (1,104-1,102 cal yr BP) (Lerbekmo, 2008; Jensen et al., 2014) to assess how this White River Ash East event (WRAe) may have influenced social relationships. We specifically assess how this event may have shaped the concurrent spread of bow and arrow technology across Subarctic Canada. Obsidian source analysis also enables examination of the theory that the WRAe event dislocated some ancestral Athapaskans (Dene), who ultimately migrated across the continent. Shortly after European contact, Athapaskan groups existed across the interior Subarctic with additional distinct populations on the British Columbia Plateau, the Oregon coast, northwest California, and in the American Great Basin and Southwest (Haskell, 1987; Ives, 1990; Jackson and Ericson, 1994; Matson and Magne, 2007; Golla, 2011; Seymour, 2012a; Hill and Trabert, 2018). Volcanic eruptions in Alaska have been hypothesized as stimuli for the movement of Athapaskan social units through interior or coastal corridors down to southern regions of the United States (Workman, 1974; Ives, 2003, 2010, 2014; Magne and Matson, 2010).

3.2 Background geology and geography of obsidian in Northern Canada and Alaska

Analyses by portable X-ray Fluorescence (pXRF), Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS), and Instrumental Neutron Activation Analysis (INAA) have identified six major and 31 minor geochemical groups of obsidian[1] used by First Nations of the Yukon, N.W.T, northern British Columbia, and Alaska (Table 3.1) (Wheeler and Clark, 1977; Van Dyke and Jackson, 1981; Fladmark, 1984; Carlson, 1994; Clark and Clark, 1993; Cook, 1995; James et al., 1996; Reuther et al., 2011; Reimer, 2015). Each geochemically distinct group represents a distinct obsidian deposit. Half have been pinpointed to specific locations – termed here sources – while the remaining half remain to be identified at their geological origin.

Major identified sources in Alaska include Batza Tena, Wiki Peak, and the Obsidian Cove source on Suemez Island. The major identified obsidian sources in the Yukon and northern British Columbia are Hoodoo Mountain and Mount Edziza, respectively. Yukon archaeological sites have yielded obsidian from four known sources – Edziza, Batza Tena, Wiki Peak, and Hoodoo Mountain – and these are the primary focus of this paper (Figure 3.1). Hoodoo Mountain obsidian spread northwest into central Alaska as early as 11,500 cal yr BP and Edziza obsidian has been found in coastal Alaskan sites with dates as early as 11,600 cal yr BP (Potter et al., 2017). The Wiki Peak and Batza Tena sources saw even earlier use dating back to 13,300 cal yr BP (Potter et al., 2017). Edziza obsidian has perhaps the widest distribution of obsidian in Subarctic North America, ranging from central Alaska to southern British Columbia, and east to Alberta, over 2.2 million km^2 (Kristensen and Woywitka, 2013; Kristensen et al., 2016; Woywitka, 2017; Springer et al., 2018).

[1] We adopt the Alaska Archaeological Obsidian Database (AAOD) convention of calling geochemical groups with known geological outcrops ‘sources’ while geochemical groups with unknown locations are called ‘groups’ (Reuther et al., 2011).

Table 3.1 List of obsidian sources and groups of relevance to the current study area (adapted from Reuther et al., 2011). A' is likely from central Alaska near Gulkana and the Copper River (see Figure 3.1) (Goebel et al., 2008). Known sources are in bold.

Source group	Location
A	**Wiki Peak, AK**
B	**Batza Tena, AK**
E, E1, E3	**Mount Edziza, BC**
J, M	**Hoodoo Mountain, YT**
Z	**Suemez Island (Obsidian Cove), AK**
A'	Unknown – interior AK
AH	Unknown
AL	Unknown
H	Unknown
K	Unknown
N	Unknown – interior AK
P	Unknown – interior AK
Y1	Unknown – southern YT
Y2	Unknown
Y3	Unknown – southern YT
Y4	Unknown

Batza Tena, Wiki Peak, and Hoodoo Mountain formed in the Early to Mid-Tertiary Period (Patton et al., 1979). Wiki Peak and Hoodoo Mountain are within the Late Cenozoic Wrangell volcanic belt of the Nutzotin and St. Elias Mountains (respectively) where volcanism developed due to both subduction of oceanic plates at the edge of the Yakutat terrain and magmatism associated with extension across the large Duke River Fault from roughly 26 to 10 mya (Richter et al., 1990; Skulski et al., 1992). Neighbouring creeks of Wiki Peak drain mostly into the Tanana River, which flows through central Alaska (Figure 3.1). Wiki Peak is also relatively close to the headwaters of White and Donjek rivers that flow north from the Alaska border to the Yukon River (Figure 3.1). Tributaries surrounding Hoodoo Mountain flow north and northeast into the Donjek River but the outcrops closely neighbour the Alsek watershed that drains southwest into the Pacific Ocean. Of the four known sources, Hoodoo Mountain is the easiest for people in southern and central Yukon to access in terms of distance and elevation gradients from navigable rivers and valleys.

Batza Tena is within the Yukon-Koyukuk Basin (Clark, 1995) and lies near the junction of the Koyukuk terrain, an arcuate belt of Jurassic and Early Cretaceous subduction-related volcanic rocks and later Cenozoic volcanic rocks (Patton and Box, 1989). Batza Tena may have formed during one of several widespread magmatic events near this borderland from 65 to 40 mya (Moll-Stalcup and Arth, 1989; Patton and Box, 1989). The Koyukuk River near Batza Tena is a tributary of the Yukon River that flows through the Yukon and Alaska *en route* to the Pacific Ocean. The most feasible transport routes of Batza Tena obsidian into the Yukon (based on linear distance and movement along valley corridors) are via ascent of people up the Porcupine River (northern Yukon) and via the wide Yukon River (central and southern Yukon).

Mount Edziza is within the Stikine Volcanic Belt of the Coast Mountains and is thought to have formed in the last 8 my (Souther et al., 1984). The Mount Edziza Volcanic Complex consists of five magmatic cycles and 15 formations, at least four of which produced obsidian (Souther et al., 1984). The resultant geochemistry of Edziza obsidian and the ten distinctive obsidian flows is complex (Godfrey-Smith, 1985; Reimer, 2015). Edziza sits near the Stikine River that flows southwest to the Pacific Ocean. The most feasible routes of Edziza obsidian into the Yukon (based on linear distance and movement along valley corridors) are via tributaries of the Teslin River to the north and by the relatively short distance west to the Pacific Coast and then north into the Yukon through southeast Alaska. There are no recorded sources of obsidian in the N.W.T. or in neighbouring Alberta to the southeast.

The presence of four known sourced obsidians in the study area permits development of a hypothesis of comparative obsidian movement based on basic geography (linear distance). Straight-line distances from archaeological sites to known obsidian sources are perhaps poor measures of expected utilization given the region's rugged topography, glaciers, and the known combination of river, ocean, and overland travel employed by First Nations. However, other methods of inferring movement (e.g., least-cost path analyses) are complicated here by poorly known variables and assumptions of energetic and temporal costs of ocean, river, and terrestrial travel. In addition, movement corridors were perhaps influenced more by qualitative than quantitative traits, e.g., religious beliefs, taboos, the presence of hostile or amicable neighbours, socio-political control over trails and passes, and the willingness (and even desire) to travel in dangerous areas (de Laguna, 1972; McClellan, 1975; Hebda et al., 2017). Straight-line distances may be unrealistic but are simple, transparent, and permit an objective comparison. Figure 3.2 presents an expected distribution of known obsidian sources if each archaeological site in the Yukon obsidian dataset yielded obsidian from the nearest known source. This hypothesis assumes that the raw materials from all obsidian sources were valued equally, that the decision to transport different obsidians was based solely on distance to quarries, and that only the four known sources were exploited. While these assumptions are problematic, this hypothesis enables comparison to actual obsidian source distributions discussed in the remainder of the paper. We expect that 78% of the obsidian in the Yukon dataset should derive from Hoodoo Mountain, which will dominate southwest Yukon. Edziza obsidian should appear in southeast Yukon and into southern N.W.T. while Wiki Peak obsidian should dominate west central Yukon. Lastly, we expect Batza Tena obsidian to be confined to northern Yukon. If the WRAe volcanic eruption was severe enough to displace people, we hypothesise that the greatest change in obsidian utilization will be in the frequency of Hoodoo Mountain use because the tephra footprint (Figure

3.3) most extensively overlaps with the expected distribution of Hoodoo Mountain obsidian (Figure 3.2). These hypotheses are tested below with provenance data and contextualized with ethnohistoric records of culture contact and exchange.

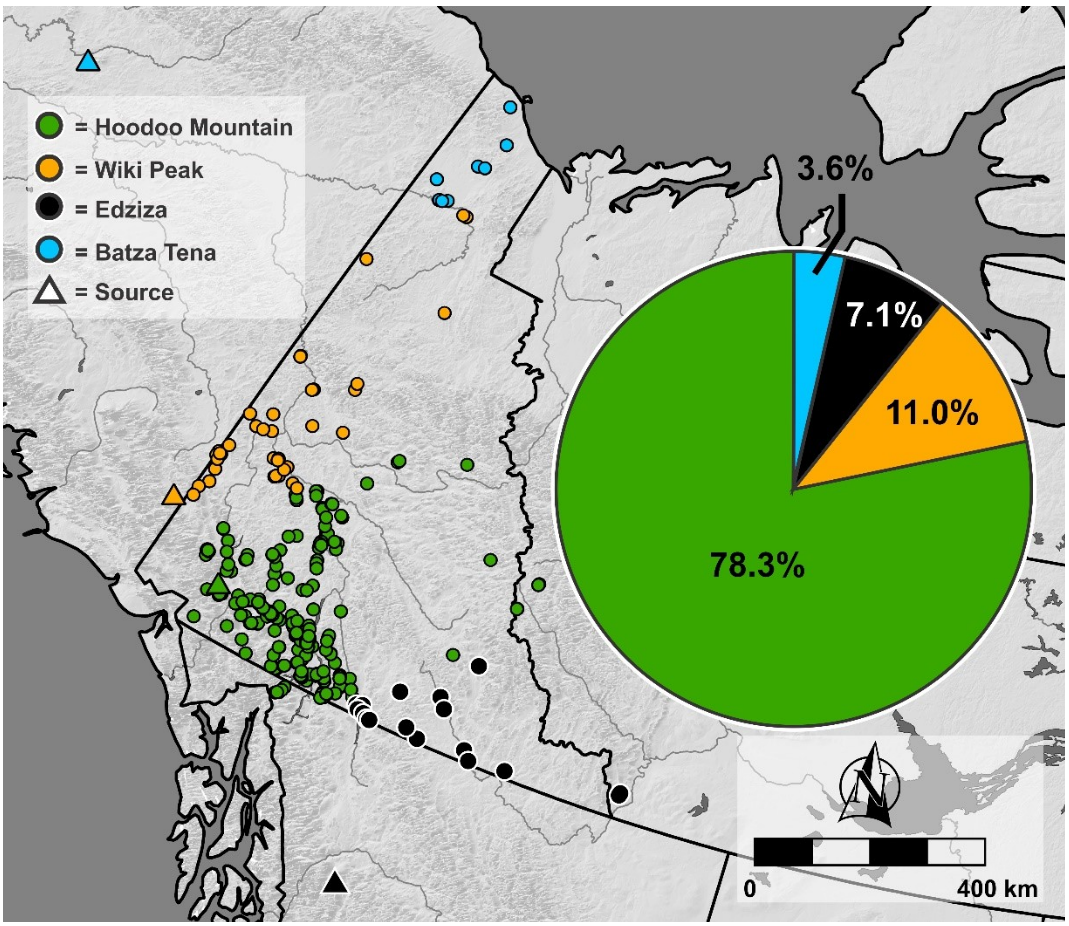

Figure 3.2 Hypothesis of obsidian source distributions in Yukon based on linear distance from sites in the Yukon dataset to known quarries. Distances were measured from each site in the current Yukon obsidian dataset to each known source in ArcGIS 10.0 and the shortest distance determined the hypothesised source. The pie chart represents the

expected percentage of sites in the Yukon dataset that should yield obsidian from each known source.

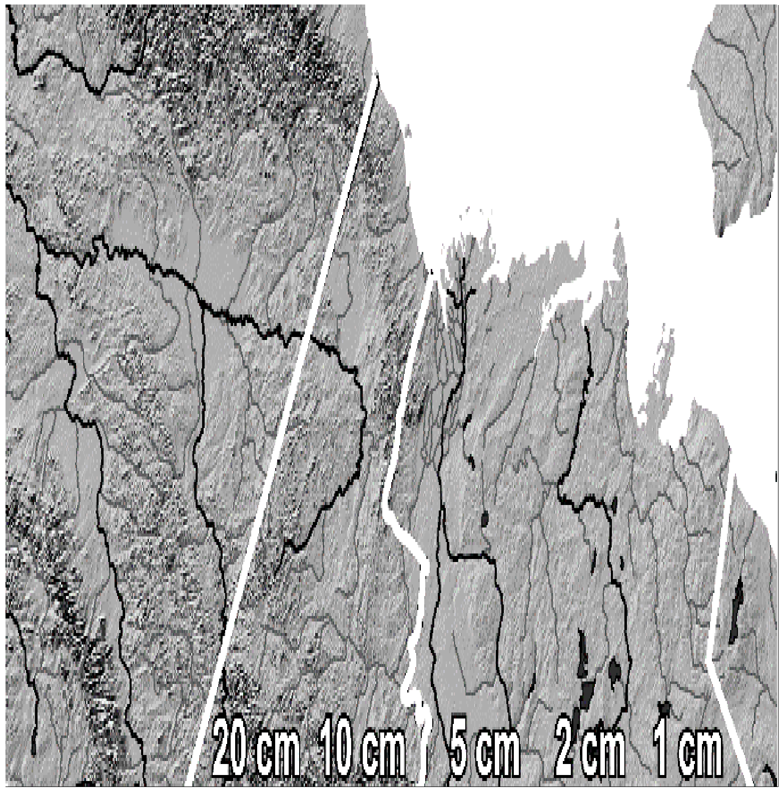

Figure 3.3 Tephra isopachs of WRAe (adapted from Lerbekmo, 2008) extending from an origin near Mount Churchill, Alaska.

3.3 Data and methods

3.3.1 Obsidian sourcing data

The data on which this paper is based (1354 artifacts from 462 archaeological sites) have been compiled over 40 years. Published accounts of 54 sourced artifacts (e.g., Van Dyke and Jackson, 1981) were amalgamated with new analyses conducted on 1300 Yukon and N.W.T. artifacts.

Obsidian artifacts were sourced by pXRF, INAA, and LA-ICP-MS. These data from the Yukon and N.W.T. represent a component of the larger Alaska Archaeological Obsidian Database (AAOD) maintained by the U.S. National Park Service in Alaska, the University of Alaska Museum of the North, and the Center for Applied Isotope Studies at the University of Georgia. Reuther et al. (2011) provide a history and synopsis of the AAOD, data sources, and calibration measures. For discussions of pXRF, INAA, and LA-ICP-MS analytical methods employed to source obsidian in the AAOD, see Cecil et al. (2007), Coffman and Rasic (2015), Glascock et al. (1998), Glascock and Neff (2003), Glascock et al. (2007), Speakman and Neff (2005), Speakman and Shackley (2013), and Speakman et al. (2007).

3.3.2 Spatial and chronological analyses

All archaeological sites that yielded obsidian sourced in this study were plotted in ArcGIS 10.0 and distances were measured to respective outcrop sources to generate spatial statistics. Ethnographic and ethnohistoric records of culture contact were reviewed to help explain spatial patterns of obsidian exchange (Dawson, 1889; Emmons, 1911, 1991; Olson, 1936; McClellan, 1953, 1975; Honigmann, 1954; Krause, 1956; Teit, 1956; de Laguna, 1972; Albright, 1982; Legros, 1985, 2007; Grinev, 2005).

Each artifact was assigned to a temporal period based on radiocarbon dates, typological information (e.g., projectile point morphology), and/or the stratigraphic presence of WRAe ash that typically appears in excavation units and shovel tests as a distinct band of tephra from 1-20 cm thick in much of the Yukon (Figure 3.3). Three temporal periods are used: Early (12,000 to 8,000 years ago and encompassing terms/phases/complexes of Chindadn/Nenana, Denali, Northern Cordilleran); Middle (8,000 to 1,200 years ago and including the Northern Archaic tradition, Little Arm phase, Taye Lake phase, and Annie Lake complex); and Late (1,200 to 200 years ago, including all sites post-WRAe, within the Late Prehistoric Period and Aishihik phase) (Workman, 1978; Hare, 1995). Because of our focus on central and southern Yukon and the

WRAe footprint, sites along the Porcupine River and north were excluded from chronological analyses and are discussed separately.

Of a total 462 sites in the Yukon/N.W.T. obsidian dataset, only 161 (35%) had temporal context; of these, 111 are from the pre-WRAe interval and 50 are post-WRAe (Figure 3.4). To further explore potential impacts of WRAe, the study area was subdivided into three zones relative to a 5 cm tephra isopach. A footprint of tephra ≥5 cm was chosen on the basis of botanical and faunal studies of modern eruptions that indicate that the most significant ecological impacts of ash are in tephra fall zones of roughly 5 cm depth or greater because of plant mortality, associated fires, and mechanical/toxic damage to mammals (Capps, 1915; Kurenkov, 1966; Mack, 1981; Seymour et al., 1983; Black and Mack, 1984; Hinckley et al., 1984; Martin et al., 1984; Antos and Zobel, 1985; Tsuyuzaki, 1995; Grishin et al., 1996; Dale et al., 2005; Talbot et al., 2010; Flueck, 2016). The three zones of our study area are: 1) north of the WRAe footprint; 2) within the WRAe footprint; and 3) south of the WRAe footprint (Figure 3.4). We explore whether or not obsidian distributions differ pre- and post-WRAe in these zones and the implications for theories of human responses to this volcanic eruption at A.D. 846-848.

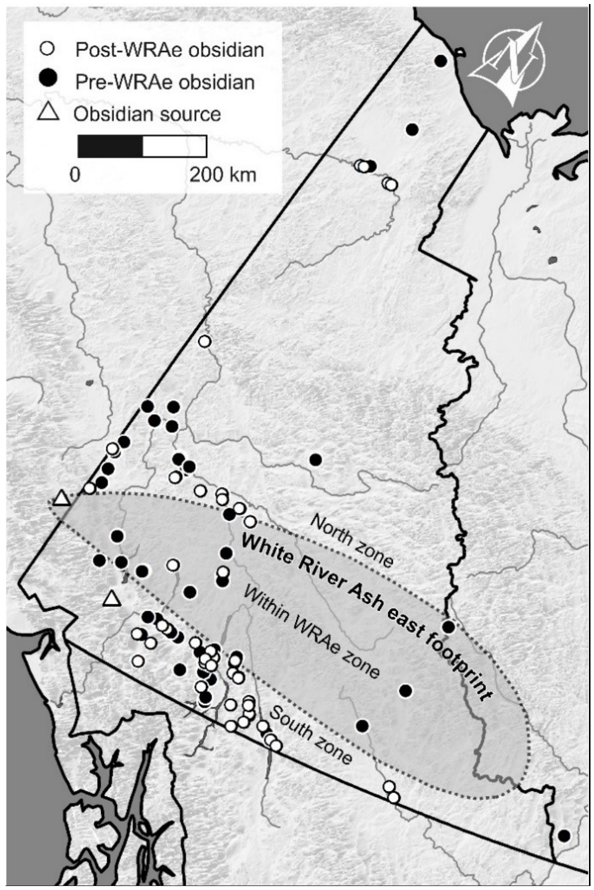

Figure 3.4 Pre- vs. post-WRAe sites with sourced obsidian. The "White River Ash east footprint" is a 5 cm tephra thickness isopach (after compression). Also depicted are the three zones (North, Within WRAe, and South) that the study area was subdivided into in order to evaluate differences in pre- vs. post-WRAe obsidian exchange.

3.3.3 Limitations

The database is not a complete representation of obsidian artifacts in the Yukon. Samples selected for analyses tend to be curated tools and thicker flakes because thin specimens return less reliable geochemical results. Also, artifacts close to obsidian sources were less likely to be analysed; the database is skewed towards those sites in which it was deemed that geochemical analyses would offer particularly informative results. As a result, the spatial analyses below are likely to exaggerate long-distance movement of obsidian and perhaps undervalue domestic use patterns in close proximity to outcrops. The dataset is also influenced by a stronger survey intensity in southwest Yukon and along the Yukon River (e.g., Workman, 1978). Furthermore, with the exception of the Little John (KdVo-6) dataset, not all obsidian artifacts recovered from a site were sourced. This may over-represent dominant source groups and under-represent minor ones. The Little John dataset, which represents over one quarter of the total sample considered here (382 sourced artifacts), heavily skews analyses. To reduce bias while retaining the contribution of these data, artifact totals of KdVo-6 were down-weighted by multiplying them by 0.1. In the revised totals, KdVo-6 artifacts represent 3.6% of the Yukon dataset as opposed to the actual value of 27.7%. A value of 0.1 was chosen because the revised total percentage approximates the second most commonly represented site (JjVi-37), which has 37 artifacts of sourced obsidian (3.5% of the down-weighted artifact total). Lastly, we acknowledge that we are comparing over 10,000 years of pre-WRAe archaeological material to only 1200 years of post-WRAe material, which are not a symmetrical datasets, but the approach has several justifications. Each millennia of human networks in the study area likely involves short-term oscillations (e.g., decades of personalities or family traditions) that may mask informative broader trends. We reasoned that the larger the comparative data set on either side of the WRAe tephra, the more likely we are to detect meaningful patterns about regional exchange vs. short-term oscillations. In addition, the temporal resolution of many archaeological finds is simply 'pre-WRAe' or 'post-WRAe' because they were recovered from undated components either below or above the WRAe tephra. While it may be informative to compare 1000 years of pre-WRAe material to 1000 years of post-WRAe material, there are simply too few dated specimens to do so and the low sample size would prohibit any statistical significance of the findings.

3.4 Results

3.4.1 Sources and spatial results

Figures 3.5 to 3.7 summarize obsidian source results in the Yukon and N.W.T. The majority of obsidian is from Wiki Peak, Hoodoo Mountain, or Edziza (with a combined total of roughly 80%). Batza Tena, AH, and Y1 appear to be minor obsidian sources (a combined 10% of the sample) while A’, AL, H, N, Y2, Y3, and Y4 are sparsely represented (roughly 0.2-1.5% of the sample each).

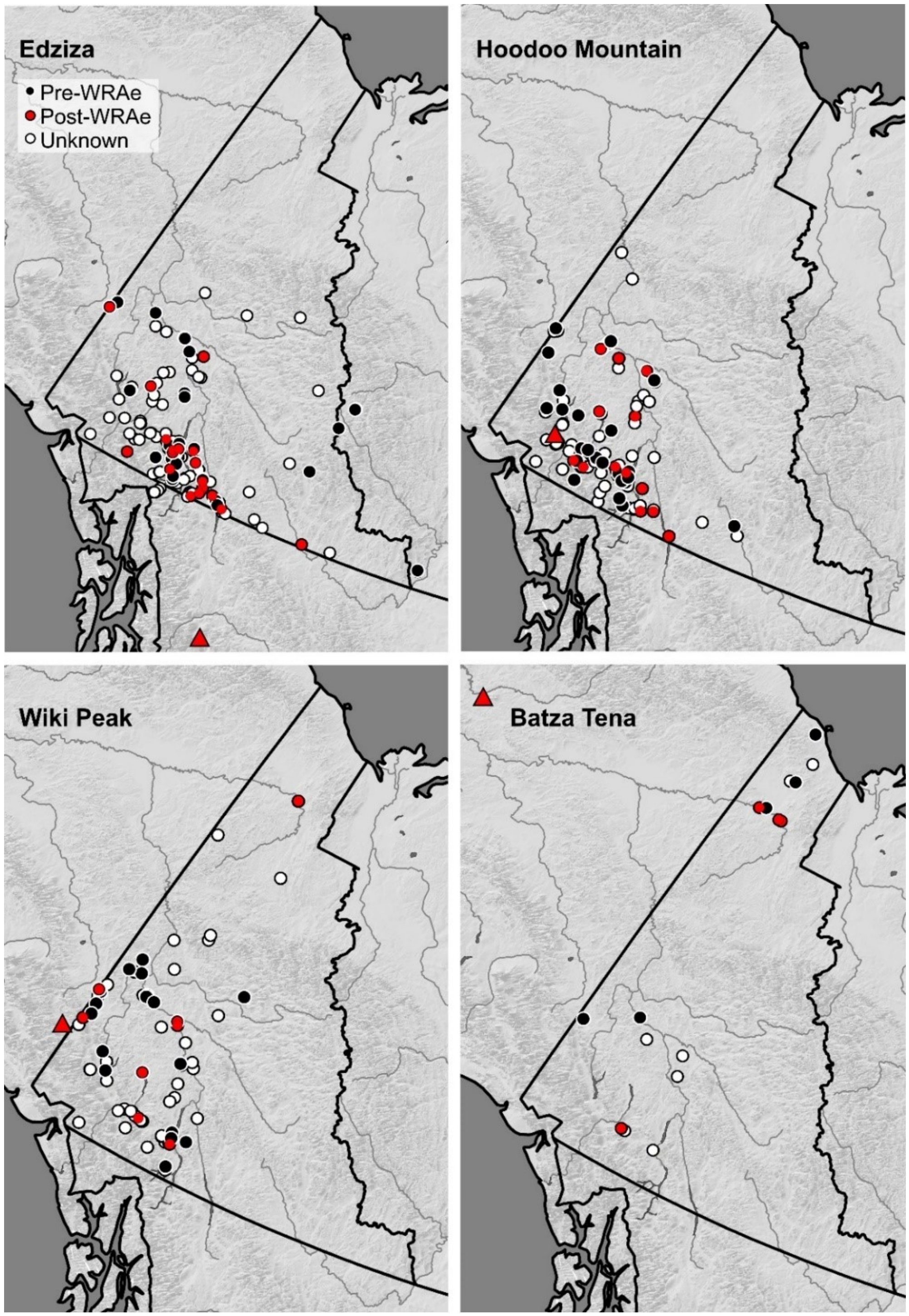

Figure 3.5 Archaeological sites with sourced obsidian from known sources (red triangles). Note that the current figure masks those sites that yielded the same obsidian source group in both pre- and post-WRAe components.

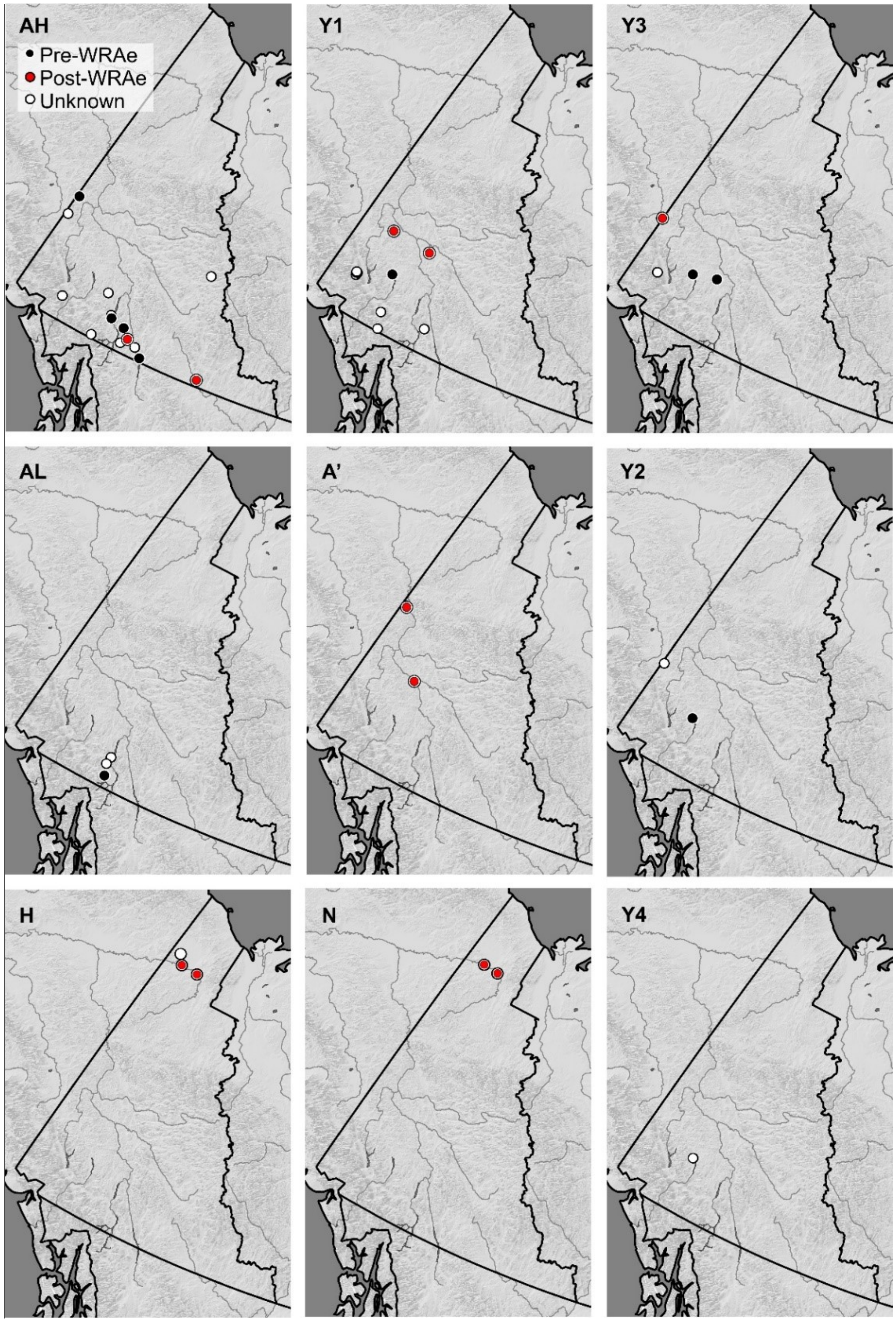

Figure 3.6 Archaeological sites with sourced obsidian from unknown groups.

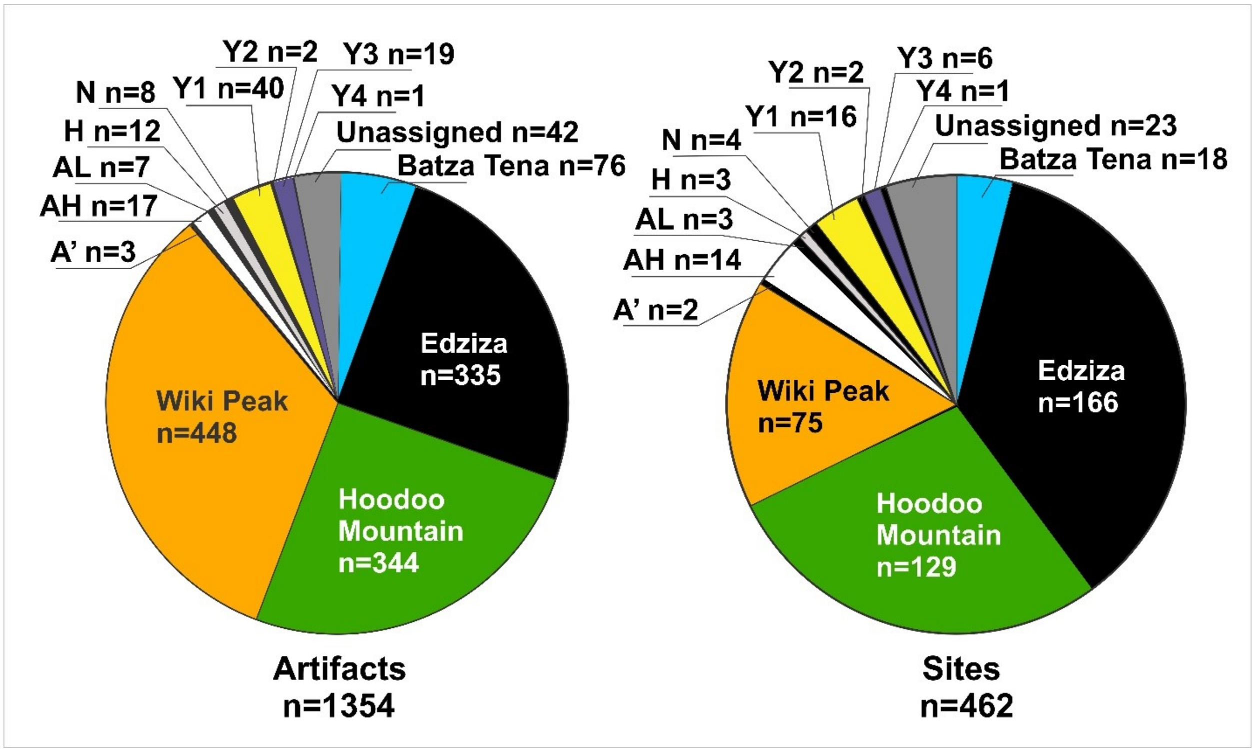

Figure 3.7 Sourced artifacts (left) and archaeological sites (right) that have yielded source groups. These values are raw and do not incorporate a down-weighted representation of material from KdVo-6.

A total of 88% (n=336) of the KdVo-6 sourced obsidian is from Wiki Peak, which lies about 65 km south of the site. Excluding the Little John artifacts, Hoodoo Mountain comprises 35% of all sourced obsidian in the Yukon/N.W.T., Edziza is 33%, Wiki Peak is 11%, and Batza Tena is 8%. Table 3.2 indicates that, of the known sources, Hoodoo Mountain is the most locally distributed while Batza Tena obsidian traveled the greatest distance. On average, Edziza obsidian travelled over three times the linear distance of Hoodoo Mountain obsidian to arrive at Yukon archaeological sites and over one and a half times the distance of Wiki Peak obsidian (Figure 3.8). The site totals in Table 3.2 indicate that sites with Edziza and Hoodoo Mountain obsidians are roughly twice as common as those with Wiki Peak obsidian.

Table 3.2 Straight line distances from obsidian artifact occurrences to known sources.

Source	Ave. distance sites to source (km)	Standard deviation (km)	Min. to max. distance (km)	No. of sites
Batza Tena	812	146	669-1106	18
Edziza	454	119	277-797	166
Wiki Peak	251	116	34-681	75
Hoodoo	133	92	10-459	142

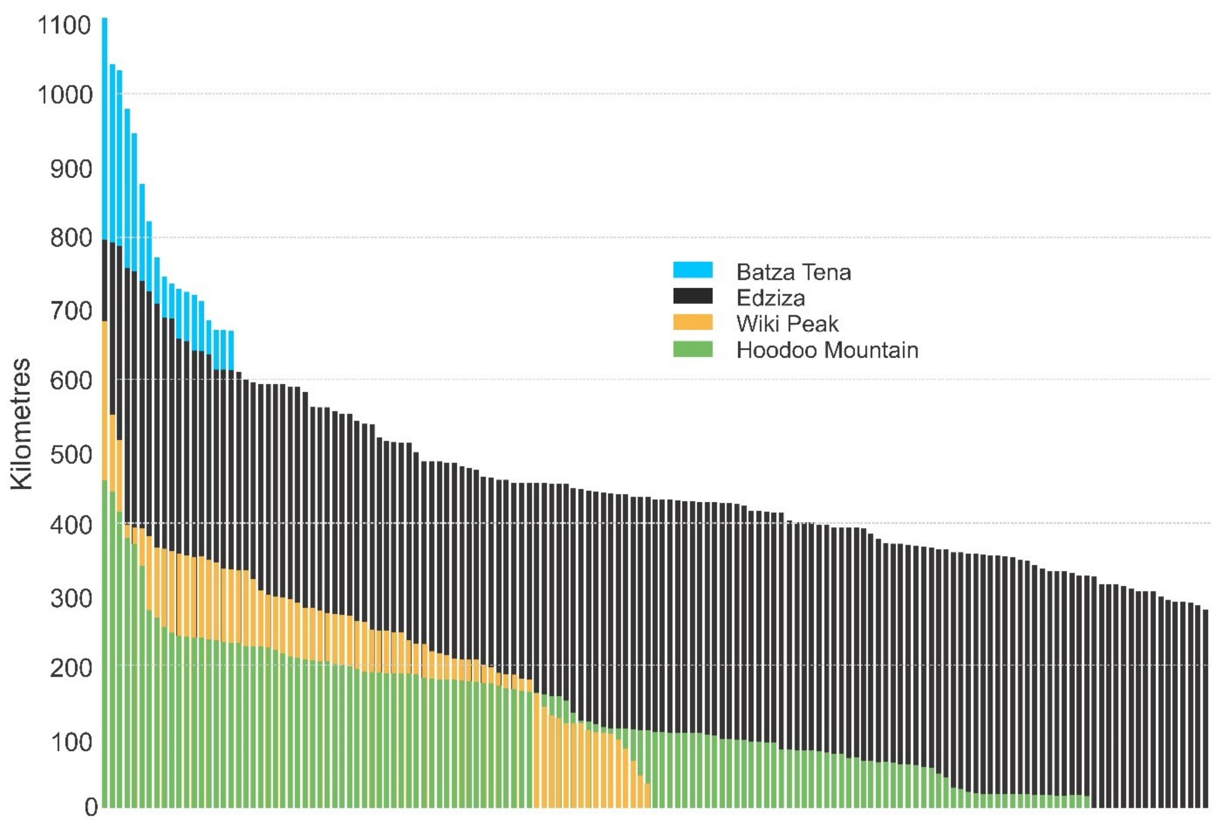

Figure 3.8 Distance drop-off comparison of Yukon archaeology sites with Batza Tena, Edziza, Wiki Peak, and Hoodoo Mountain obsidian artifacts. The y-axis represents

distance from archaeology site to obsidian source. Each bar along the x-axis represents one archaeological site.

Figure 3.9 summarizes artifact types in the Yukon obsidian dataset and the percentages of obsidian groups among each type. Although included in the general analysis, this figure does not include artifact types of which there are less than 10 artifacts; blades (n=3), burins/burin spalls (n=2), microblade cores (n=1), and tested pebbles (n=8). Edziza is generally the most common source group with the exception of decortication flakes (defined here as flakes containing cortex from the outer rind of the original obsidian nodule) and microblades. Most obsidian microblades are from northern sites where Batza Tena is a logical source based on site proximity to outcrops. The relatively consistent percentages of sourced obsidian groups (Wiki Peak, Hoodoo Mountain, and Edziza) across artifact types implies that the lithic reduction strategy did not differ despite two sources being local and one being exotic. This is perhaps logical in a subsistence strategy characterized by high mobility: raw materials moved in a near-finished stage (likely biface blanks in the case of obsidian) regardless of the distance involved.

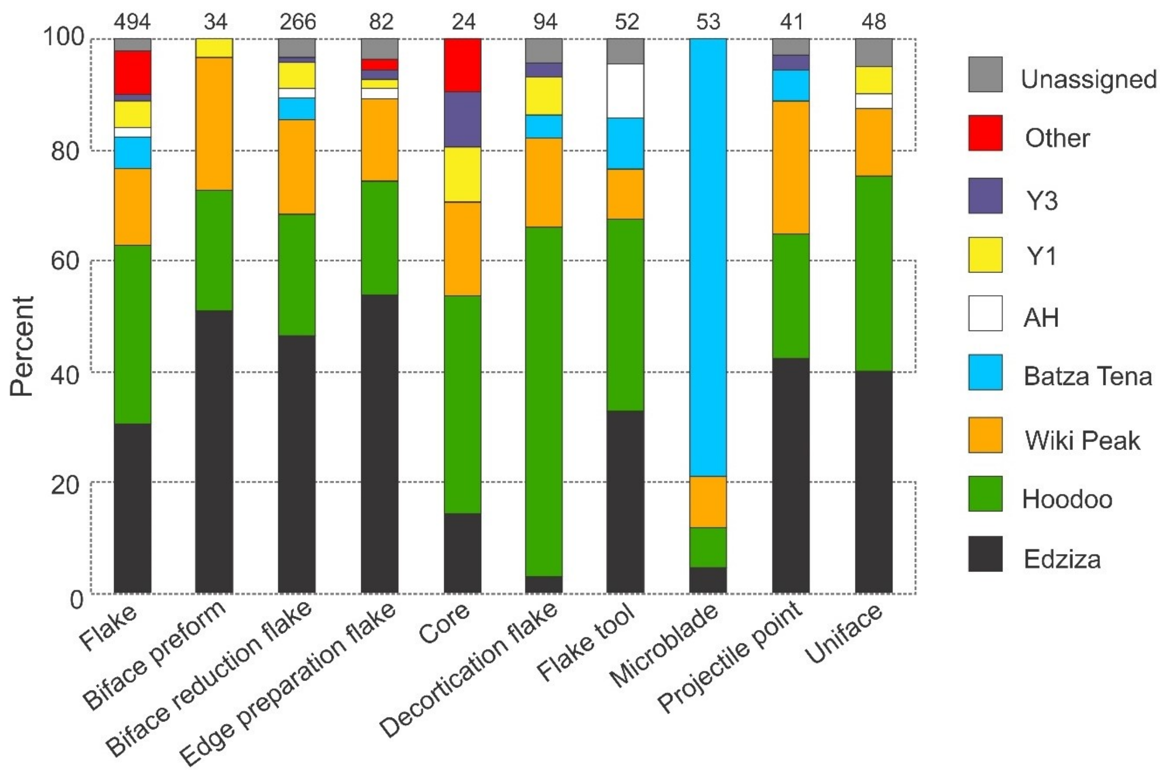

Figure 3.9 Percentages of obsidian source groups in each artifact type. Artifact totals are listed above each column. The current figure depicts a down-weighted contribution of KdVo-6. Note that 'biface reduction flake' includes bifacial percussion flakes and bifacial pressure flakes while the 'flake' category includes those flakes that were not categorized as biface reduction flakes, edge preparation flakes, or decortication flakes.

3.4.2 Chronological results and patterns of obsidian use

Wiki Peak, Hoodoo Mountain, and Edziza are the dominant obsidian sources in all time periods (Table 3.3). In the Late Period, the use of Wiki Peak drops while Edziza increases. The diversity of obsidian types increases from six in the Early Period (Late Pleistocene/Early Holocene) to 11 in the Late Period (Late Holocene); while this may represent increased familiarity over time with smaller outcrops, it may also relate to an increase in sample sizes in the Middle and Late categories compared to Early.

Table 3.3 Comparison of Early (Late Pleistocene/Early Holocene), Middle (Middle Holocene), and Late Period (Late Holocene) chronological designations (based primarily on dated contexts) of Yukon/N.W.T. obsidian artifacts. Bracketed values exclude artifacts from KdVo-6.

Source	Early	Middle	Late
Batza Tena	1	1	2
Edziza	15	21	29
Hoodoo Mountain	19	16	19
Wiki Peak	35 (8)	92 (20)	34 (6)
Group A'			2
Group AH	1		2
Group H			11
Group N			5
Group Y1		1	2
Group Y3		1	6
Unassigned	1	1	1
Total	**72**	**133**	**113**

Obsidian artifacts and sites in the entire study area and within each zone relative to the WRAe 5 cm tephra footprint display variable patterns from pre to post-WRAe time periods (Figure 3.10). Student chi square tests were run to compare the differences between observed and expected values of post-WRAe obsidian source ratios. That is, how did the post-WRAe observed values differ from what would be expected if the three major obsidian sources (Edziza, Hoodoo Mountain, and Wiki Peak) maintained their pre-WRAe ratios? Figure 3.11 presents the pre- and post-WRAe ratios of the three major sourced obsidian groups at Yukon archaeological sites.

Edziza artifacts significantly increased across southern and central Yukon after the ash while Wiki Peak significantly dropped (Figure 3.11). Hoodoo Mountain obsidian stays relatively consistent. Within the divided regions (north, within, and south of the WRAe 5 cm isopach), statistical significance is evasive because of small sample sizes. However, the most statistically significant change occurs in sourced artifacts south of the footprint (p=0.2062) where Edziza is notably higher than expected and Wiki Peak is notably lower than expected (Figures 3.10 and 3.11). Changes in sourced obsidian by archaeological site in the study area as a whole were not statistically significant (p=0.4816) while changes in the frequency of sourced artifacts were statistically significant (p=0.0091). For example, the percentage of Edziza obsidian artifacts (relative to those of Wiki Peak and Hoodoo Mountain obsidian) shifts from 34.5% pre-WRAe to 52.6% post-WRAe (an increase of 18.1%; Figure 3.11).

In all chi square calculations, p values were lowered by the consistency of Hoodoo Mountain obsidian. For example, removing Hoodoo Mountain obsidian from the chi square test of sourced artifacts south of the WRAe 5 cm isopach returns a p value of 0.0857, which exceeds a 90% confidence level in the significance of observed changes in Edziza and Wiki Peak ratios after the ash fall. In other words, a background consistency of Hoodoo Mountain exploitation partially masks the statistical significance of changes in Edziza and Wiki Peak. Obsidian diversity is difficult to track because of small sample sizes but it remains more or less consistent across the study area (south and central Yukon) before and after the ash. Table 3.3 and Figure 3.6 demonstrate that much of the increase in diversity of obsidian group use from the Middle to Late Holocene occurs in northern Yukon (e.g., groups A', H, N), which was beyond the spatial scope of the pre- and post-WRAe comparison.

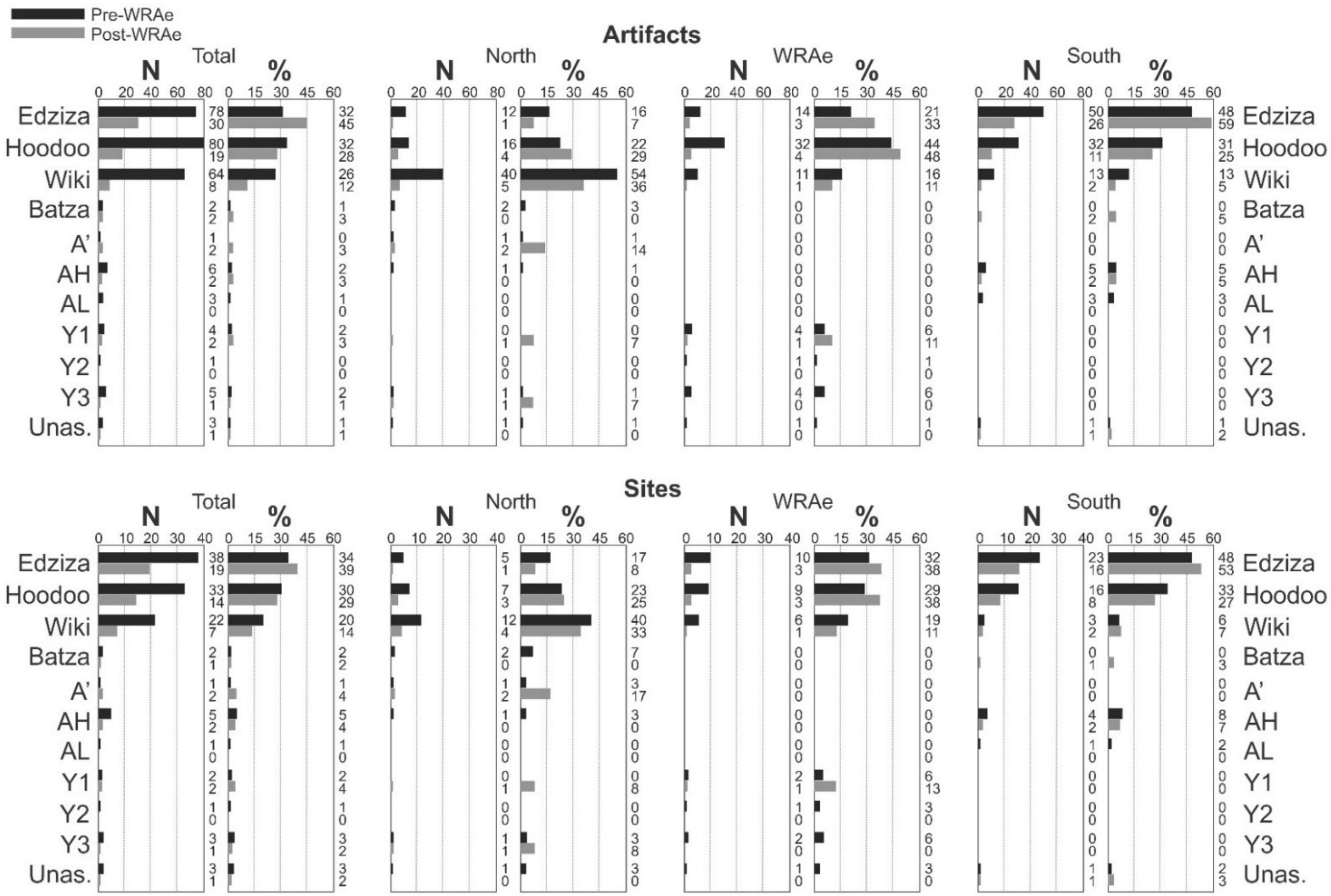

Figure 3.10 Comparison of pre- vs. post-WRAe obsidian artifacts (above) and sites (below) that yielded sourced obsidian. The divided zones (North, WRAe, and South) are depicted in Figure 3.4. ‘Pre-WRAe’ includes roughly 10,000 years of human occupation while ‘post-WRAe’ includes 1200 years, therefore, the most valid comparisons are those of percentages (right column in each zone) as opposed to the numbers (N) of sites or artifacts (left column). Artifact and site numbers are listed at the right side of each column. Note that these values reflect a down-weighted value (0.1) of material from KdVo-6.

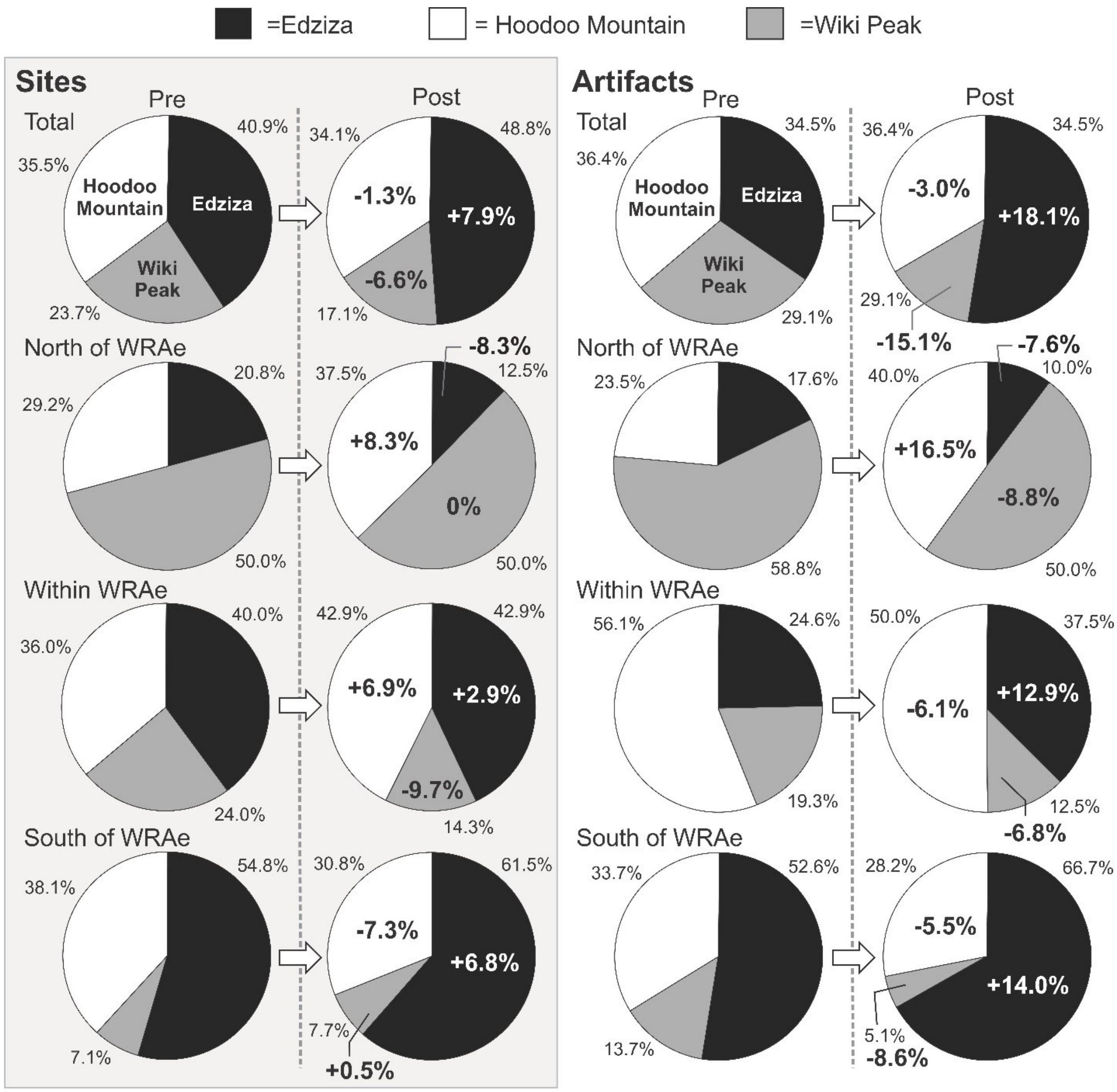

Figure 3.11 Comparison of pre- vs. post-WRAe ratios of Edziza, Wiki Peak, and Hoodoo Mountain obsidian. The number of sites containing sourced obsidians are at left (within the grey box) and the number of artifacts of sourced obsidian are at right. The percentage of each obsidian source is listed outside the pie chart margins. The percentage change of each sourced obsidian group from pre- to post-WRAe is indicated as a positive or negative value (+ or -) if the relative percentage increased or decreased, respectively.

3.5 Discussion: geography and conduits of exchange

The spatial patterns of obsidian are unexpected (Figures 3.5 and 3.6). Hoodoo Mountain and Wiki Peak obsidian distributions generally fit expectations based on proximity to outcrops - they accord with a standard distance-decay model (Blumenschine et al., 2008; Renfrew, 1977). However, the widespread and overlapping occurrences of Edziza and Batza Tena obsidian defy expectations. Edziza obsidian artifacts are present in over two times as many archaeological sites in the Yukon (n=166) than Wiki Peak (n=75) despite the fact that the Wiki Peak obsidian outcrops are half the distance from southern and central Yukon than Edziza (Figure 3.8). Similarly, sites in southern and central Yukon with Batza Tena obsidian are roughly three to four times closer to Wiki Peak and Hoodoo Mountain than Batza Tena. The hypothesis of Hoodoo Mountain obsidian dominance among sites in southern Yukon (illustrated in Figure 3.2) is not supported. These patterns are likely not attributable to a later formation, exposure, or discovery of these sources by people since obsidian artifacts from all four sources are found in archaeological contexts in Alaska dating earlier than 11,500 cal yr BP (Potter et al., 2017).

First Nations territories at European contact in the 1800s (Figure 3.12) illustrate the position of obsidian sources within social units that may have controlled access to, and distribution of, obsidian in pre-contact times. However, territories at European contact may be poor analogues for deeper ancestral ones. Researchers in other regions posit that changes brought about by the introduction of bow and arrow technology (between about 2500 and 1000 cal yr BP in northwest North America) reduced hunting band sizes and territories and contracted exchange networks (Churchill, 1993; Bettinger, 2013; Angelbeck and Cameron, 2014). Territories may have also been larger several thousand years ago when North American population densities were lower (Denevan, 1992; Steele et al., 1998; Lanata et al., 2008). However, MacNeish (1964) and Workman (1978) argued that densities in southwest Yukon may have been highest during the Middle Holocene (Northern Archaic tradition) when grasslands supported larger bison populations. Related to this notion is our inferred decrease in human mobility following the spread of coniferous forests in the study area 6000 years ago (Keenan and Cwynar, 1992; Dyke, 2005; Gajewski et al., 2014; Edwards et al., 2015), which may have altered group territories. Lastly, Potter (2008) documents a shift ca. 1000 BP among people in Alaska towards more permanent settlements, a greater reliance on storage, and increased logistical mobility. If these patterns apply to the Yukon, they may have altered obsidian exchange dynamics. However, Figure 3.12 remains informative about access to, and control over, obsidian shortly before Europeans arrived in southern Yukon in the 1800s. The associated ethnohistoric records of these territories are one of the few means of contextualizing Holocene raw material distribution patterns and inferred trade networks.

Based on these territories (Figure 3.12) and ethnographic data of group mobility and range (Binford, 2001; Kelly, 1983, 1995; Shott, 1986), the majority of sites with Edziza obsidian in the Yukon/N.W.T. are unlikely to be from people who directly accessed Mount Edziza. It is also likely that Batza Tena obsidian exchanged hands several times *en route* to southwest Yukon given the very long transport distances (>1000 km in some cases). The exceptionally broad regional distribution of Edziza and Batza Tena obsidian indicate inter-territory exchange. People in southern Yukon and N.W.T. appear to have received obsidian from distant sources when much more local sources were available.

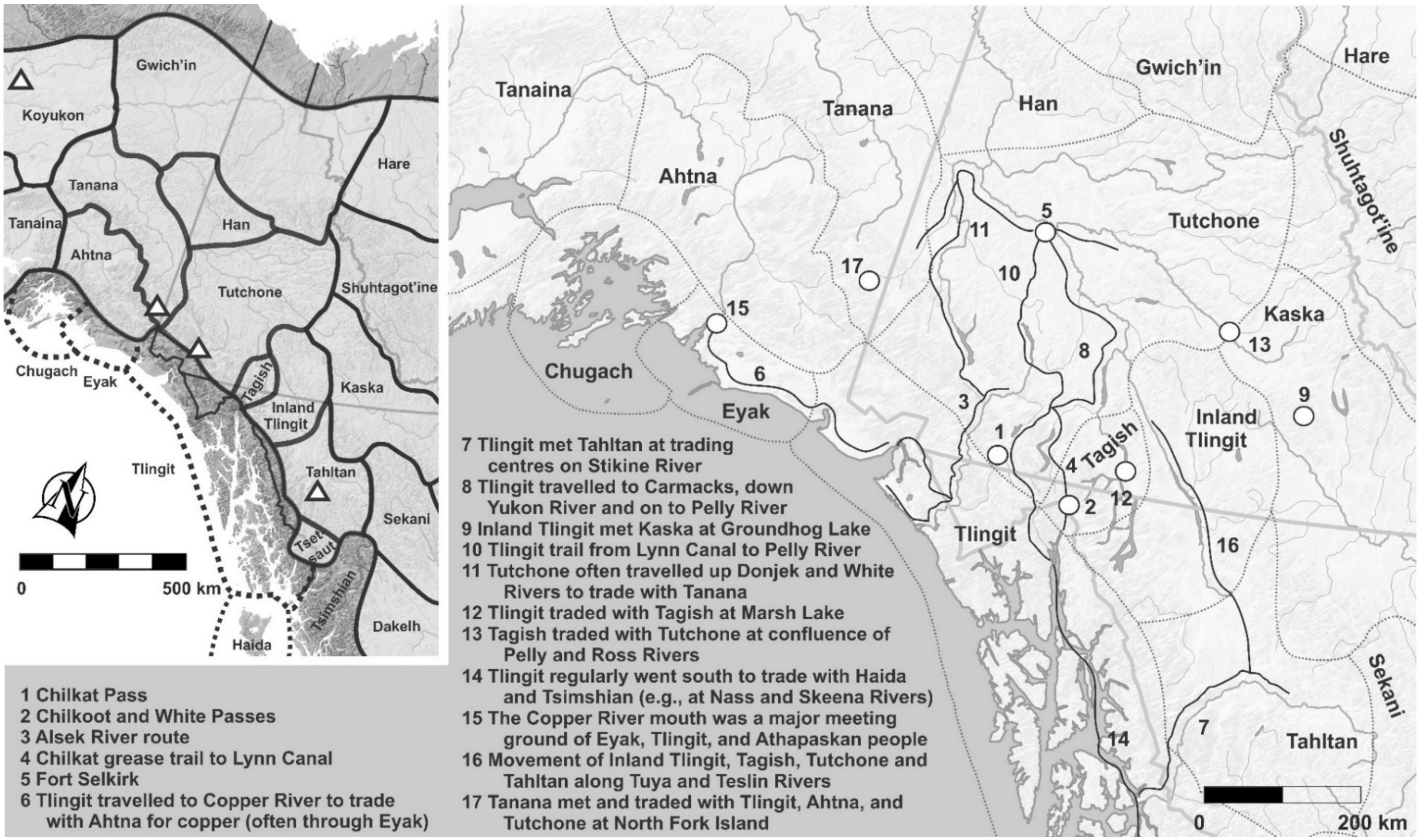

Figure 3.12 Approximate territories of First Nations at European contact (based on de Laguna, 1972; Ives, 1990). The shaded territories at left are Athapaskan (Dene). White triangles are obsidian sources. At right are major trading conduits and localities based on ethnohistoric accounts (Emmons, 1911, 1991; Honigmann, 1954; Teit, 1956; de Laguna, 1972; McClellan, 1975; Legros, 1985, 2007).

Although the Edziza obsidian source area is within interior Dene territory, it remained accessible to coastal people. Historic records indicate that Tlingit bands controlled those stretches of the Stikine River closest to Mount Edziza (Emmons, 1911:6-7). In the 1800s, these interior river reaches were utilized by coastal people because of prime salmon fisheries, access to berries, and an arid climate conducive to drying fish for winter. Seasonal exploitation of these interior river reaches would have afforded opportunities for short expeditions to quarry obsidian directly or to acquire it indirectly through exchange with the local Dene people. Emmons (1911:7, 33), for example, documents the exchange of coastal goods from the Tlingit for Tahltan furs and caribou skins at trading centres along the upper Stikine River (Figure 3.12). It appears that obsidian was quickly replaced by metal goods upon (or ahead of direct) European contact because very few early Tlingit or Tahltan ethnographic records mention collection or exchange of obsidian. Teit (1956:97-98) notes that Tahltan had once traded obsidian to the Tlingit, and Albright (1982:215) makes brief mention that the Tahltan recalled making 1-2 day trips to stone quarries in alpine areas during late summer or early fall. This relative gap in oral history, and the widespread extent of Edziza obsidian, prompted Fladmark (1984) to state that Edziza likely fell within the economic realm of coastal people who facilitated its exchange through networks that transcended the trading spheres of interior Athapaskan people. Archaeological occurrences of Edziza obsidian in coastal settings near the British Columbia/Washington border (Springer et al., 2018), on Haida Gwaii (Carlson, 1994), along the central coast of British Columbia (Coupland, 1988; Reimer, 2015), and into the Alaska Panhandle (Ackerman, 1996) all suggest that Edziza obsidian moved widely through coastal exchange networks. Regardless of who quarried Edziza obsidian, it appears that the Stikine River was a major conduit of its movement to the Pacific Coast, where it moved through extensive coastal networks.

Historical records also offer explanations for the relative abundance of Edziza obsidian in the Yukon despite closer proximity to Wiki Peak and Hoodoo Mountain. In the 1700-1900s, the Chilkat Tlingit of coastal Alaska traditionally travelled over the Coast Mountains (Figure 3.12) two to three times a year to trade with Tutchone who lived along the Yukon River (Emmons, 1991:56; Castillo, 2012). Items that moved east into the interior included obsidian (Krause, 1956:108) along with coastal raw materials and foods like seaweed, dentalia, baskets, clams, ochre, and eulachon oil (McClellan, 1953, 1975:502-506; Grinev, 2005:32). Interior groups provided Chilkat with furs, sinew, clothing, copper, porcupine quills, and plant products such as lichen, berries, and spruce gum (de Laguna, 1972:216, 350; McClellan, 1975:505-506; Grinev, 2005:32; Legros, 2007). McClellan (1975:512) also notes that the Tlingit brought "smooth stone like glass" among their trade goods to exchange with interior Tagish at places like Marsh Lake near the upper reaches of the Yukon River (Figure 3.8). Trading parties of coastal groups (up to 100 men) spent considerable time in the interior to exchange primarily luxury goods (Olson 1936:211-214; de Laguna 1972:350, 356-7; McClellan 1975:505). Obsidian distribution patterns, particularly the unexpected appearance of distant obsidian (from Edziza), indicates that historically documented modes of coastal-interior exchange (between Tlingit and Dene people) extended far into pre-contact times. That obsidian movement was dictated by luxury exchange and social relationships may partially explain why obsidian patterns in the Yukon and N.W.T. are unexpected based on linear distance (Figure 3.2). In other words, obsidian assumed a social and cultural capital that exceeded its utilitarian value (Reimer, 2011, 2018), therefore, the conduits of its exchange were shaped more heavily by social relationships than time and energy expenditure. Figure 3.12 depicts some of the many historically recorded economic centres and corridors that facilitated the exchange of coastal goods to interior peoples in northwest British Columbia, southern Yukon, and southeast Alaska in the 1700s to early 1900s.

Archaeological evidence beyond sourced obsidian supports the antiquity of this movement of coastal people and goods into southwest Yukon: an arrow shaft of hemlock (likely a coastal source) was found at a southwest Yukon ice patch (Alix et al., 2012) as was a bow of coastal maple (Hare et al., 2012). Furthermore, the frozen remains of Kwaday Dän Ts'inchí, containing marine food in his gut contents and a marine dietary signal in his isotopes and lipids, were found roughly 50 km east of Alsek River in interior northwest British Columbia (Richards et al. 2007; Corr et al., 2008; Hebda et al., 2017). The hemlock arrow is dated to 410+/-100 yr BP (calibrated) (Alix et al., 2012), the maple bow is dated to 1180+/-40 BP (uncalibrated) (Hare et al., 2012), while Kwaday Dän Ts'inchí is dated to 280-100 yr BP (calibrated) (Richards et al., 2007). All three records point to coastal-interior connections in pre-contact to protohistoric times.

Associated with the historic coastal-interior exchange system were considerable intermarriage and kin networks, with two possible material implications. Ethnohistoric records suggest that most intermarriages along coastal-interior exchange axes involved coastal Tlingit men marrying interior Dene (Athapaskan) women, although the opposite sometimes occurred (Emmons, 1911; de Laguna, 1972:526; McClellan, 1975:507; Tybjerg, 1977; Hebda et al., 2017:432). This tendency emerged because trading parties were predominantly male, and men often accrued material wealth by marrying women to solidify economic relations. Marriages typically involved a bride price – materials exchanged from the husband's family to that of the wife's – McClellan (1975:347, 367) discussed bride price among the Southern Tutchone, Tagish, and Inland Tlingit and de Laguna (1972:526) noted this practice among coastal Tlingit. Obsidian may have been among the materials that moved to the interior via marriages.

A second mode of kin-related exchange are potlatches during which lavish gifts were given to neighbouring and distant relatives to commemorate the dead and secure prestige (Grinev, 2005; Litke, 1987). Of the Yakutat Tlingit, de Laguna (1972:610) states that all of the host chief's moiety were expected to provide gifts for a potlatch. It is reasonable that moieties along the Stikine River provided obsidian for such events, which would have been novel and cherished gifts among coastal First Nations who otherwise lacked access to this toolstone. While records of Dene involvement in historic potlatch ceremonies are meagre, this may reflect curtailment of potlatch ceremonies deemed hazardous by federal governments in the 1800s and 1900s. McClellan (1975:490) notes that potlatches were not a traditional activity among Tutchone and other Dene people in the Yukon but potlatches were established practices among interior Dene of northern British Columbia, including Tahltan, Kaska, and Carrier (Morice, 1893:118; Jenness, 1943; Honigmann, 1954). Because of trade relations and kinship established through marriage, Dene people from what is now Yukon and northern British Columbia were probably common guests at potlach ceremonies. Tybjerg (1977), writing of the Tlingit, noted that the more distant the origin of the guest, the more prestige was conferred upon the host.

Potlatches along the Northwest Pacific Coast were frequently conducted and witnessed massive exchanges of material goods that surely have archaeological implications. It is a viable means for obsidian to have moved from interior British Columbia to the coast (to supply potlatch ceremonies) and back to interior Yukon via kin networks. Obsidian had some luxury value but retained a practical importance, which may have made it particularly amenable to incorporation into patterns of kin-related exchange like bride price and the potlatch. This is illustrated in Figure 3.9, in which obsidian from distant sources appears as both curated and more mundane or expedient artifact types. Sourcing studies to the south in coastal British Columbia also suggest that obsidian was tied to social networks and modes of kin-related exchange (Reimer, 2011; Springer et al., 2018). The potlatch explains why obsidian from distant sources appears in portions of the Yukon that contain local, high quality sources: obsidian gifts in a potlatch context had primary value related to associated relationships and alliances, and were valued secondarily for technical and utilitarian purposes. In other words, gifts were significant because of the social conditions that created them (Appadurai, 1986; Mauss 1990).

Overlapping distributions of distant Edziza obsidian and local Hoodoo Mountain/Wiki Peak obsidian may therefore reflect oscillating trade relations and gift-giving associated with kin networks. Edziza obsidian appears to have moved from the Stikine River west to the coast and then northeast across mountain passes to the Yukon. Interior trade networks to the south were also documented in historic times. The Tahltan utilized established trails to trade with the Kaska (Dawson, 1889:194; Honigmann, 1954; Teit, 1956), who in turn interacted with the Shuhtagot'ine (Figure 3.9) in fluctuating periods of violence and peace (Gillespie, 1981; Reedy-Maschner and Maschner, 1999). The Chilkat were said to exert considerable control over major valleys at the edges of Tahltan territory, including the Stikine (Teit, 1956), so it seems likely that over 10,000 years, some Edziza obsidian was transported north and northeast via interior corridors while some moved west to the coast before moving back north to the Yukon interior. It is not known if obsidian was a driver of trade and exchange or just a proxy indicator of the movement of other important materials and relationships. However, there results do indicate that historic exchange patterns documented during the fur trade in the Yukon (Legros, 2007) extend well back into the Holocene.

The presence of Alaskan obsidians in southern Yukon (e.g., Batza Tena and A') demonstrates that northern influences extended south up the Yukon River. Alaskan obsidians along the Porcupine River and north (Batza Tena, H, and N) coincide with historic movement of Kutchin people west to the headwaters of Koyukuk River for gatherings and/or during the seasonal round (Osgood, 1936). It appears to be a pattern of deep antiquity that northern Dene groups in the Yukon allied closely with those of northern Alaska. The Batza Tena component of this dataset may be a productive area for future research concerning the Beringian 'stand still' model of New World colonization (Moreno-Mayar et al., 2018) as well as potential links between obsidian movement, tracking barren ground caribou, and the movement of microblade technology across the Subarctic.

3.6 Obsidian, social networks, and the White River Ash east eruption

Although the ecological impact of the WRAe eruption at A.D. 846-48 was likely significant (Anderson et al., 2005; Lerbekmo, 2008; Kuhn et al., 2010; Bunbury and Gajewski, 2013; Gajewski et al., 2014), sourced obsidian suggests that people responded without major long-term interruption to prior ways of life, presumably by relying on fluid social networks. We did not detect evidence that the eruption decimated populations or caused population replacements in southwest Yukon. However, some changes in obsidian movement patterns are visible, and they inform reconstructions of Late Holocene relationships and responses to the WRAe event.

A few published scenarios of human movement in response to the WRAe tephra are evaluated below. 1) If people moved down the Yukon River (north) after the WRAe event (as suggested by Derry, 1975), the archaeological record should contain more Wiki Peak obsidian or other obsidians from Alaska, including Batza Tena, when these groups of people returned to the south (a product of strengthened networks), which does not appear to have occurred (Figures 3.5, 3.6, 3.10, and 3.11). 2) If people within the thickest tephra footprint moved east (as proposed by Moodie et al., 1992) to rely on kin across the Mackenzie Mountains, Edziza obsidian in southern and central Yukon would predictably drop and perhaps other materials from the N.W.T. would appear in higher frequency in the Yukon upon their return. In the case of Tertiary Hills Clinker, a lithic material that outcrops west of Mackenzie River, no increase in exchange occurs across the Mackenzie Mountains to the Yukon post-WRAe (Kristensen et al., 2019). Furthermore, all N.W.T. assemblages with obsidian that can be assigned to either a pre- or post-WRAe component in the current dataset pre-date the ash, suggesting that obsidian movement east into the N.W.T. may have stopped or significantly decreased following the WRAe eruption. 3) Lastly, if an entirely different population of people colonized a vacated landscape after WRAe, sourced obsidian ratios (e.g., the comparative exploitation of Hoodoo Mountain obsidian) would presumably be much different before and after the eruption. Although changes in obsidian distribution are detectable, they were not drastic. This suggests that local ancestral groups mostly moved south or west, strengthened social networks with coastal kin, and returned within a few generations when ecological conditions stabilized.

In the south and central portions of the Yukon, Edziza obsidian increases (particularly the number of artifacts) while Wiki Peak obsidian decreases after WRAe (Figures 3.10 and 3.11). North of the 5 cm footprint, the proportion of sites with sourced Edziza obsidian decreases, as does the number of artifacts from this source (Figures 3.10 and 3.11). When contextualized with ethnohistoric records, this suggests that the social networks leaned on by Yukon First Nations to weather the ecological impact of the WRAe were most strongly oriented to the south or southwest to coastal groups and previously established trade and kin connections in southeast Alaska. A decrease in Edziza obsidian north of the WRAe 5 cm tephra footprint suggests that when groups that resided within the 5 cm tephra isopach returned to their home, the old patterns of exchange with northern neighbours were permanently disrupted (Figures 3.10 and 3.11).

Wiki Peak is geographically close to the origin of the WRAe event (it is roughly 65 km north-northeast of Mount Churchill) so access to obsidian was perhaps hindered for some time by the ashfall event. Lerbekmo's (2008) tephra isopach data indicate that less than 5 cm of ash fell at Wiki Peak. Moreover, ash blankets are far from uniform and may actually expose surface materials in many habitats by killing vegetation and spurring large-scale erosion (e.g., mudslides). Hoodoo Mountain may have received 2-5 cm of ash according to isopachs proposed by Lerbekmo (2008), but it does not appear to have altered exploitation patterns. Furthermore, despite the ash blanket, copper from areas in proximity to the WRAe eruption underwent an increase in exploitation after WRAe (Cooper, 2012), suggesting that surface ash deposits were no hindrance to people's access to the area, or their procurement activities. Climatic drivers of glacier growth in the Late Holocene (e.g., the Little Ice Age from A.D. 1400 to 1850) may have impeded access to Wiki Peak, although records indicate that glacial growth in the Wrangell and St. Elias Mountains was not as extensive during phases of the Late Holocene as coastal Alaska (Barclay et al., 2009).

A general lack of drastic disruptions to obsidian exchange after WRAe suggests that people reoccupied homelands fairly quickly, perhaps after a generation or two of avoidance of the thickest tephra footprint area. It remains possible that the area was still frequently visited to assess conditions. The ash may have disrupted normal subsistence patterns including the predictability of caribou and salmon. It may have taken several decades for subsistence resources to recover and for people to re-establish reliable seasonal rounds and to grow in numbers to support previous population densities. This time scale accords with modern understandings of the ecological resilience of landscapes in response to major volcanic eruptions (Antos and Zobel, 1985; Grishin et al., 1996; Anderson et al., 2005; Bisson et al., 2005; Pellow, 2006; Bunbury and Gajewski, 2013). The current obsidian research is also in agreement with other archaeological inferences that describe extensions of historic socio-economic relations deep into pre-contact times and that espouse theories that ancestral kin networks braced populations against ecological disturbances (e.g., Pendea et al., 2016; Torrence, 2016).

3.7 White River Ash east and Dene (Athapaskan) migration

Obsidian provenance results inform reconstructions of Dene (Athapaskan) migration from the Subarctic to the American Great Basin and Southwest, which some argue was initially stimulated by the WRAe eruption (Workman, 1979; Ives, 1990:42-46; Matson and Magne, 2007; Magne, 2012). Some researchers have noted a general lack of major cultural disruption associated with the WRAe (Workman, 1979; Thomas, 2003; Easton, 2007) and some have suggested it is an unlikely trigger of large-scale migrations of Dene people (Gordon, 2012a, 2012b). The southward or westward movement of people following WRAe, as supported by the increase in Edziza obsidian and decrease in Wiki Peak obsidian following the eruption, does suggest that eruptions can spur migration or at least temporarily disconnect people from places.

A lesson emerging from growing palaeoenvironmental and archaeological research is that we should expect a mosaic of environmental and cultural impacts in the 600,000 km^2 region where WRAe tephra is visible (e.g., Kuhn et al., 2010; Kristensen et al., 2019). The obsidian data reported in this paper focus on a region very near the primary impact zone in southwest Yukon. It is difficult to argue that ash deposits of 20 cm or more did not create severe conditions for a number of years. A logical response would be to flee toward communities where trade and social relationships already existed.

The obsidian data suggest that southwest Yukon populations were temporarily displaced in directions where populations could make a relatively rapid return to the impact zone as conditions ameliorated. However, in a landscape with oscillating social and political dynamics, a volcanic eruption may have severed contact significantly enough to permanently dislocate a group of people. If ideology, ecology, or political relationships impeded a return to former territories, this initial dislocation may have prompted a southward search for a home that culminated centuries later in the American Southwest, Great Basin, California, and/or Oregon (Magne and Matson, 2010; Brunswig, 2012; Gilmore and Larmore, 2012; Magne, 2012; Malhi, 2012; Rice, 2012; Seymour, 2012b; Ives et al., 2014; Hill and Trabert, 2018). The ultimate cause of dramatic and continual southward movement is beyond the purview of this paper but changes in obsidian distribution pre- and post-WRAe suggest that the Late Holocene volcanic eruption was of sufficient impact and magnitude to provide a preliminary nudge. Some groups of people returned but others may have begun a series of relocations that led them too far from home to come back[2]. If people relied on social networks to adapt to ecological disturbances, and if some Dene groups temporarily resided with coastal kin following the WRAe event, coastal Alaska may be a point of origin for the movement of Dene people to the south (i.e., a Dene social unit that sought refuge on the coast and then decided not to return). It remains plausible that Dene groups farther to the east in southeast Yukon and N.W.T. may have been seriously displaced by this volcanic event, which triggered movement to the south into northeast British Columbia, although this theory must be borne out with other lines of evidence.

[2] Mullen (2012) employed radiocarbon dates to reach a similar conclusion - the WRAe (and the earlier WRA north eruption) appear to have stimulated a drop in population density within the ash footprints and an increase in population density in surrounding areas that is indicative of an out migration. He further noted that the use of Wiki Peak obsidian significantly dropped during the WRAe and WRA north eruptions (through utilization of the same obsidian database used here). While our results are supportive, Mullen (2012) does not appear to have accounted for the previously discussed bias in the Yukon dataset of Wiki Peak artifacts from KdVo-6 and he equates the footprints of detectable ash with zones of negative impact. For example, portions of western N.W.T. and central Yukon that received 0.5 cm of ash are treated the same as portions of southwest Yukon with over 20 cm of ash deposition. Perhaps most importantly, occupations at Yukon archaeological sites above WRAe tephra tend not to be radiocarbon dated, which underrepresents Late Pre-contact period sites in tabulations of dated occupations. Mullen's (2012) spatial comparisons of radiocarbon dated occupations (and obsidian data) informed an insightful mathematical model but one that ultimately neglected data skews and modern studies of ash impacts on biota.

3.8 Obsidian, White River Ash east, and the bow and arrow

Our inferred south- or southwestward movement of people, and ensuing return, following the WRAe volcanic eruption has a direct bearing on understanding the timing and movement of bow and arrow technology. The following link of obsidian provenance work to broader cultural patterns points to an origin and mechanism of technological spread, as well an explanation for why the bow and arrow did not diffuse sooner. The bow occurred on the margins of Dene territory for millennia before adoption (Blitz, 1988); perhaps cultural (e.g., linguistic) differences that extend deep into the Holocene provided a barrier for technological exchange into Subarctic northwest North America. On the northern margins of the study area, Ives (2010) postulated that bow cognates (words having the same linguistic derivation) that are shared widely among Dene groups reflect interactions that Dene ancestors had with mid-Holocene Arctic Small Tool tradition (ASTt) neighbours (who had the bow and arrow), without Dene adoption of that technology before the divergence of the Athapaskan language family. If, as Dumond (2010) suggested, ASTt represented arrival of Dene-Yeniseian people in the New World, the cognate forms of bow and arrow terminology would stem from a deeper language family history, one in which ASTt ancestors brought bow and arrow technology from northeast Asia (cf. Flegontov et al., 2017). This does not appear to be the case, and it is supported by provenance studies that demonstrate a lack of meaningful exchange among ASTt people and Dene ancestors in N.W.T. (Kristensen et al., 2019).

On the southwest margins of the study area, archaeologists have employed projectile point metrics and transitions of projectile point morphologies to argue that the bow and arrow reached the Pacific Northwest Coast from 3500 to 1600 BP (Maschner, 1992; Carlson, 2008; Morrissey, 2009; Rorabaugh and Fulkerson, 2015). This implies that bow and arrow technology existed in coastal southeast Alaska for several centuries to a millennium before movement into the interior northwest because it appears that the bow and arrow were largely absent from interior Alaska, the Yukon, and N.W.T. until after WRAe. Ice patch records of alpine hunting in southern Yukon indicate a rapid transition from atlatl to bow and arrow after the WRAe event (Hare et al., 2012;

Grund and Huzurbazar, 2018). With the exception of one potentially anomalous radiocarbon date, all occurrences of organic projectile shafts in Yukon ice patches prior to the eruption are associated with darts while all occurrences after the eruption are associated with arrows (Hare et al., 2012). Dixon et al. (2005) and VanderHoek et al. (2012) present a similar pattern in interior Alaska with evidence there that the dart persisted after bow and arrow introduction.

Technological conservatism may explain a lack of adoption of the bow and arrow in interior northwest North America; the atlatl and spear were successful for millennia. However, barriers between distinctly different nations may have been a more significant impediment to the transmission of technologies, particularly of a weapon system that could be employed on people. Even if relations were amicable, strong incentives and appropriate opportunities for knowledge exchange would be needed to willingly transmit a complicated new technology across linguistic and ancestral barriers. What does obsidian provenance data suggest about human relations that can inform models of technological spread?

Obsidian data, namely the spread of Edziza obsidian, when combined with ethnohistoric records in the Yukon and Alaska, support a theory that economic patterns of exchange from coastal to interior groups were sufficient to bridge linguistic barriers for thousands of years but a catalyst was needed to spur the type of contact necessary to transmit a complicated weapon system. The residence of a First Nations group among southern or southwestern allies for a decade or two after the eruption possibly provided sufficient time and contact with new technologies to enable their spread. Sourced obsidian and changes to obsidian exchange patterns, when combined with ice patch records, point to an origin of the bow and arrow in coastal British Columbia or Alaska, which then spread north and east. Maschner and Mason (2013) advocate a coastal origin of bow and arrow technology and correlate its movement from Asia with escalating conflict. Our obsidian results suggest that we may instead associate the movement of the bow and arrow with prolonged positive contact with coastal kin and/or trading partners. Intuitively, this scenario would foster information exchange to a greater extent than violence, particularly the transmission of the complicated skill set required to manufacture and maintain bows and arrows (Wilson, 2011). In this context, the WRAe event may have been a stimulus that promoted cultural fluorescence by bringing neighbouring groups into an extended period of contact that in turn ushered new developments.

3.9 Conclusion

Lithic provenance analyses of 1354 obsidian artifacts from 462 pre-contact sites in the Yukon and N.W.T. present a history of widespread social and trade relationships that spanned millions of square kilometres. These networks may have ensured long-term survival through short-term ecological events. On the basis of sourced obsidian, we argue that the White River Ash east volcanic eruption in the Late Holocene spurred short-term movement of people, which in turn may have expedited the movement of bow and arrow technology into southern and central Yukon. The use of obsidian from Edziza in northwest British Columbia increases while the use of Wiki Peak obsidian from Alaska decreases in southern and central Yukon following the WRAe eruption. This suggests that exchange patterns were altered and that people of the Yukon relied on kin and/or economic relationships to the south or southwest where channels of exchange and obsidian movement were historically located. Overlapping distributions of exotic and local obsidians through the Holocene also help establish that historic socio-economic relations between interior Dene (Athapaskans) and coastal Tlingit have a deep antiquity. Raw materials can serve as proxy indicators of kin and trade relationships that influenced ecological resilience and the movement of ideas.

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CHAPTER 4: IDENTIFYING AND SOURCING PYROMETAMORPHIC ARTIFACTS: CLINKER IN SUBARCTIC NORTH AMERICA AND THE HUNTER-GATHERER RESPONSE TO A LATE HOLOCENE VOLCANIC ERUPTION

Abstract

Pyrometamorphic rocks produced by natural coal combustion appear at archaeological sites across North America but have received little archaeological attention regarding provenance studies. Tertiary Hills Clinker is a distinct pyrometamorphic rock from Subarctic Canada utilized by hunter-gatherers from 10,000 years ago to European contact. We employ X-ray diffraction, thin section analyses, and electron probe microanalyses to characterise Tertiary Hills Clinker and inform archaeometric studies of rock produced by combustion metamorphism. We geochemically compare pyrometamorphic rocks used by pre-contact people across North America to demonstrate that Tertiary Hills Clinker can be sourced using portable X-ray fluorescence. Results indicate that Late Pleistocene/Early Holocene exchange networks in North America were larger than previously thought. A later change in the distribution of Tertiary Hills Clinker may relate to a Late Holocene volcanic eruption (White River Ash east) that fragmented modes of lithic exchange and associated social networks with potential stimulus for a subsequent large-scale migration of northern hunter-gatherers across the continent. Provenance studies of pyrometamorphic artifacts offer untapped opportunities to study social networks in coal-bearing regions across the world.

4.1 Introduction

Pyrometamorphism (also called combustion metamorphism) generally occurs when coal, oil, or gas burn with sufficient energy to bake or fuse neighbouring rock (Allen, 1874; Bentor, 1981; Cosca et al., 1989; Grapes, 2011:21; Stracher et al., 2010). Beds of fused rock were targeted for stone tool production because of the raw materials' internal uniformity (Cinq-Mars, 1973; Clark, 1986; Curran et al., 2001; Fredlund, 1976). Pyrometamorphic rock has received geological attention in North and South America (Hefern and Coates, 2004; Henao et al., 2010), Europe (Žáček et al., 2015), Russia (Sokol et al., 1998), China (Song and Kuenzer, 2017), and Africa (Pone et al., 2007). Despite the global distribution of rock produced by coal combustion and the use of it by people, comparatively few efforts have been made by archaeologists to formally identify pyrometamorphic rock in archaeological assemblages (Estes et al., 2010; Hughes and Peterson, 2009; Le Blanc, 1997; Vapnik et al., 2015).

We use X-ray diffraction (XRD), thin sections, and electron probe microanalyses (EPMA) to characterise and identify a distinct pyrometamorphic rock called Tertiary Hills Clinker (THC) that was distributed over 1.25 million km^2 and utilized for over ten millennia in North America (Andrews et al., 2012; Cinq-Mars, 1973). We geochemically compare pyrometamorphic rocks used by pre-contact people across the continent with portable X-ray fluorescence (pXRF) to verify provenance of THC and infer hunter-gatherer exchange networks from the Late Pleistocene to European contact. A volcanic eruption dated at A.D. 846-848 called the White River Ash east event (Jensen et al., 2014; Lerbekmo, 2008) may have severed social relationships between people in two major river basins in North America: the Mackenzie River that flows north to the Arctic Ocean and the Yukon River that flows north and west to the Pacific Ocean (Gordon, 2012a; Workman, 1979). This may have provided the initial stimulus of one of the largest pre-contact migrations of people (Athapaskan) in the New World (Haskell, 1987; Ives, 2003, 2010, 2014; Magne and Matson, 2010; Moodie et al., 1992; Seymour, 2012).

4.2 Pyrometamorphism and North American Clinkers

Pyrometamorphism by coal combustion typically occurs near geological fracturing that exposes flammable strata to oxygen (Cosca et al., 1989). Natural fires spread horizontally along exposed coal seams and can burn underground for over 100 m. Pyrometamorphism products range from thermally altered but unmelted rocks (dubbed burnt or baked rocks), partially fused rocks (termed clinker), or totally melted rocks (called paralava or slag) (Grapes, 2011). Porcellanite is a specific type of clinker formed from shale or siltstone that is heated near the point of melting; the rock recrystallizes (sinters) and takes on a ceramic or porcelain texture (Hefern and Coates, 2004). The term porcellanite has been used in other geological contexts, e.g., formation as a siliceous duricrust (McNally et al., 2000), but in North America it is generally limited to pyrometamorphic origins with major outcrops on the Northern Plains of the US (Figure 4.1). Flaked porcellanite artifacts dominate some Holocene assemblages in Montana and Wyoming (Clark, 1985; Fredlund, 1976). A related pyrometamorphic rock called non-volcanic natural glass (NVNG) was also used in pre-contact times on the US Northern Plains (Frison, 1974; Hughes, 2007a). In addition to coal sources, clinkers can also form from combustion of carbonaceous sediment like Cape Bathurst Clinker (CBC) (Mathews and Bustin, 1984) that outcrops in the Canadian Arctic (Figure 4.1). CBC was used for several thousand years by coastal hunter-gatherers (Le Blanc, 1991). Hefern and Coates (2004) note that clinkers vary due to: 1) grain size and mineralogy of parent rock; 2) degree of heat alteration; and 3) degree of oxidation or reduction during and after heating. Different thermal regimes can create a diverse array of clinkers within a single outcrop.

Outcrops of THC are 30 km west of the second largest fluvial system in North America – the Mackenzie River of Canada's Northwest Territories (Figure 4.1). Subarctic hunter-gatherers quarried THC from approximately 10,000 years before present to European contact (Andrews et al., 2012; Hanks and Pokotylo, 2000). Specifically, THC has been reported in association with a Late Pleistocene fluted point in Alberta (Bereziuk, 2016), middle Holocene microblades in Yukon and Northwest Territories (Andrews, 1999; Clark, 1986; Le Blanc 1997), and Late Holocene copper in Yukon (Thomas, 2003) (Figure 4.2). Like other clinkers used by hunter-gatherers in North America, little archaeological research has been published about identification, provenance, and overall significance of THC. In this study, we present summaries of XRD, thin section investigations, and EMPA to support the pyrometamorphic origin of THC prior to discussion in the remainder of the paper of our pXRF provenance results and their implications for detecting human responses to a Late Holocene volcanic eruption.

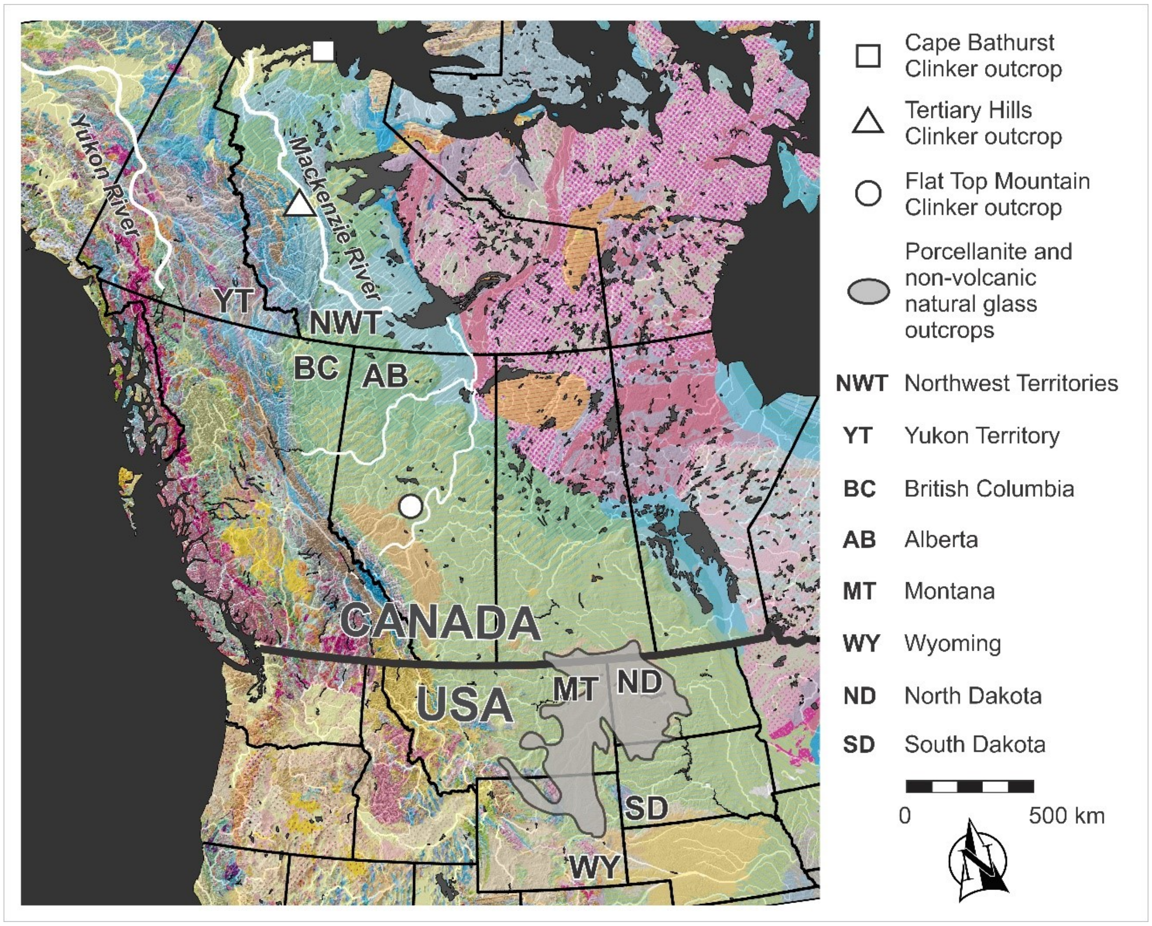

Figure 4.1 Outcrops of recorded vitreous clinkers in Canada and northern United States discussed in text (bedrock geology data from USGS, 2014).

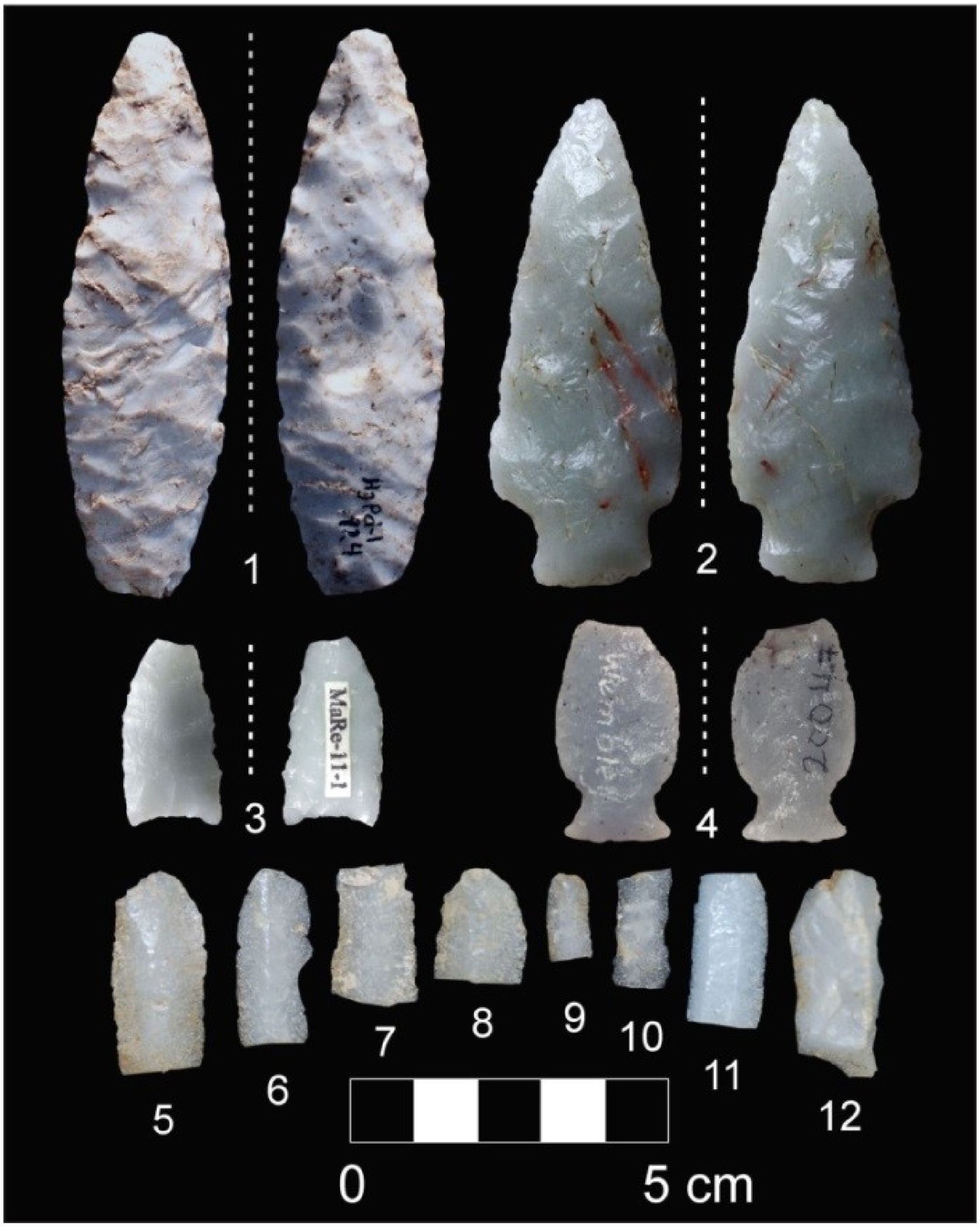

Figure 4.2 Tertiary Hills Clinker artifacts. Specimen 1: HjPd-1:924, from northern Alberta (Royal Alberta Museum); Specimen 2: No catalogue number, from north central Alberta (Athabasca Archives); Specimen 3: MaRe-11:1, from western Northwest Territories (Prince of Wales Northern Heritage Centre); Specimen 4: 2004.7, from northwest Alberta (Grande Prairie Pioneer Museum); Specimens 5-12: KaVa-3:25-28, 56-57, 91, 102 (Yukon Heritage Branch).

4.3 Identification of Tertiary Hills Clinker

Vitreous rocks produced by coal combustion are particularly easy to overlook or misidentify in knapped stone tool assemblages because of superficial similarities to non-pyrometamorphic materials such as chert, quartzite, quartz, obsidian, or chalcedony (Hughes, 2007b; Hughes and Peterson, 2009; Kristensen et al., 2016). Tertiary Hills Clinker (THC) was variously called Keele River Obsidian (MacNeish, 1954:248), ignimbrite (a welded pyroclastic flow) (Millar, 1968), Tertiary Hills Welded Tuff (presumed by Cinq-Mars (1973) to be a volcanic ash welded by subsurface contact with magma domes), and Tertiary Hills Tuffaceous Clinker (ash fused by naturally ignited coal seams) (Pokotylo and Hanks, 1989). Systematic analyses to support the identification of THC have not been published and uncertainty persists concerning its parent materials and formation processes. Additionally, a lack of archaeological knowledge of THC, and clinkers in general, has limited reconstructions of their significance in North America.

THC is white, grey, brown, or purple (Kristensen et al., 2016) and varies from translucent to opaque with vitreous to glimmering lustre (Ives and Hardie, 1983). Cobbles display variable degrees of fusion, often with cracks and cortices reddened by oxidation, which is comparable to other North American vitrified clinkers (Figure 4.3). Artifacts made from THC are typically a uniform white variety that has been informally described as glassy with a powdered sugar texture. A general diagnostic trait of clinkers in general is a high density of polydisperse circular vesicles (from <10 µm up to 2 mm in diameter) produced by gas trapped during combustion (Table 4.1 and Figure 4.4). THC fractures in a similar fashion to obsidian and was presumably highly sought after because of its unique appearance, hardness, and excellent workability (Hanks, 1993).

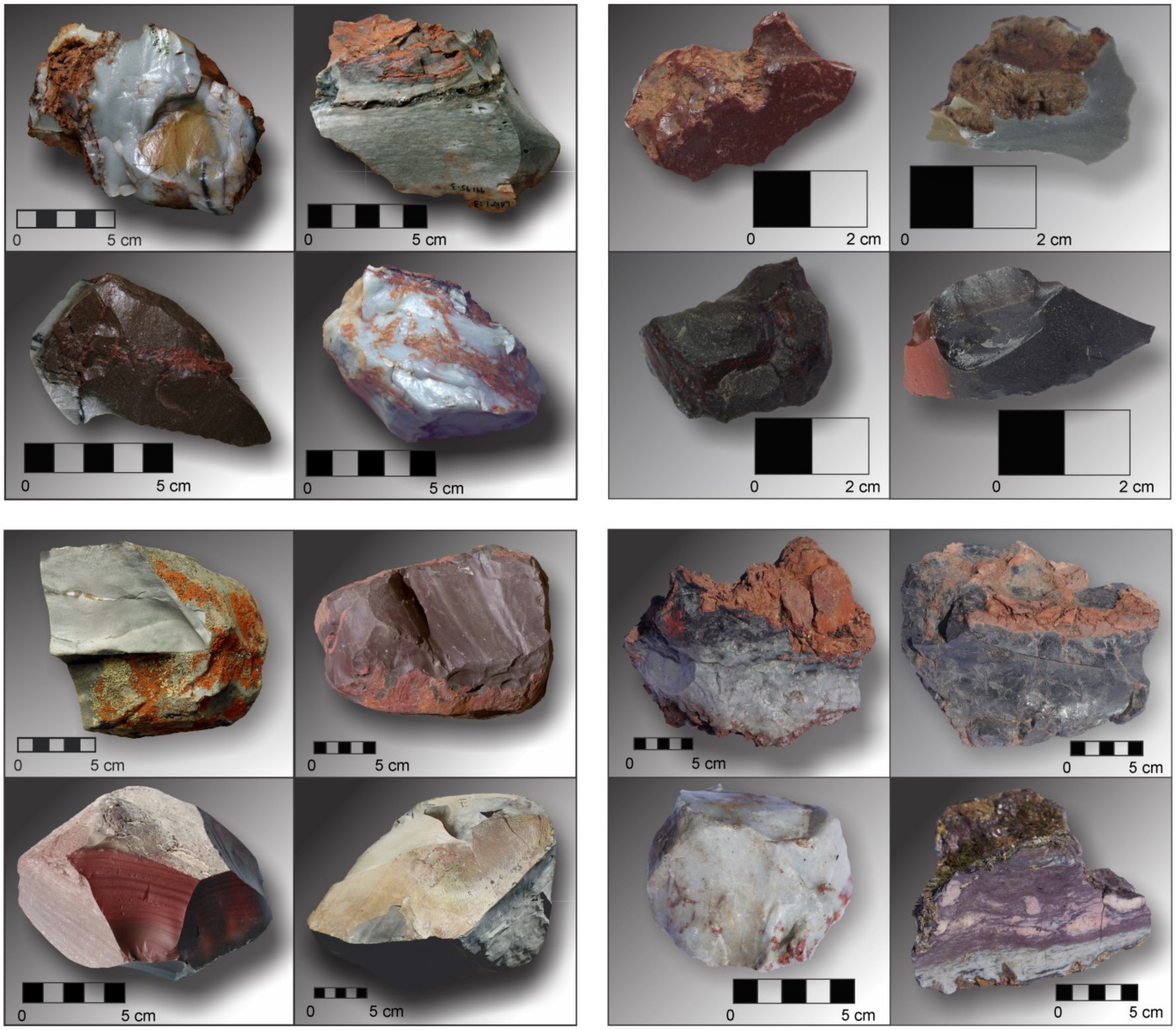

Figure 4.3 Unmodified clinker cobbles. Top left quarter: Tertiary Hills Clinker, from top left clockwise: LcRq-7:45, LdRr-1:3, LcRq-7:38; and uncatalogued specimen likely from LdRq-3, Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories. Top right quarter: Non-volcanic natural glass from southeast Montana, specimens uncatalogued, courtesy of Craig Lee. Bottom right quarter: Flat Top Mountain Clinker, specimens uncatalogued, Archaeological Survey of Alberta, Edmonton, Alberta. Bottom left quarter: porcellanite from southeast Montana, specimens uncatalogued, images courtesy of Jim Miller, Patrick Rennie, and James Keffer.

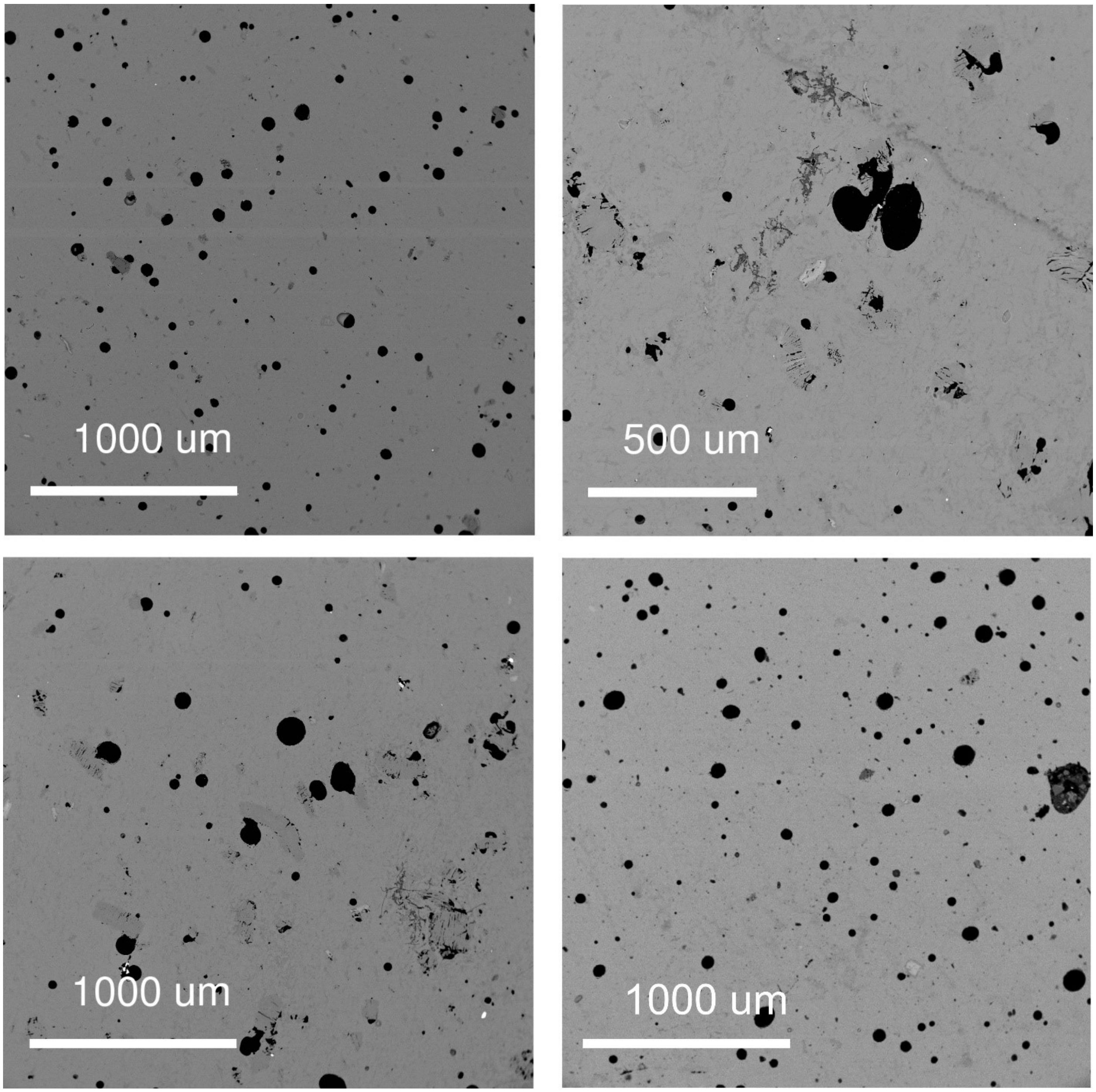

Figure 4.4 Back-scattered electron images of THC. Vesicles are shown as black. Inclusions are either darker or lighter in grayscale than the medium grey glass matrix. Top left: KfTd-3; top right: GbPt-11 area 1; bottom left: GbPt-11 area 2; bottom right HhOu-113.

Table 4.1 Proportions (%) of vesicles and inclusions from back-scattered electron images determined with ImageJ.

Sample	KfTd-3	GbPt-11	HhoU-113
Vesicles (void space)	1.9	2.6	2.7
Dark (in BSE) inclusions	2.3	12.8	3.8
Bright (in BSE) inclusions	0.1	0.2	0.2
Matrix glass	95.7	84.4	93.3

4.3.1 XRD materials, methods, and results

X-ray diffraction (XRD) is used to identify crystalline material based on the pattern produced by the elastic scattering of monochromatic radiation by the crystal structure of the material (Calvo Del Castillo and Strivay, 2012). Identifications are made by comparison of the experimental pattern to a database of diffraction patterns of known materials. Three samples of THC (two artifacts from Alberta and one natural outcrop piece) were ground to fine powders with an agate mortar and pestle, and XRD patterns acquired using Bragg-Brentano parafocussing reflection geometry with a Rigaku Ultima IV θ-θ diffractometer. This instrument has a Co X-ray source ($K\alpha$ 1.78899 Å) and Fe filter and was operated at 38 kV and 38 mA. The detector was a 1D silicon strip (D/tex Ultra). Each diffraction scan was run from 5 to 90° 2θ in continuous mode with a step size of 0.02° 2θ, and a count time of 0.6 seconds per step.

XRD results indicate that THC is heavily dominated by non-crystalline amorphous material with minute amounts of cristobalite, quartz, and mullite (a needle-shaped aluminosilicate mineral characteristic of high-temperature non-volcanic conditions) (see Cosca et al., 1989, and Clark and Peacor, 1992 for comparative mullite detection in pyrometamorphic rock). The presence of amorphous material (glass) explains why THC was used as a toolstone: it fractures conchoidally with sharp edges. XRD results support tentative identifications of several minerals that may have existed in the parent sedimentary rock (e.g., muscovite, dolomite) or were produced as a result of pyrometamorphism (e.g., olivine) or weathering (e.g., rozenite). The XRD results support an origin of THC via fusion of sedimentary rock from the combustion of coal seams.

4.3.2 Thin section materials, methods, and results

Samples of THC, porcellanite (found mostly in the Powder River Basin of Montana and Wyoming), and NVNG (also found across southeast Montana and northeast Wyoming) were cut, ground, and polished for thin section viewing. The behaviour under cross-polarized light indicates that THC, like NVNG and porcellanites, is composed primarily of isotropic material, interpreted to be amorphous (glass) (Figure 4.5). THC lacks any remnants of internal bedding, which are often visible in NVNGs, and has generally undergone more thorough fusion and vitrification than porcellanites. NVNG vesicles tend to be more elongate than THC, which suggests that NVNG experienced minor flow during formation whereas THC did not appear to undergo lateral movement. Porcellanite is more uniformly opaque indicative of less intense thermal alteration during formation (Fredlund, 1976). The thin section results support the formation of THC in close proximity to an underlying coal bed as opposed to the more mobile chimney structure (i.e., gas vent) associated with the formation of NVNG (dubbed a glassy paralava by Cosca et al., 1989). Microscope images (Figure 4.6) help illustrate different thermal regimes and the influence of different parent materials in the formation of North American clinkers. Porcellanite, THC, and NVNG derive from coal combustion of fine-grained sedimentary rock while CBC is a more heterogeneous material formed from combustion of carbonaceous sediment.

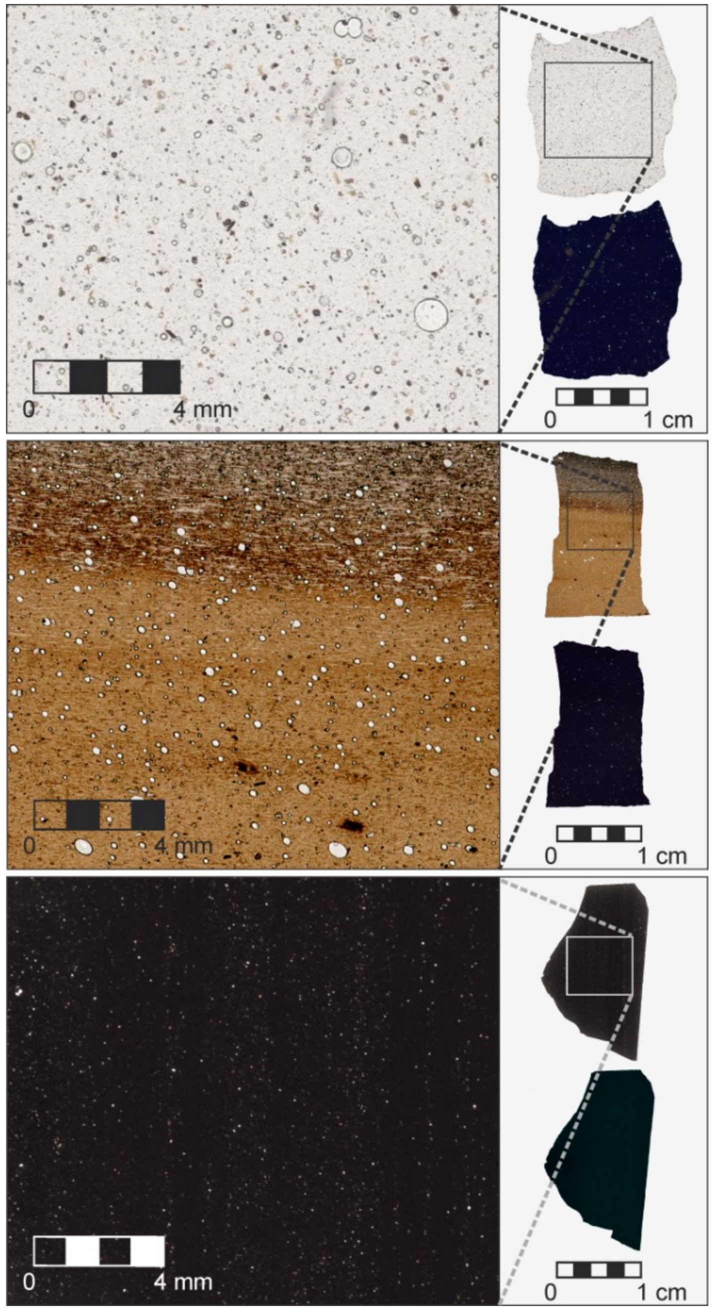

Figure 4.5 Thin sections of THC (top), NVNG (middle), and porcellanite (bottom). At right are images of each thin section flake under normal light (top) and cross-polarized light (bottom).

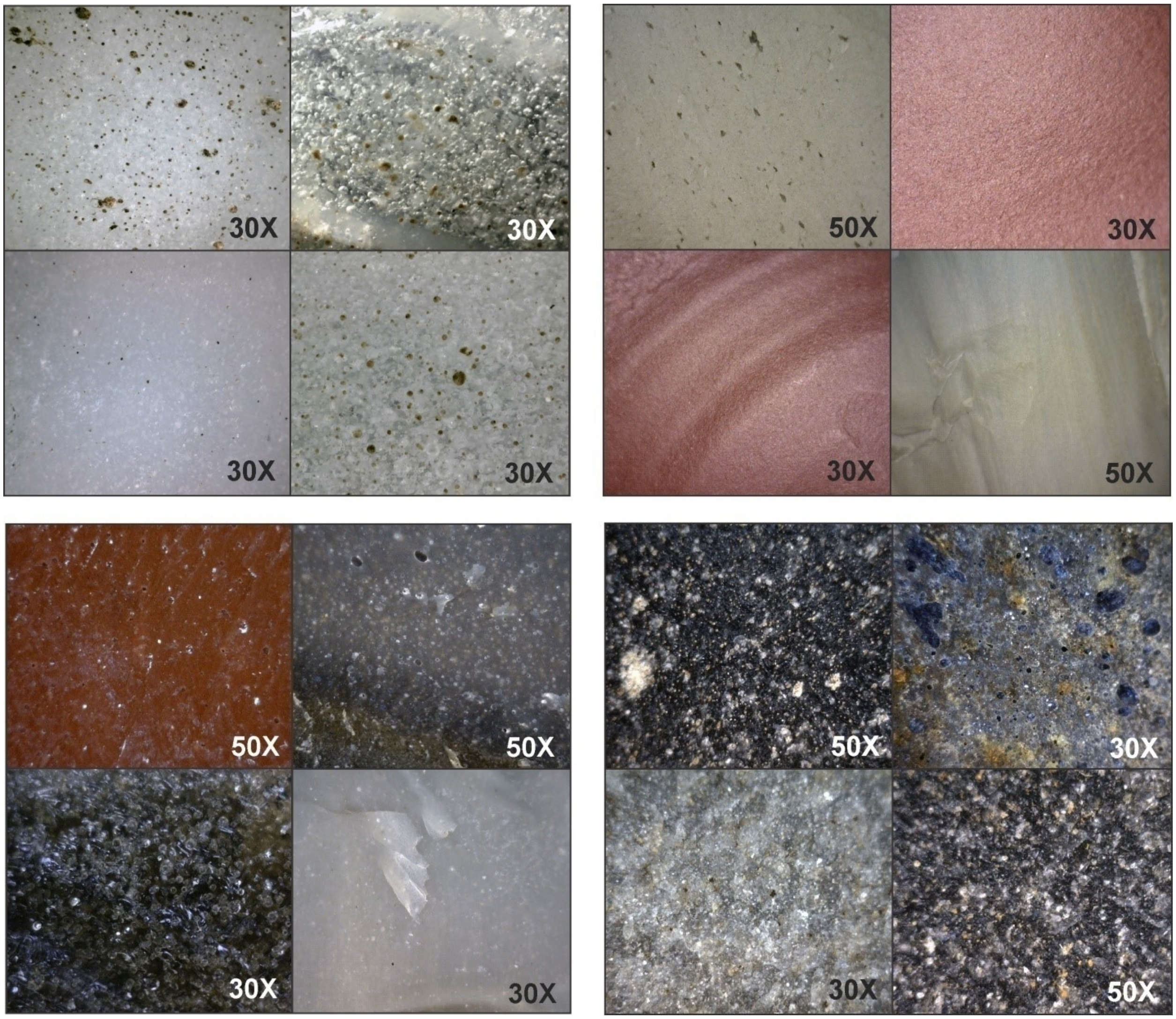

Figure 4.6 Microscope images and magnification; THC (top left), Montana porcellanites (top right), CBC (bottom right), and Montana NVNG (bottom left). Porcellanite provided by Jason Roe, NVNG provided by Craig Lee.

4.3.3 EPMA materials, methods, and results

An electron probe microanalyzer (EPMA, or electron microprobe) uses a high-voltage focussed electron beam to generate characteristic X-rays in a polished sample. The intensity of these X-rays is measured with wavelength dispersive spectrometers and converted to elemental abundances with respect to standard materials after correction for matrix effects (Potts, 1987). The electron beam can be focussed to <1 μm, which permits separate examination of matrix material vs. inclusions. Figure 4.4 depicts back-scattered electron images (BSE) acquired with a JEOL 8900R electron microprobe in beam-scan mode with a focussed electron beam operated at 20 kV and 10 nA beam current. The back-scattered-electron signal is proportional to the mean atomic number of the material analyzed: materials with more heavy elements will therefore appear brighter in such images (Lloyd, 1987). Image analysis of the BSE images using the program ImageJ (Schneider et al., 2012) yields the area (volume) percentages of vesicles, dark- and bright-inclusions, with respect to the glass matrices (Table 4.1).

A total of 88 points in the glassy matrices and 22 inclusions were selected for more detailed examination from three round samples of THC fragments. A JEOL 8900R electron microprobe operated at 20 kV and 10 nA with a beam diameter of 10 μm was used for analysis of the glass matrices (Table 4.2). Count times for wavelength-dispersive spectrometry were 30 s on peaks and 15 s on backgrounds for the $K\alpha$ lines of: Si, Ti, Al, Cr, Fe, Mn, Mg and K, whereas conditions of 40 s on peak and 20 s on backgrounds were used for Na $K\alpha$.

Following Grapes (2011), liquidus temperatures (the temperature at which the material would have been completely molten) were calculated for the average anhydrous glass compositions at 1 bar (1 atmosphere) pressure using the Excel spreadsheet rhyolite-MELTS v1.0 (Gualda and Ghiorso, 2015). The glass compositions are reminiscent of high-K rhyolites (Table 4.2). The solid inclusions in the glasses were identified as sekaninaite (the iron analog of cordierite, Grapes et al., 2011), metakaolin (Sperinck et al., 2011), feldspar, and silica.

Clinker melting temperatures range in general from 400°C to 1600°C (Grapes, 2011); the presence of metakaolin and sekaninaite in THC, along with the calculated liquidus temperatures of glasses, suggest melting between 800-1130°C. Studies of coal reflectance in the Tertiary Hills (Sweet et al., 1989) produced Ro random values of 0.39 to 0.59 indicating ranks ranging from lignite to high volatile-C bituminous coal, which would be capable of high temperature combustion.

This assemblage of phases, in conjunction with the high calculated liquidus temperatures of the glasses, is consistent with a pyrometamorphic origin for THC (Grapes, 2011), as opposed to an igneous origin as a tuffaceous rock. Therefore, THC most likely formed through the combustion of coal and resultant pyrometamorphism of surrounding shale or mudstone parent materials.

Table 4.2 EPMA average analyses of the glass matrices of three THC samples. Cr was sought but not found above the limit of detection. Mean weight-percent compositions are listed with standard deviations in brackets.

Sample	**KfTd-3**	**GbPt-11**	**HhOu-113**
# of points	28	31	29
SiO_2	78.22 (0.19)	76.98 (0.85)	77.85 (0.32)
TiO_2	0.06 (0.02)	0.07 (0.01)	0.06 (0.01)
Al_2O_3	12.77 (0.10)	13.16 (0.45)	12.62 (0.09)
FeO_{total}	1.03 (0.04)	1.25 (0.10)	0.94 (0.08)
MnO	0.05 (0.01)	0.04 (0.01)	0.05 (0.01)
MgO	0.04 (0.01)	0.09 (0.02)	0.03 (0.02)
CaO	0.53 (0.02)	0.89 (0.10)	0.48 (0.02)
Na_2O	0.46 (0.03)	1.62 (0.08)	0.45 (0.04)
K_2O	6.56 (0.12)	5.09 (0.33)	6.63 (0.14)
Total	99.72 (0.19)	99.19 (0.34)	99.11 (0.32)
Liquidus °C (1 bar)	1126	1079	1128

4.4 Geological Origins and Formation Processes

We here combine XRD, thin section, and EPMA results with field studies to infer geological origins and formation processes of THC, which have archaeological implications both in terms of pre-contact hunter-gatherer exploitation of localized outcrops and the ability to perform provenance studies on clinkers. THC outcrops in the Summit Creek Formation (Figure 4.7): a roughly 3000 km^2 Late Maastrichtian (Late Cretaceous) to Paleocene (roughly 66 to 53 mya) succession of conglomerate, sandstone, ash beds, carbonaceous shale, and low grade coals (Fallas et al., 2013; Sweet et al., 1989; Yorath and Cook, 1981). The Summit Creek Formation formed as an alluvial fan that was subsequently uplifted, folded, and faulted during several phases of the Laramide Orogeny (Sweet et al., 1989; Yorath and Cook, 1981). Sections of the Summit Creek Formation contain small lens-like bodies (less than 20 cm thick) of THC surrounded by baked, red siliceous mudstone (Figure 4.8) (Hanks, 1993; Yorath and Cook, 1981). XRD, EPMA, and thin section results (e.g., spherical vesicles) are consistent with field evidence that the parent material of THC is clay or mudstone shale. Neither stratigraphy nor laboratory analyses suggest any evidence of formation of THC from contact with volcanic ash or magma (as suggested by Cinq-Mars, 1973; Millar, 1968; and Pokotylo and Hanks, 1989).

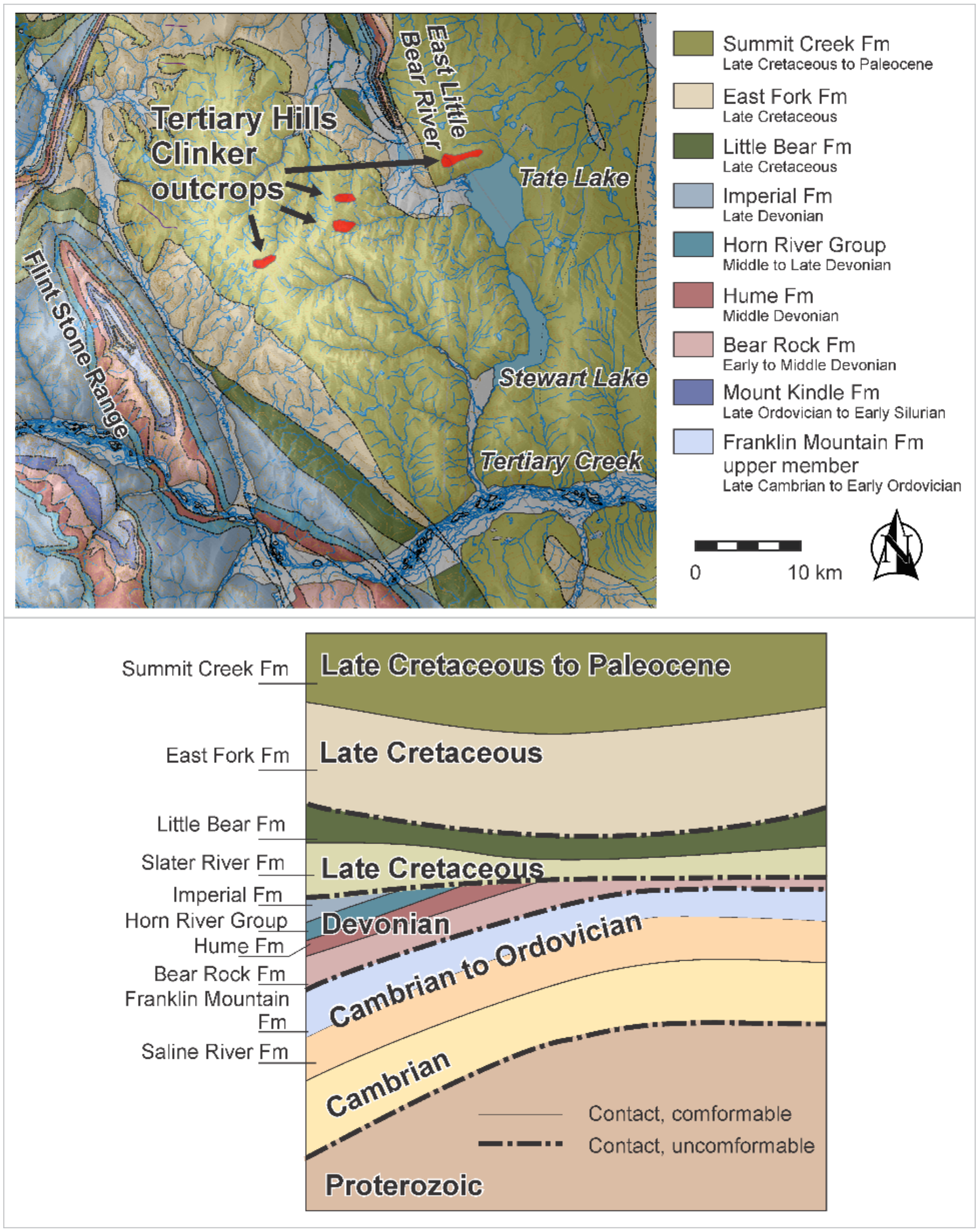

Figure 4.7 THC outcrops (top) in the Summit Creek Formation. An adapted schematic stratigraphy of bedrock including the Summit Creek Formation (from Fallas et al., 2013).

Figure 4.8 THC outcrops are found in the Summit Creek Formation visible here as the upper reddened strata in this exposure, people at centre for scale (image courtesy of David Pokotylo).

Coal and bituminous sediments associated with clinkers are typically exposed by stream cutting or glacial activity (Grapes, 2011). The Tertiary Hills experienced numerous cycles of glaciation and scour (Duk-Rodkin et al., 1996) that may have also exposed coal beds to some form of ignition (e.g., forest fires). While clinkers in Montana and Wyoming formed 4 mya (Hefern and Coates, 2004), the metastable nature of the THC minerals detected by EPMA suggests formation in the last 12,000 years. During *in situ* coal burning, active smoke vents would be visible and a likely source of curiosity to Holocene tool makers. Smoking vents (bocannes) are thought to have similarly attracted pre-contact people to Cape Bathurst Clinker outcrops (Le Blanc, 1991). The Shuhtagot'ine Dene First Nations, whose traditional territory encompasses the Tertiary Hills, are well aware of modern active coal burns and interpret them to be remnants of burning fat that dripped down from a giant beaver killed by culture hero Yamǫ́ria (Blondin, 1990).

Archaeometric and field studies suggest that THC is a more localized and uniform material compared to widely distributed and variable outcrops of porcellanite and NVNG (Figure 4.1). These latter materials form in complex chimney and bed structures across the US Northern Plains (Cosca et al., 1989; Hefern and Coates, 2004) with a predictably broader variety of parent materials and combustion dynamics. Spatial confinement of THC outcrops to a comparatively small area, and the likelihood of greater geochemical consistency compared to US clinkers, make THC a candidate for provenance studies.

4.5 Sourcing

4.5.1 PXRF materials and methods

PXRF analyses were conducted to determine if different clinkers have distinct geochemical signatures that could lend reliable quantitative support to connections drawn between clinker artifacts and outcrops. XRF can provide a geochemical summary of the elements present within individual specimens and their respective concentrations. When employed on silica-rich rocks like clinkers, pXRF is particularly effective at detecting and quantifying concentrations of the elements Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, Nb, and Th (Glascock et al., 1998; Speakman et al., 2011).

THC artifacts from Northwest Territories (n=45), Alberta (n=10), and Yukon (n=10), and 35 raw outcrop samples from the Tertiary Hills were analysed along with samples of Montana porcellanites (n=10), CBC (n=7), and Montana NVNG (n=10). Twelve samples of clinker from Flat Top Mountain in north central Alberta (FTMC) were also included for comparative geochemistry although there is currently no evidence that it was quarried in pre-contact times. In addition, samples of quartzite, quartz, chalcedony, and other materials that may superficially resemble clinkers (n=20 in total) were analysed to assess whether or not they can be differentiated by pXRF.

XRF analyses were completed using a Bruker AXS Tracer III-SD handheld spectrometer attached to a laptop computer running Bruker software S1PXRF. The Bruker AXS Tracer III-SD instrument is equipped with a Rh X-ray tube and a 10 mm² Silicon Drift Detector (SDD) with a resolution of 145 eV FWHM for 5.9 keV X-rays. To optimize determination of elements of interest, a Bruker AXS excitation filter (comprised of 0.1523 mm Cu, 0.0254 mm Ti, and 0.3047 mm Al) was used. Data were collected for 300 second live-time count periods with the device set at 40 kV and 30µA. Manganese, Fe, Zn, Ga, Rb, Sr, Y, Zr, and Nb were quantified *via* their $K\alpha$ X-ray emissions, while Th was determined using its $L\alpha$ X-rays. The proprietary obsidian calibration supplied by Bruker AXS was employed for THC elemental analyses. Speakman et al. (2011) found the obsidian calibration gave relatively accurate results for the analysis of ceramic data, which they considered reasonable because obsidian and pottery are silica-rich materials. Given the expected elemental similarity between THC and obsidian, we deemed it reasonable to use the obsidian calibration in this study. Furthermore, pXRF analysis of a powdered sample of NIST 278 (obsidian), NIST 2710a (soil), and the USGS rock reference materials RGM-2 (rhyolite), QLO-1 (quartz latite), and GSP-2 (granodiorite), for quality assurance purposes, gave results for the elements listed above in good agreement with their certified or recommended values.

4.5.2 PXRF results

The analysed clinkers were determined to have distinct but variable elemental signatures (Table 4.3 and Appendix B), which is predictable given that different thermal regimes create a wide variety of pyrometamorphic rocks within a single outcrop (Grapes, 2011:30). High levels of iron and sulphur (not quantified in this study) are likely due to the presence of pyrite (FeS_2) from coal combustion; Sweet et al. (1989) found that the average sulphur content of coal in the Summit Creek Formation was 0.6 percent. We found that clinkers in general contain levels of Zr, Rb, Sr, and Y, and other trace elements commonly associated with coal-baked origins (although comparable concentrations can occur in volcanic materials). The relatively high Rb concentration also points to an original shale or mudstone (argillaceous) precursor of THC. As in obsidian-sourcing studies, trace element comparisons including Rb, Sr, Zr, Ga, Y, Th, and Mn are useful for differentiating THC from similar-looking materials, as well as other clinkers (Figures 4.9-4.10 and Table 4.3).

Table 4.3 Average element concentrations in parts per million (i.e., µg/g) (standard deviation in brackets) as measured by pXRF (n=number of samples of each group analysed).

Sample	(n)	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
Tertiary Hills Clinker	35	380 (40)	11000 (6100)	106 (70)	21 (4)	17 (1)	280 (63)	25 (6)	27 (5)	125 (16)	12 (2)
Flat Top Mountain Clinker	12	340 (20)	10600 (700)	79 (17)	16 (1)	19 (1)	188 (14)	77 (10)	35 (1)	193 (8)	14 (1)
Cape Bathurst Clinker	7	780 (290)	32100 (35200)	355 (424)	39 (12)	20 (6)	149 (18)	161 (123)	39 (6)	174 (8)	20 (5)
Natural Non-Volcanic Glass	10	450 (80)	12900 (1300)	96 (18)	36 (7)	33 (5)	198 (11)	19 (4)	69 (4)	216 (11)	57 (3)
Porcellanite	10	660 (240)	36200 (9100)	118 (38)	31 (6)	16 (5)	147 (21)	112 (19)	32 (3)	160 (24)	18 (4)

The majority of THC artifacts from Northwest Territories and Yukon fall within 95% confidence ellipses of several element bivariate plots of THC outcrop material (Figures 4.9-4.10). NVNG and porcellanite from Montana and CBC from the Mackenzie Delta consistently plot outside the geochemical variability of THC and can be distinguished by pXRF. The relatively tight spatial clusters of CBC, porcellanites, NVNG, and FTMC are supportive of future sourcing work with these clinkers. On a broader level, pXRF offers rapid and non-destructive means to quickly distinguish clinkers from similar-appearing materials such as quartzites and chalcedonies.

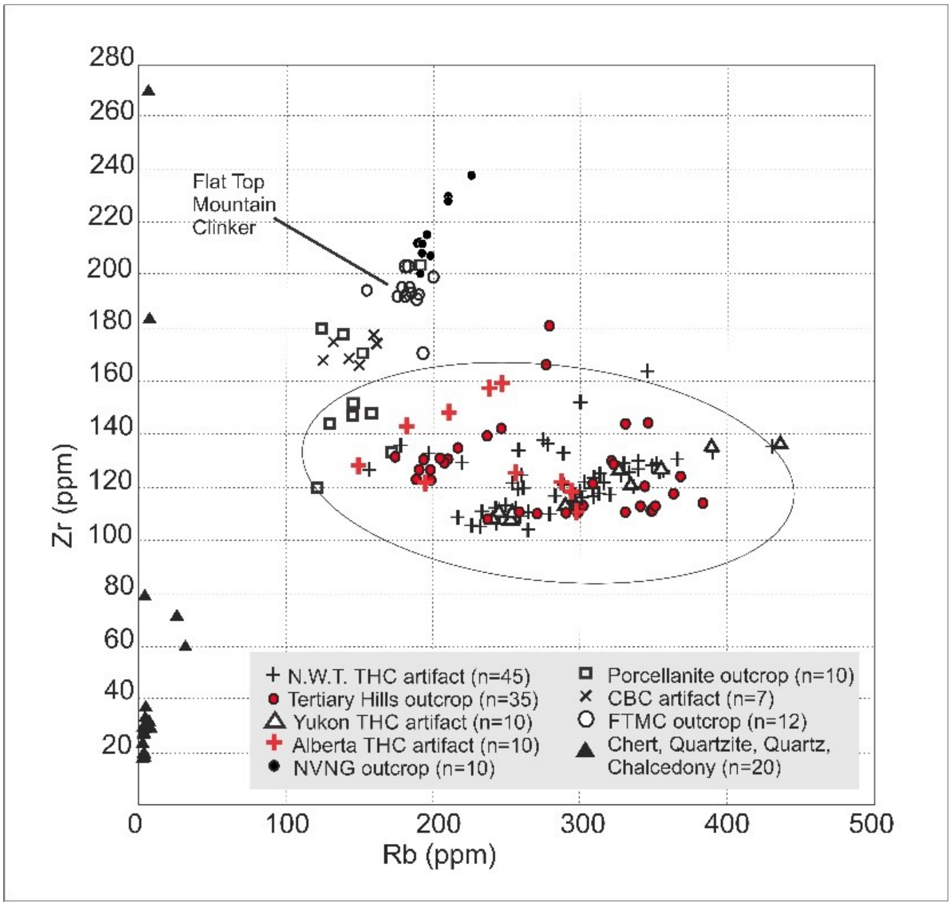

Figure 4.9 Bivariate plot of element concentrations with 95% confidence ellipse around THC outcrop material.

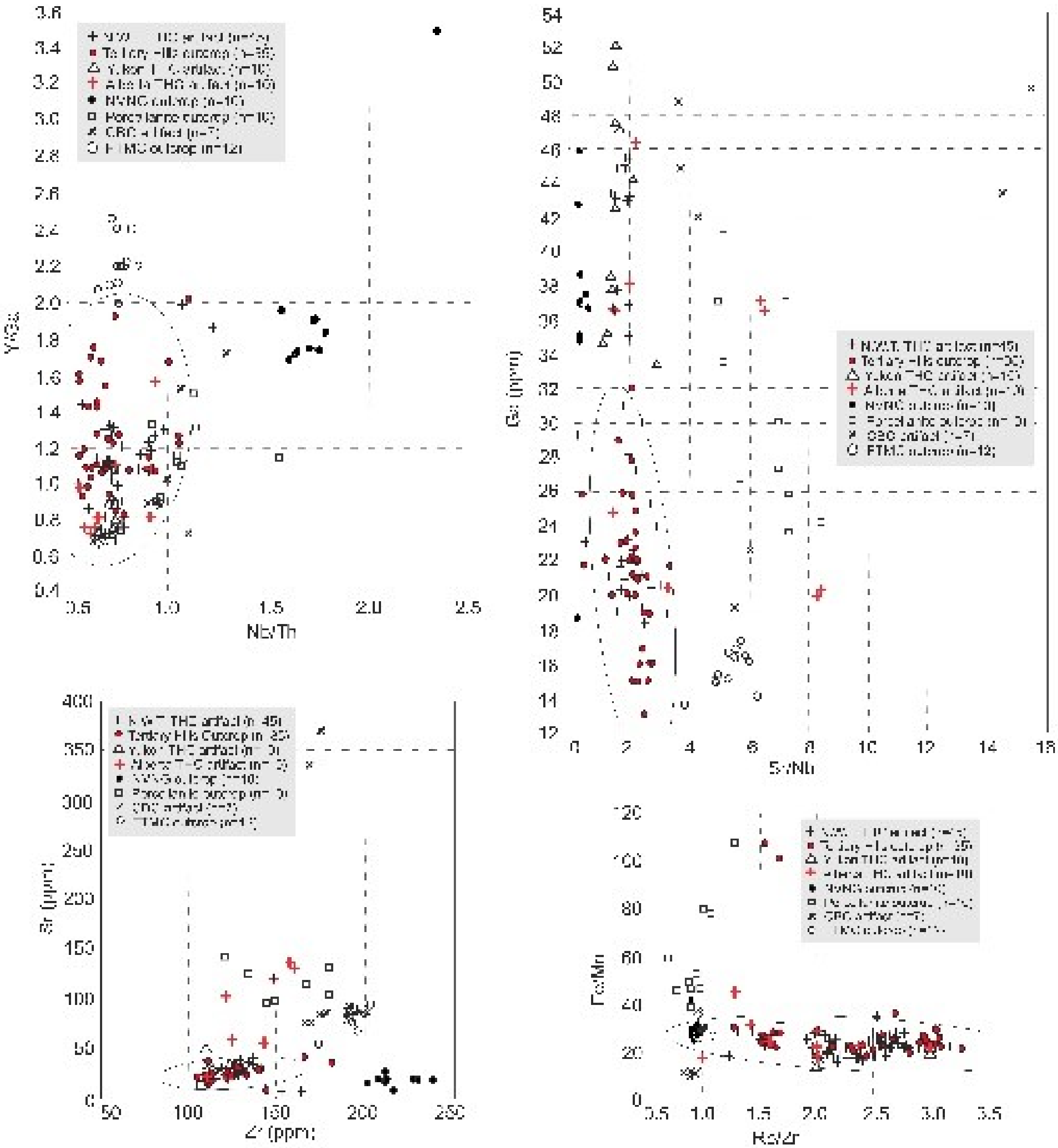

Figure 4.10 Bivariate plots of element concentrations with 95% confidence ellipses around THC outcrop material (cherts, quartzites, quartzes, and chalcedonies were excluded).

A plot of Ga vs. Sr/Nb indicates that some Yukon, Alberta, and Northwest Territories artifacts are beyond the 95% confidence ellipse of THC outcrop material suggesting that the outcrop samples analyzed in this study may not capture the full variability of these elements and that these elements may be of future utility to distinguish particular THC outcrops. Purported THC artifacts in central Alberta (GbPt-11 and GfPt-3) exhibit levels of Mn, Sr, and Ga outside the variability displayed by THC outcrop material and could indicate that this clinker was quarried from a particular outcrop in the Tertiary Hills that was not captured in this study. Variability in the detected elements is to be expected considering the variability in source rock over the distribution of THC. Lastly, Fe should be interpreted with caution: it is suspected that two THC outcrop samples yielded abnormally high Fe levels due to the presence of cortex within areas of the samples analysed by pXRF. The cortex covering THC tends to consist largely of iron oxides. Results of the pXRF analysis indicate that clinker artifacts across Subarctic North America can be reliably differentiated from one another, and can be sourced to THC outcrops in Northwest Territories.

4.6 Archaeological significance

4.6.1 Distribution

THC artifacts were transported 600 km both east and west of Tertiary Hills, 530 km to the north, and 1200 km south of their outcrops with a total area that encompasses roughly 1.25 million km^2 (Figures 4.11 and 4.12). In comparison, we estimate that Edziza obsidian artifacts from northern British Columbia extend 1.5 million km^2 into Yukon and northern Alberta (Potter, et al. 2017; Woywitka, 2017) while Knife River Flint from North Dakota extends 3.7 million km^2 across the Northern Plains into Alberta (Ahler, 1986:105; Kristensen et al., 2018). A particularly wide distribution across irregular and forested terrain (not known for ease of human movement) likely relates to THC's proximity to the second largest river network in North America.

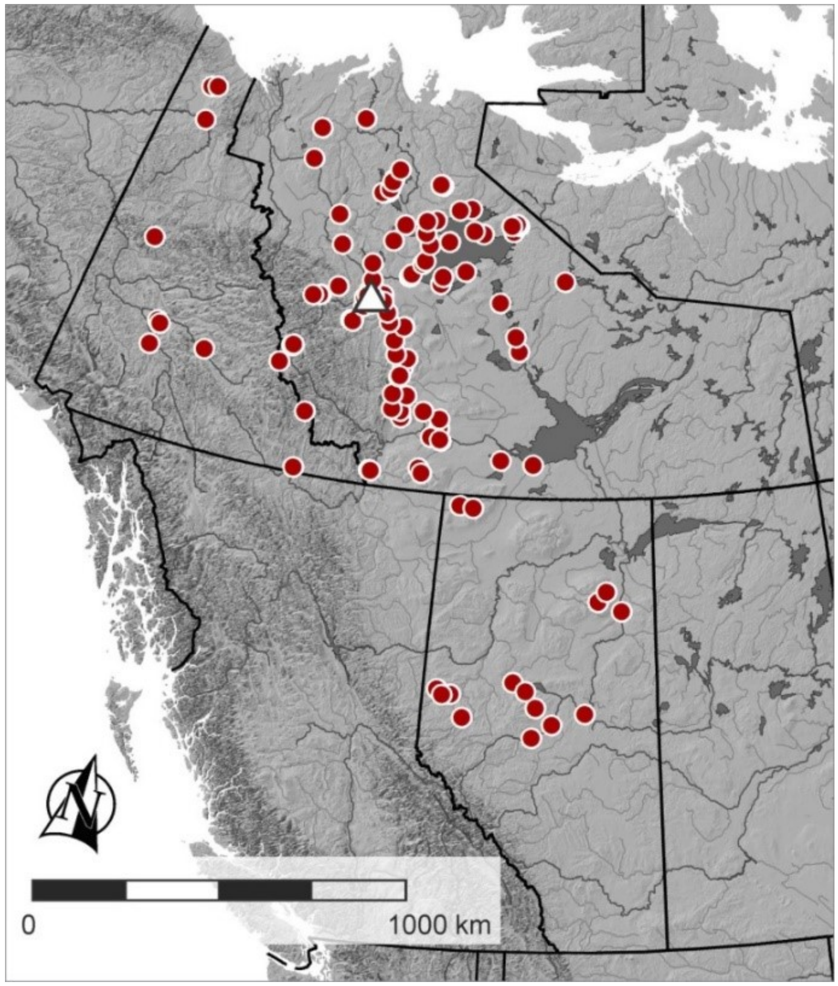

Figure 4.11 All confirmed occurrences of pre-contact sites (n=160) with THC artifacts in Yukon, Northwest Territories, and Alberta. More sites likely exist but THC was not mentioned in site records or collections were inaccessible.

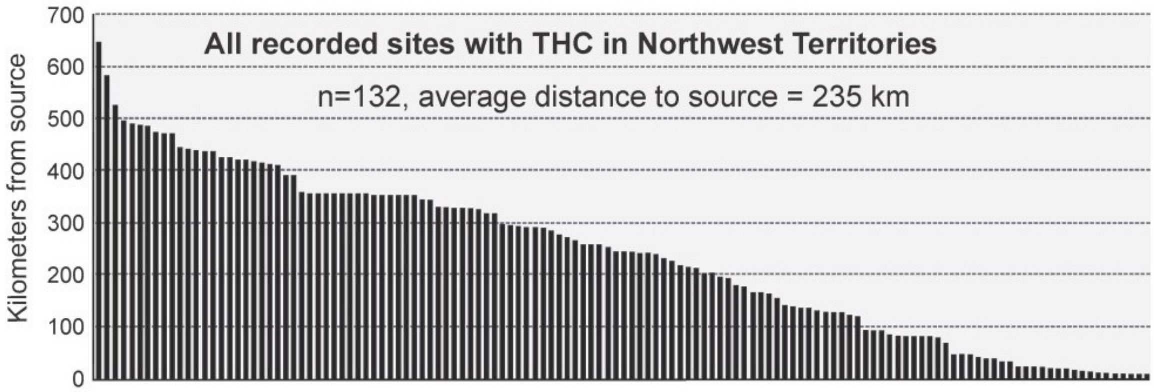

Figure 4.12 Distance drop-off chart. The x-axis consists of archaeological sites, each represented by one bar.

4.6.2 Frequency

THC is comparatively rare but when it does occur, it is often a significant portion of site assemblages (Table 4.4). Roughly one quarter of all THC-bearing sites in Northwest Territories contain a THC tool (THC tools comprise roughly 6.5 percent of site assemblages with THC) but it most commonly occurs as small bifacial reduction or tertiary flakes indicating that THC generally moved in the form of curated tools. Tool to debitage ratios do not differ significantly with distance from the source. A similar pattern prevails in Alberta and Yukon where nine of the 28 sites with THC have assemblages in which the only THC artifact recovered is a curated tool. All THC debitage recovered beyond Northwest Territories is late stage debris. THC is relatively brittle and would not be a suitable raw material for repetitive blunt force tasks like chopping or early stage scraping of hides and this presumably limited its utility to piercing and slicing; typical THC tools are projectile points, knives, and microblades.

Table 4.4 Comparison of assemblages with THC from Northwest Territories, Alberta, and Yukon. Sites with less than ten artifacts are excluded in the fourth row to remove a skew caused by small lithic scatters.

Jurisdiction	**Northwest Territories**	**Yukon**	**Alberta**	**Total**
Number of sites with THC	132	12	16	160
Frequency of THC in assemblages with THC	33.3%	12.3%	12.8%	32.1%
Frequency of THC in assemblages with THC excluding sites with less than 10 artifacts	16.6%	5.3%	5.4%	16.0%
Rough total of pre-contact sites in territory/province	~4000	~4000	~36,000	-
Percentage of pre-contact sites that contain THC in territory/province	~3%	<1%	<0.1%	-
Average distance from source	235 km	585 km	1067 km	341 km

4.6.3 Chronology

Fourteen sites with THC artifacts have yielded radiocarbon dates that span the Holocene (Table 4.5 and Figure 4.13). Sites in Alberta (GdQn-1) and Yukon (NcVi-3) produced THC flakes (see Appendix B for pXRF results) and fluted points (Bereziuk, 2016; Clark and Clark, 1983; Esdale, 1998; Le Blanc, 1997) while JcRw-3 in Northwest Territories (Millar 1968) produced a date from 10,124 to 9534 cal years BP (Stuiver et al., 2018) although stratigraphic control is poor. HhOu-113 is a single occupation site in Alberta (Roskowski, 2012) that yielded THC flakes (see Appendix B) and a date of 8150 to 7970 cal years BP (Stuiver et al., 2018). THC occurrences at

Late Pleistocene/Early Holocene sites suggest a wide Subarctic social network during deglaciation when continental ice sheets had not fully melted to the west and east. If the Tertiary Hills deglaciated earlier than surroundings (Hanks, 1993), they may have been connected to Alberta and Yukon through a navigable corridor as early as 12,000 cal years BP (Dawe and Kornfeld, 2017). Fluted KRF points have been found in Alberta (Kristensen et al., 2018) at a similar latitude to the fluted point and THC site at GdQn-1: fluted point makers in Alberta appear to have maintained contact from North Dakota to Northwest Territories (a linear distance of 2500 km equivalent to that between southern Greece and northern Denmark). The geographic connection highlighted by THC movement through the Middle to Late Holocene demonstrates conduits of exchange that, with future identification and provenance analyses of THC, can inform models of how communal hunting, the bow and arrow, linguistic groups, and DNA families spread across interior North America.

Table 4.5 Sites with THC recovered from radiocarbon dated components. CARD is the Canadian Archaeological Radiocarbon Database (Martindale et al., 2016).

Site	Conventional RC date BP	Lab Number	Material	$\delta^{13}C$ (per mil)	Location	Reference
JcRw-3	8720+/-190 4920+/-110 3780+/-160	GAK 1275 I-3190 GAK 1274	Charcoal Carbonaceous soil Charcoal	-25.0 Not known -25.0	Northwest Territories	Millar 1968
HhOu-113	7220+/-40	Beta-33309	Calcined bone	-23.1	Alberta	Roskowski 2012
KaVa-3	5870+/-40	Beta-86359	Charcoal	-26.1	Yukon	CARD
LgRk-2	4965+/-220 4065+/-220	S-5 S-8	Peat Plant remains	-27.0 -27.0	Northwest Territories	Clark 1986
LgRk-1	4430+/-240 3890+/-180 4800+/-200 4650+/-200	RIDDL-322 RIDDL-323 S-10 S-9	Caribou bone collagen Caribou bone collagen Charcoal plant remains	-20.0 -20.0 -25.0 -25.0	Northwest Territories	CARD
KdVa-8	3630+/-140	AECV-1560C	Charcoal	Not known	Yukon	Thomas 2003
JcRw-8	2460+/-160	GSC 844	Charcoal	-25.0	Northwest Territories	CARD

JlRq-1	2225+/-170 2265+/-385	S-691 S-703	Charcoal Charcoal	-25.0 -25.0	Northwest Territories	CARD
JePw-1	1860+/-135 1635+/-280	S-2873 S-2875	Charcoal Charcoal	-25.0 -25.0	Northwest Territories	Hanks and Irving 1986
MiRh-5	1690+/-110	S-922	Calcined bone	-20.0	Northwest Territories	Clark 1975, CARD
LhRe-1	1690+/-50	Beta-099129	Charred plant material	-27.0	Northwest Territories	Toews and Pickard 1997
KlRk-1	1570+/-60	S-704	Charcoal	-25.0	Northwest Territories	CARD
KlRs-5	1285+/-205 1070+/-215	S-2873 S-2877	Charcoal Charcoal	Not known Not known	Northwest Territories	Hanks 1993
LcRq-3	335+/-80	I-7788	Charcoal	-25.0	Northwest Territories	Cinq-Mars 1975

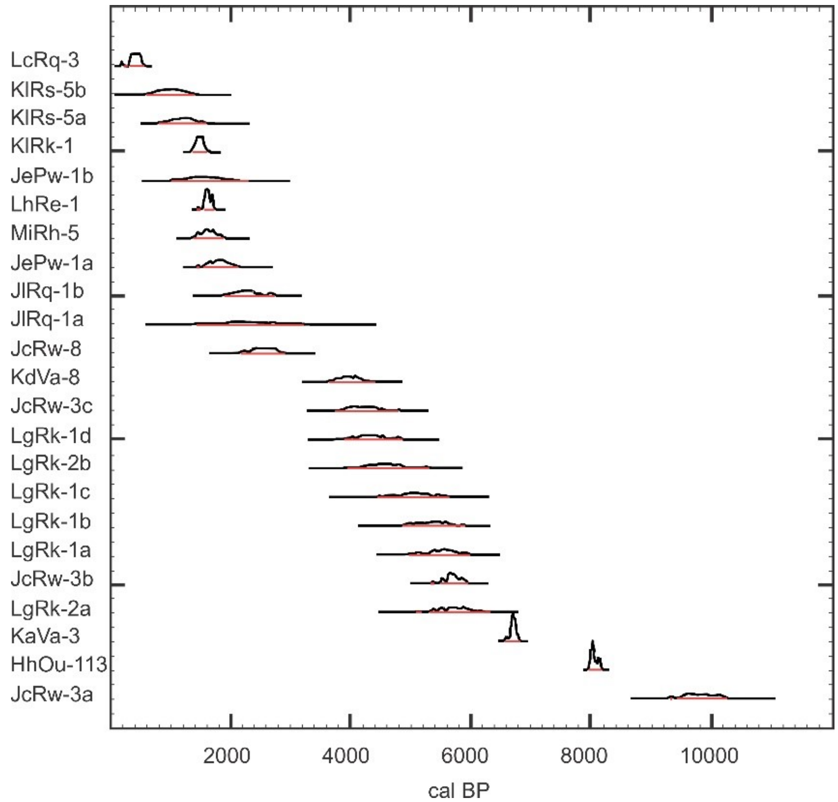

Figure 4.13 Probability distribution of radiocarbon dated archaeological sites with THC. Probability distributions based on calibrated 2σ range generated using Calib 7.1 (Stuiver et al., 2018) and CORELdraw 6.0.

4.6.3.1 White River Ash east and volcanic eruptions

The majority of archaeological sites containing THC lack datable material due to taphonomic processes but many contain a well-defined stratigraphic marker that can be used for relative dating of occupations. The White River Ash east (WRAe) eruption dated to A.D. 846-848 (Jensen et al., 2014) created an ash lobe that extended across Yukon into Northwest Territories over 600 km east from its origin at or near Alaska's Mount Churchill (Figure 4.14). An estimated 47 km^3 of ash descended across roughly 1 million km^2 making this one of the largest Holocene eruptions in North America (Lerbekmo, 2008; VanderHoek and Nelson, 2007). Permit reports, site forms, and publications were analysed for all available THC-bearing sites to assign pre- vs.

post-WRAe ages (Table 4.6) based on the presence of ash and typological information (e.g., projectile points and microblades).

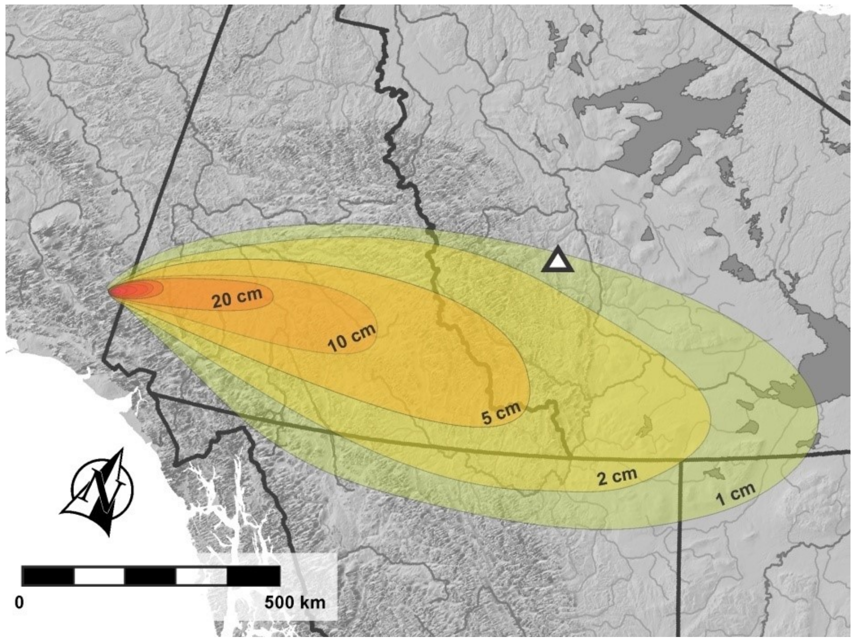

Figure 4.14 WRAe isopach map of tephra depth (adapted from Lerbekmo, 2008). The white triangle is the THC outcrop.

Table 4.6 Comparison of pre- vs. post-WRAe assemblages with THC in Northwest Territories.

Chronology	Pre-WRAe	Post-WRAe	Unknown Age	Total or Average
Sites with THC	44	26	62	132 (total)
Frequency of THC in all sites with THC	10%	48.3%	48.1%	33.3% (average)

Frequency of THC in assemblages with THC (but excluding sites with <10 artifacts)	5.2%	42.5%	16.9%	16.6% (average)
Number of sites with THC tools	17	1	12	30 (total)
% of total assemblage that is a tool	5.5%	0.2%	10.1%	6.5% (average)

A comparison of pre- vs. post-WRAe assemblages indicates that the eruption altered hunter-gatherer mobility and exchange patterns. When pre- vs. post-WRAe chronologies could be assigned to Yukon and Alberta assemblages with THC, all sites are pre-WRAe despite the fact that a relatively high percentage of pre-contact sites in Subarctic Canada are from the last 1000 years (e.g., due to visibility, connections to oral history, and erosion factors). It appears that long-distance relationships with people of Northwest Territories broke down after the eruption based on the absence of post-WRAe THC in Yukon and Alberta.

Changes in THC movement before and after WRAe suggest that the eruption weakened contact and material exchange across the Mackenzie Mountains that separate Yukon and Northwest Territories. While landscapes and biota may have been minimally affected by ash in the Mackenzie Basin (MacDonald, 1987; Slater, 1985; Szeicz et al., 1995), human adaptations in the Yukon River Basin, particularly regions with over 5 cm of ash deposition, were likely heavily stressed (e.g., Anderson et al., 2005; Bunbury and Gajewski, 2013; Gajweski et al., 2014; Kuhn et al., 2010). In general, volcanic eruptions in the arctic/Subarctic with significant ash deposition (5 cm or greater) experienced more dramatic impacts on ecosystems and people than in temperate environments because of relatively simpler trophic pyramids and more fragile landscapes (Dumond, 2004; Fitzhugh, 2012; Grishin et al., 1996; Jacoby et al., 1999; Pendea et al., 2016; Sheets, 2012; VanderHoek and Nelson, 2007). Oral history indicates that in the last 500 years, people maintained regular contact and kin networks across the Mackenzie Mountains (Gillespie, 1981; Hanks, 1993; Michea, 1963); with a lack of access to Yukon River resources and social networks caused by ash and ecological stress, people of the Mackenzie Basin may have shifted to a more insular economy and endogamous kin network (Ives, 1990). This may explain a drop in the movement of curated THC tools away from the source and an increase in domestic production because the Tertiary Hills were more frequently visited during seasonal rounds of Mackenzie Basin hunter-gatherers. A lack of access to social networks to the west (towards Yukon), may have weakened Northwest Territories hunter-gatherer economic systems that, in turn, had once helped support long-distance exchange south to Alberta. We argue that the WRAe eruption destabilized a social landscape that had previously fostered long-distance exchange.

Within Northwest Territories, sites with THC increase from roughly one per 200 years (pre-WRAe) to one site per 50 years (post-WRAe). The frequency of THC tools drops significantly from pre- to post-WRAe while the relative percentage of THC in Northwest Territories assemblages significantly increases from pre- to post-WRAe (Table 4.6). Overall, the movement of curated THC artifacts drops while domestic production (increased percentages of debitage) increases after the eruption. Spatial data also indicate that post-WRAe long distance movement of THC drops (Figure 4.15). However, several archaeological sites in Northwest Territories with THC in both pre- and post-WRAe components indicate a local continuity of exploitation (e.g., LgRk-1, LcRq-3, and KlRs-5 on Figure 4.15).

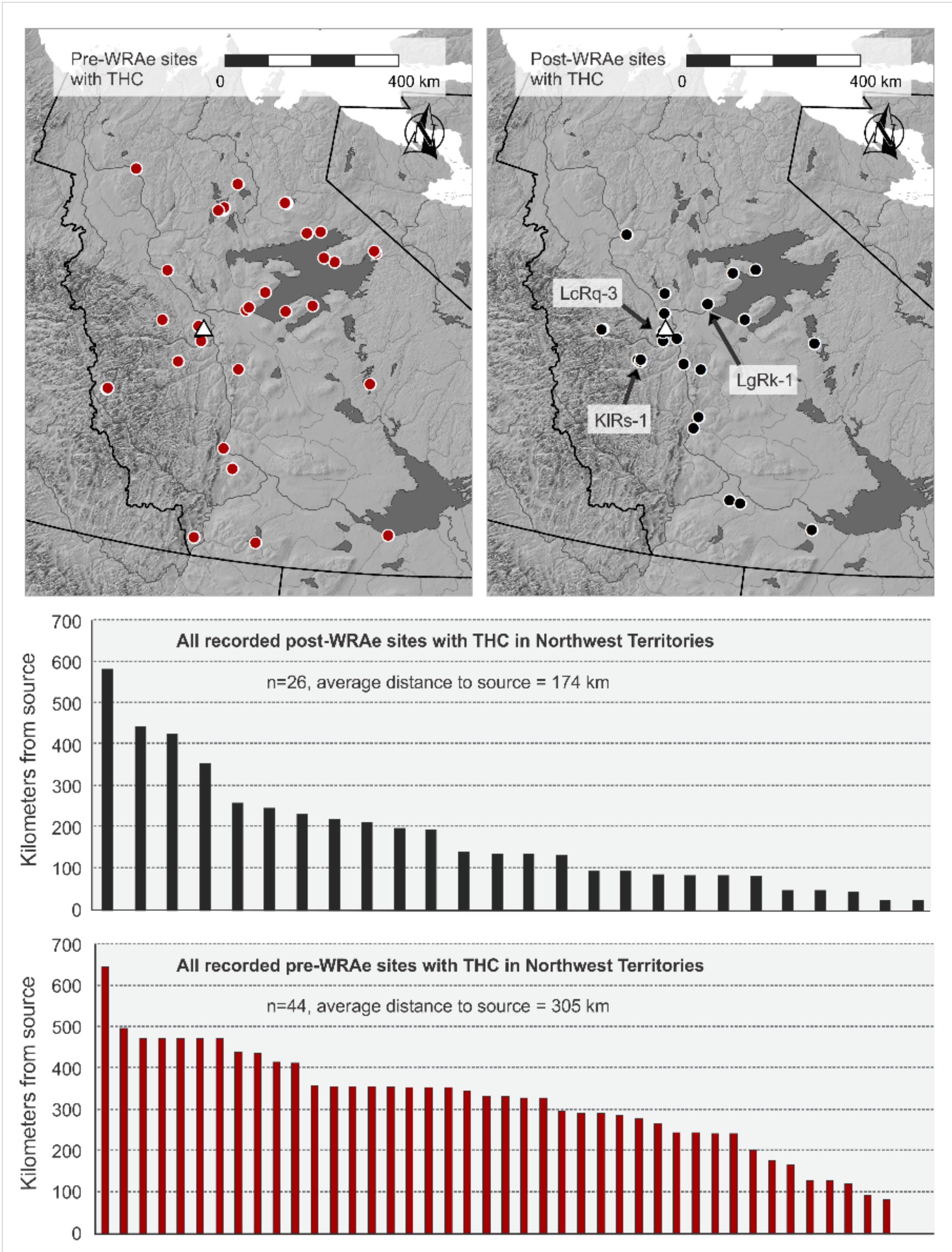

Figure 4.15 Distance drop-off chart comparison and maps of pre- vs. post-WRAe archaeological sites with THC. The x-axis consists of archaeological sites, each represented by one bar. The white triangle in the maps above is the outcrop of THC.

4.7 Discussion

Long-term exploitation of pyrometamorphic raw material outcrops (Tertiary Hills Clinker) implies some degree of stability and continuity in Subarctic hunter-gatherer adaptations in Northwest Territories. Knowledge of THC outcrops was presumably passed down from generation to generation with high fidelity despite cultural and technological changes over 10,000 years. Conversely, the visibility of burning bocannes and vents may have been a continuous beacon for raw material exploitation. The identification of THC and provenance results support the assertion that for much of the Holocene, contact between cultures has at least sporadically existed from Alberta to Yukon.

The Mackenzie River and its tributaries appear to have been conduits of contact and exchange, which supports historic records of the river acting as a meeting ground of Dene people (Gillespie, 1981; Michea, 1963). Figure 4.16 is an overlay of Dene First Nation territories at the time of European contact (Ives, 1990) superimposed on THC site distribution and illustrates the significance of the Mackenzie River as a definer of social boundaries and possible mode of exchange. If extended into pre-contact times, the majority of sites with THC artifacts (Figure 4.12) could have been produced by hunter-gatherers who personally visited outcrops: First Nations of the Mackenzie Mountains regularly moved distances of 300 km in traditional seasonal rounds (Andrews et al., 2012; Hanks, 1993). The majority of sites beyond a few hundred kilometers from the source can be explained by a single exchange between two neighbouring bands. The location of Tertiary Hills near the junction of four traditional territories may explain its movement within them. In times of need, Shuhtagot'ine Dene travelled beyond their traditional territory to the northeast and if this practice is of antiquity, it would explain the pre-contact presence of THC in this area. The Shuhtagot'ine Dene often travelled over the Mackenzie Mountains into Yukon to exchange goods and fish for salmon (Gillespie, 1981; Hanks, 1993; Michea, 1963) so the occurrence of THC (prior to White River Ash east deposition) at archaeological sites along rivers that drain west from the Mackenzie Mountains is not surprising.

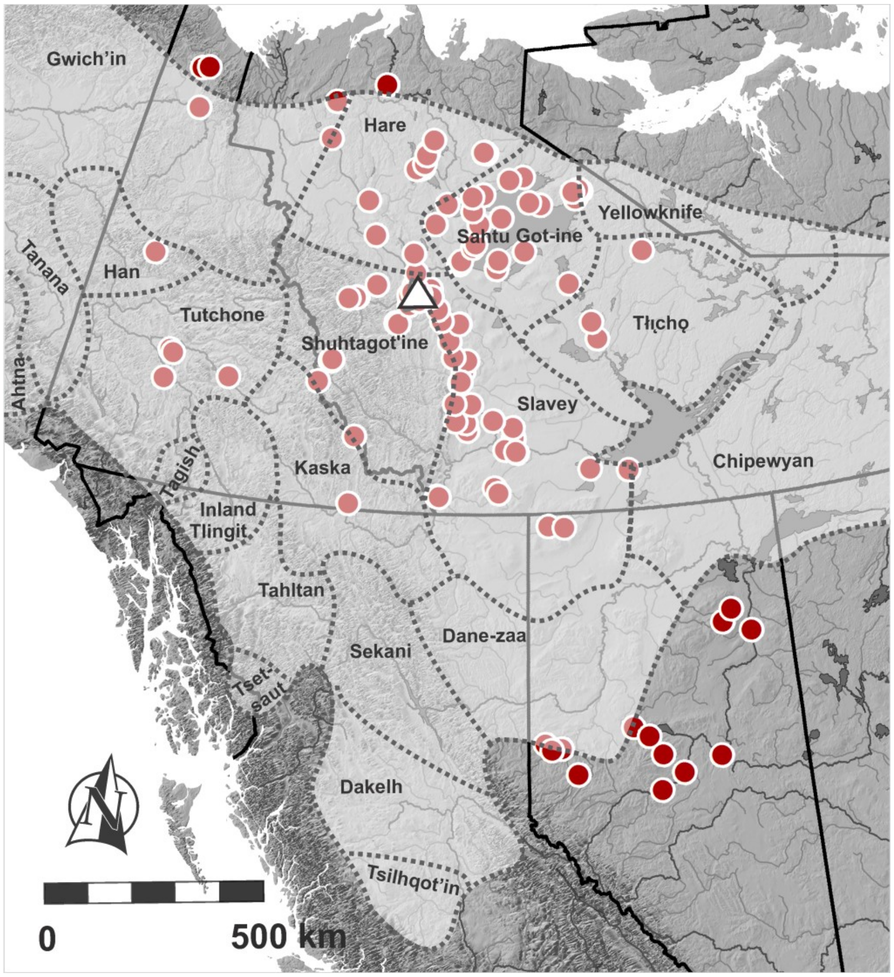

Figure 4.16 An overlay of Dene First Nations territories at the time of European contact on the distribution of archaeological sites with THC (red circles). THC may have been limited to exchange between Dene ancestors if Dene territories at one time extended further south into Alberta in the Holocene than at the time of European contact.

With an average distance of 1070 km from the source, sites in Alberta with THC are more difficult to explain and likely involved the exchange of goods multiple times. All sites in Alberta with THC are located on or between major rivers that flow north to join the Mackenzie River (Figure 4.16). It appears that rivers were routes of exchange in Subarctic pre-contact times with a corollary implication that boat technology was a major means of maintaining social connections, perhaps as early as the Late Pleistocene (Engelbrecht and Seyfert, 1994).

Despite long-term stability of THC use, the WRAe eruption decreased the movement of curated tools and increased domestic production. We surmise that hunter-gatherers in the Yukon River Basin were negatively affected by heavy ash and this severed a connection with Mackenzie Basin hunter-gatherers that, in turn, reduced exchange networks and shifted THC exploitation to greater local consumption. High resolution temporal data from pre-contact weapons recovered from ice patches in Yukon indicate a clear technological shift after the WRAe from atlatl darts to bow and arrow technology (Hare et al., 2012) with a potentially associated cultural disruption. Caribou DNA records (Kuhn et al., 2010) indicate that the ash fall may have decimated ungulate populations on which the residents of southwest Yukon relied. The earliest bow and arrow record in Yukon ice patches is a bow made of coastal maple (Hare et al., 2012) suggesting that the WRAe event either stimulated exchange of a new technology in the Yukon River Basin or triggered the influx of new people from the west.

The spread of the bow and arrow around 1200 years ago may have influenced THC exchange in Northwest Territories and abroad to Yukon and Alberta. The bow and arrow are thought to have increased dietary breadth and reduced hunting band sizes (Angelbeck and Cameron, 2014; Bettinger, 2013; Churchill, 1993), and/or increased human conflict (Maschner and Mason, 2013), with a resultant decrease in hunting territories, although applications of these hypotheses have been to cultural landscapes and ecosystems different from the Subarctic. However, large-scale hunting events, like communal caribou drives, persisted in the north to historic times, implying that hunting band sizes may not have been greatly influenced by the bow and arrow (e.g., Friesen, 2013; Gordon, 1990). Ice patch records indicate an antiquity of snare technologies for small game (Andrews et al., 2012), which suggests that dietary breadth may not have been significantly altered with bow and arrow use either.

The last 1200 years in Northwest Territories and Yukon (the Late Prehistoric Period) are generally marked by the introduction of small side-notched points (reduced in size compared to the earlier and presumed atlatl dart points), disappearance of microblades, and in Yukon, an increase in organic and copper tools (Clark and Gotthardt, 1999; Cooper, 2012; Gordon, 1996; Morrison, 1984). Land use patterns did not change significantly. It can be argued that local THC exploitation increased with adoption of the bow and arrow. However, other forms of archaeological evidence have yet to reveal a significant impact of the bow and arrow in Subarctic subsistence and social networks (Andrews et al., 2012; Morrison, 1984; Workman, 1979). It remains plausible that the WRAe event and bow and arrow spread across Subarctic Canada are related and therefore archaeologically challenging to differentiate in terms of human impact. Vegetation communities do not appear to have changed significantly in Northwest Territories in the last 3000 years (MacDonald, 1987; Slater, 1985; Szeicz et al., 1995), therefore shifting climates and changing ecosystems (long term) are unlikely explanations of the changes in pre- and post-WRAe networks of raw material exchange. Ice patch archaeology and palaeoenvironmental studies, when combined with changes in THC distribution, point to the WRAe volcanic event as a disruptive force in the Subarctic social landscape.

Changes in THC distribution offer two contributions to theories of a long debated origin and impetus of the migration of Athapaskan-speaking people (ancestors of modern Dene First Nations) from the Canadian Subarctic to the American Southwest and Great Basin (Derry, 1975; Gordon, 2012a; Haskell, 1987; Ives, 2003, 2010, 2014; Matson and Magne, 2007; Moodie et al., 1992; Seymour, 2012; Workman, 1979). Firstly, the identification of THC in Alberta and Yukon indicates that the presumed ancestral Dene contact zone extended across thousands of kilometers from the Circumpolar North to the Northern Plains east of the Rocky Mountains. This connection persisted for perhaps several thousand years before Athapaskan migration began in the Late Holocene. Secondly, the WRAe eruption appears to have altered social dynamics as revealed by a geographic reduction of THC exchange above WRAe tephra. The volcanic event was a likely stimulus of culture change and may be implicated as one factor that ultimately dislocated a group of hunter-gatherers from their homeland, which initiated a much larger-scale movement of people across the continent.

Archaeologists have long sought links between WRAe and Athapaskan migration (Derry, 1975; Ives, 2003; Workman, 1979) or downplayed the significance of this ecological event (Gordon, 2012a). Previous researchers have relied on oral history of volcanic events (Moodie et al., 1992), models of hunter-gatherer population density (Ives 2003; Mullen, 2012; Workman, 1979), or have drawn on other hunter-gatherer responses to eruptions (Gordon, 2012a) to infer impacts of WRAe on pre-contact people and then extrapolate the likelihood that this event stimulated out-migration. The identification of THC and provenance analyses offer some of the first reliable archaeological clues that ancestral Dene people maintained connections of deep antiquity from Yukon and Northwest Territories to the Northern Plains of Alberta, a valid path en route to the US Southwest and Great Basin regions. Our pXRF results and WRAe analyses also offer some of the first evidence beyond ice patch records that the volcanic event influenced northern hunter-gatherers and their social networks.

Our results are consistent with other analyses of northern hunter-gatherer responses to volcanic events (see Dumond, 2004; Fitzhugh, 2012; Jacoby et al., 1999; Pendea et al., 2016; VanderHoek and Nelson, 2007). Pre-contact people demonstrate a high resilience to ecologically rebound, either by temporarily relying on kin or altering subsistence strategies, but they existed in social landscapes where large-scale natural events tipped the balances or caused disturbances to cultural fabrics that some groups capitalized on to another's disadvantage (see Begét et al., 2008; Grattan and Torrence, 2007; Torrence, 2016; Williams, 2002; Zeidler, 2016). People of the Yukon and Mackenzie River Basins created kin and non-kin based alliances (Ives, 1990) to strengthen their socio-political hold on landscapes and buttress subsistence strategies. A large-scale event like the WRAe would have triggered alterations to social landscapes. Social processes are major means of adapting to large-scale ecological disturbances: provenance analyses when combined with the use of stratigraphic markers (pXRF analysis of THC and changes in distribution before and after the WRAe) provide a tool to evaluate social responses to large events.

4.8 Conclusion

We identify and characterise pyrometamorphic rocks using a suite of macroscopic, microscopic, and archaeometric techniques including XRD, thin section studies, and EPMA. We demonstrate that some clinkers produce geochemically distinct profiles of value for provenance studies. On the basis of results from pXRF, clinker artifacts from sites across Northwest Territories, Yukon, and Alberta can be confidently sourced to outcrops in the Tertiary Hills west of Mackenzie River. Results of these analyses (e.g., 1.25 million km^2 of THC extent that spans 10,000 years of human use) indicate that hunter-gatherer social networks beginning in the Late Pleistocene/Early Holocene were tethered to rivers and encompassed broader areas of Subarctic North America than previously thought. The White River Ash east volcanic eruption around A.D. 846-848 (Jensen et al., 2014) may have negatively influenced local hunter-gatherers in the Yukon River Basin that in turn severed modes of contact across the Mackenzie Mountains to the east with hunter-gatherers of the Mackenzie River Basin. This indicates that the volcanic event altered local hunter-gatherer social networks, and perhaps provided initial stimulus for the dislocation of a Dene hunter-gatherer group that culminated in a large-scale migration to the American Southwest and Great Basin. The application of provenance studies to pyrometamorphic rocks and the investigation of changing spatial and temporal distributions of raw materials offer means to reconstruct human movement and culture contact in global studies.

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CHAPTER 5: POWER, SECURITY, AND EXCHANGE: IMPACTS OF A LATE HOLOCENE VOLCANIC ERUPTION IN SUBARCTIC NORTH AMERICA

Abstract

We synthesise environmental and cultural change following a large volcanic eruption at A.D. 846-848 in Subarctic northwest North America to demonstrate how social relationships shaped responses to natural disasters. Paleoenvironmental records, ethnohistoric accounts, and archaeometric studies reveal differences in the adaptations of people in the Yukon and Mackenzie river basins that we argue relate to exertions of power over contested resources versus affordances of security to intercept dispersed migrating animals. The ways that pre-contact hunter-gatherers maintained or redressed ecological imbalances shaped respective trajectories of resilience to a major ecological event. Adaptive responses to a volcanic eruption influenced the ensuing movement of bow and arrow technology from coastal Alaska into Yukon and the proliferation of copper use in northwest North America.

5.1 Introduction

Hunter-gatherer resilience to natural disasters is a product of social relationships and ecological dynamics (Redman 2005; Bradtmöller et al. 2017). Large-scale disturbances, like volcanic eruptions, create a temporal succession of environmental parameters shaped by event magnitude, spatial extent, duration of recovery of predictable resources (food, water, shelter), and uniformity of impact across a disturbance footprint (Grishin et al., 1996; Martí and Ernst, 2005; Riede, 2014; Schmidt et al., 2015). How people responded to disturbance was influenced by interplays of kinship, economic partners, population densities, subsistence, and ideological perceptions of an episode's cause (Sheets 1980; Losey, 2005; Grattan, 2006; Cronin and Cashman, 2007; Fitzhugh, 2012; Riede, 2016a; Torrence, 2018). We summarise archaeometry (lithic provenance research), ethnohistoric records, and palaeoenvironmental studies to explore the interaction of these variables in the past and understand how people of Subarctic Yukon and Northwest Territories (N.W.T.) in northern Canada (Figure 5.1) coped with the high magnitude eruption of White River Ash east (WRAe) at A.D. 846-848 (Lerbekmo, 2008; Jensen et al., 2014). The event ranks among the largest short-term ecological disturbances experienced by Holocene humans in interior North America and we argue that hunter-gatherer responses to it altered local trajectories of development.

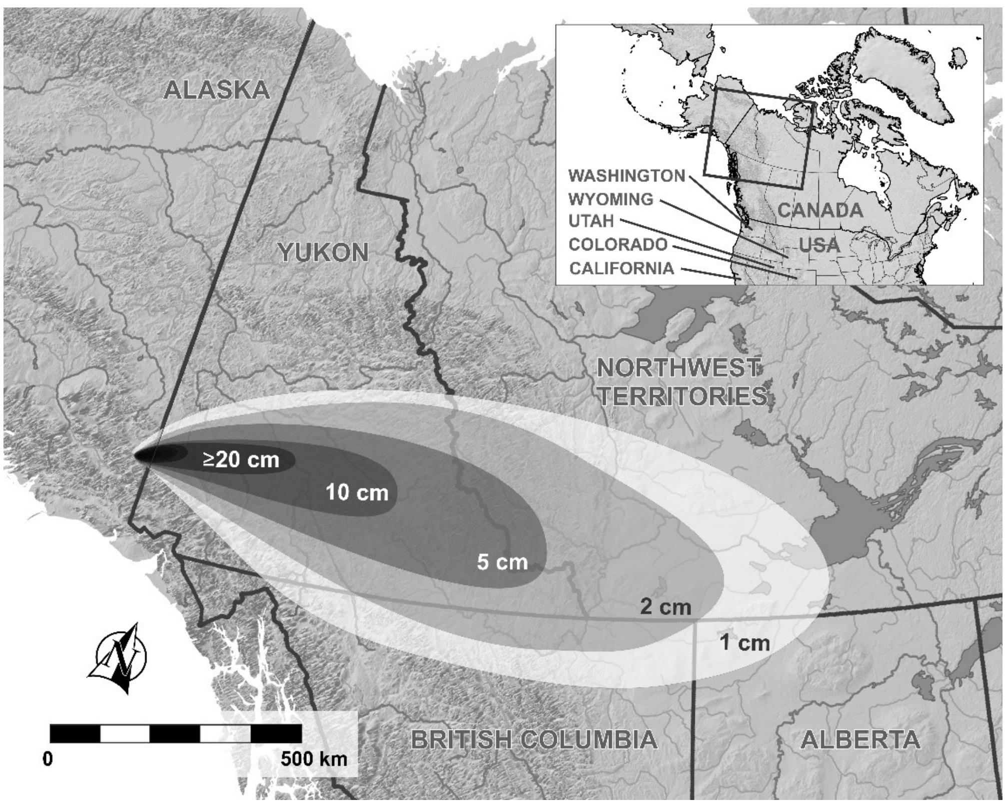

Figure 5.1 Study area (inset) and inferred WRAe tephra isopachs (adapted from Lerbekmo 2008). The isopachs indicate ash thicknesses encountered in the stratigraphic record (after compression).

Social relationships within and between Subarctic and coastal nations are here conceived of as connections developed through structural regularities in a group or society that influenced individual interaction and the channeling of resources (Wetherell et al., 1994; Otte and Rousseau, 2002). These resources can include information, people, trading relationships, and material goods. We explore resilience to a volcanic eruption in the form of network-mediated migration (Butterworth, 1962; Kemper, 1977; Kearney, 1986; Massey et al., 1987; Wilson, 1994), whereby social relationships, in conjunction with economic variables, shaped and sustained population movements (Brettell, 2000), both away from, and back to, ancestral homelands. Resilience here refers to both the capacity to recover and the shape of the resulting adaptations; resilience among groups of people following an ecological event can involve completely different behaviors or relationships than those that existed prior to the disturbance. But the nature of pre-existing social relationships imparts some form or shape to ensuing responses. In other words, a major precursor to help understand how people in the past responded to an ecological disturbance is to understand with whom they interacted prior to a large-scale event.

Major volcanic eruptions in the past, like many ecological events, were dynamic forces both destructive and creative. Certain components of a group's material surroundings were destroyed but networks of relationships persisted. New physical realities helped forge new relationships. In socio-political landscapes, certain groups capitalized on opportunities afforded by large-scale destabilizing forces, which re-organized relationships and stimulated new forms of resilience (Holling, 2001; Gunderson and Holling, 2002; Redman, 2005). In the material record of pre-contact people lie the traces of previous social networks, the impacts of large-scale disturbances, and the new relationships that were formed in response.

From its origin near Mount Churchill, Alaska (Figure 5.1), the WRAe eruption spread 50 to 5 cm of tephra (Figure 5.2) across much of southern Yukon (Lerbekmo and Campbell, 1969; Lerbekmo et al., 1975; McGimsey et al., 1992; Richter et al., 1995; Robinson, 2001; Lerbekmo, 2008; Preece et al., 2014). The study area, which includes the southwest portion of N.W.T., southern Yukon, and adjacent southeast Alaska, has a 13,000 year history of hunter-gatherer occupation (Workman, 1978; Hare, 1995; Thomas, 2003; Easton, 2007; Easton et al., 2011; Castillo, 2012). Five decades of work in the study area have produced several theories that connect local volcanic events to culture change (Workman, 1974, 1979; Derry 1975; Ives 1990; Clark, 1991; Moodie et al., 1992; Mullen, 2012; cf. Gordon, 2012a; Kristensen et al., 2019a; Kristensen et al., 2019b; Kristensen et al., in press) including links between eruptions and the migration of Dene ancestors from Subarctic Canada to coastal Washington, California, Utah, Colorado, and Wyoming of the United States (Haskell, 1987; Jackson 1989; Ives, 2003, 2010, 2014; Matson and Magne, 2007; Magne and Matson, 2010; Magne, 2012; Seymour, 2012). The current chapter overlays what we can infer about the event's ecological impact onto hunter-gatherer social relations that we anticipate to have existed in the study area based on lithic provenance and ethnohistoric records. The objective of this synthesis is to compare cultural change in the neighbouring Yukon and Mackenzie river basins, inform models of Dene movement in response to the eruption, and contextualise trajectories of technological transmission in northwest North America that post-date WRAe.

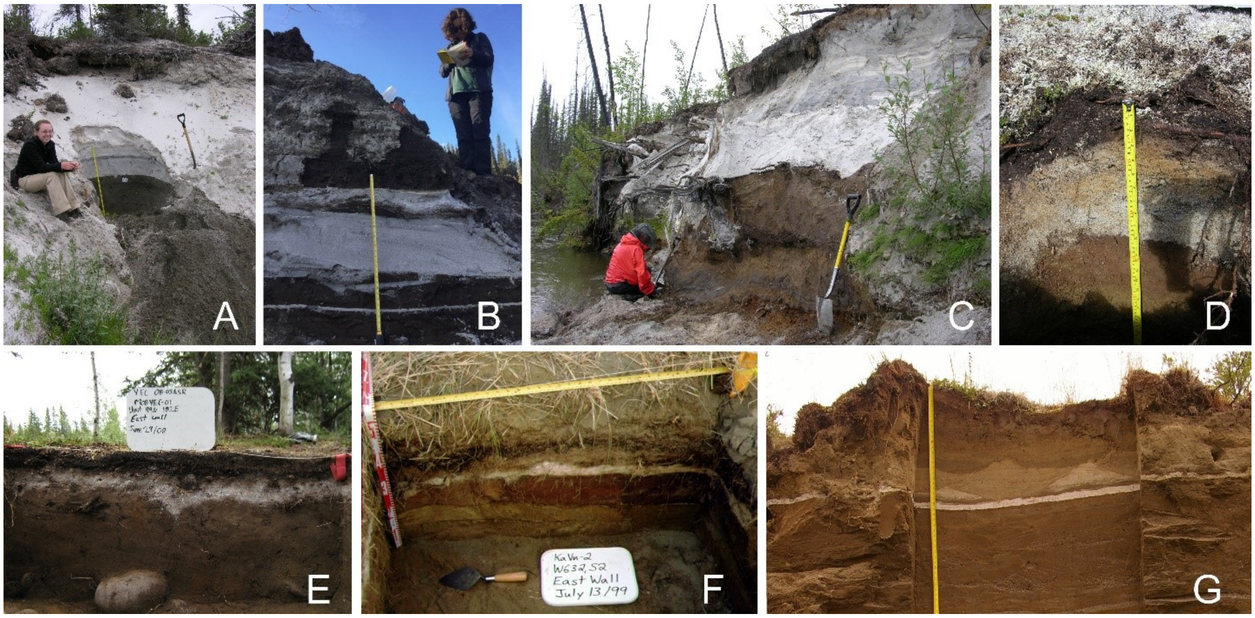

Figure 5.2 WRAe tephra in profiles. A: Toshingermann Lakes, Yukon, ~100 km from vent (courtesy of Jeff Bond); B: Donjek River, Yukon, ~80 km from vent (courtesy of Britta Jensen); C: Lower Klaza River, Yukon, ~130 km from vent (courtesy of Jeff Bond); D: Tincup Lake, Yukon, ~110 km from vent (courtesy of Jeff Bond); E: Minto Creek, Yukon, ~270 km from vent (courtesy of Ty Heffner); F: Beaver Creek, Yukon, ~100 km from vent (courtesy of Ty Heffner); G: O'Grady Lake, Northwest Territories, ~650 km from vent (Todd Kristensen). Note that in photographs A to D, a significant component of the upper tephra horizon is from re-mobilisation as opposed to original deposition.

We argue that the primary means of hunter-gatherer resilience to disturbance lay in their pre-existing social relationships defined here as a combination of kinship patterns and economic exchange partnerships. The two are related by cycles of influence as kinship partially determined with whom a group entered into economic alliances, while economic exchange systems were often intentionally manipulated or strengthened through marriages. In Subarctic landscapes, kinship patterns and group formation principles were to some degree influenced by resource dispersion while modes of economic exchange were partially shaped by ecological gradients

(Ives 1990). The temporal and spatial availability of fish and game influenced how people moved around landscapes; this in turn affected who hunter-gatherers interacted with and relied on during periods of both resource abundance (to coordinate labour for communal food harvesting) and stress (to combat starvation). Interwoven in patterns of subsistence were political and economic desires of people who capitalized on ecological gradients, or the proximity of different habitats, to control goods and fuel their exchange. Underlying socio-economic systems helped shape resilience, i.e., the capacity to re-organize in response to disturbances (Gunderson and Holling, 2002; Berkes et al., 2003; Redman and Kinig, 2003; Folke, 2006).

5.2 Data and context: Basin interaction in the Subarctic

Northwest Subarctic Canada is characterized by two major rivers: the Yukon River that drains west to the Pacific Ocean and the Mackenzie River that drains north to the Arctic Ocean (Figure 5.3). At the time of the WRAe eruption, both river basins were occupied by speakers of Dene or Athapaskan languages (Figure 5.3). To the southwest and north were maritime nations of the Pacific Northwest and Arctic coasts, respectively, who belonged to different language families, each of which exerted markedly different influences on Dene people (Workman, 1978; Krauss and Golla, 1981; Morrison, 1984; Ives, 1990; Dorais, 2010). We compare below the ecology, kinship, linguistics, economic exchange, and subsistence patterns in the Yukon and Mackenzie basins as context for the ensuing investigation of resilience to the WRAe eruption at A.D. 846-848 that deposited tephra across these basins.

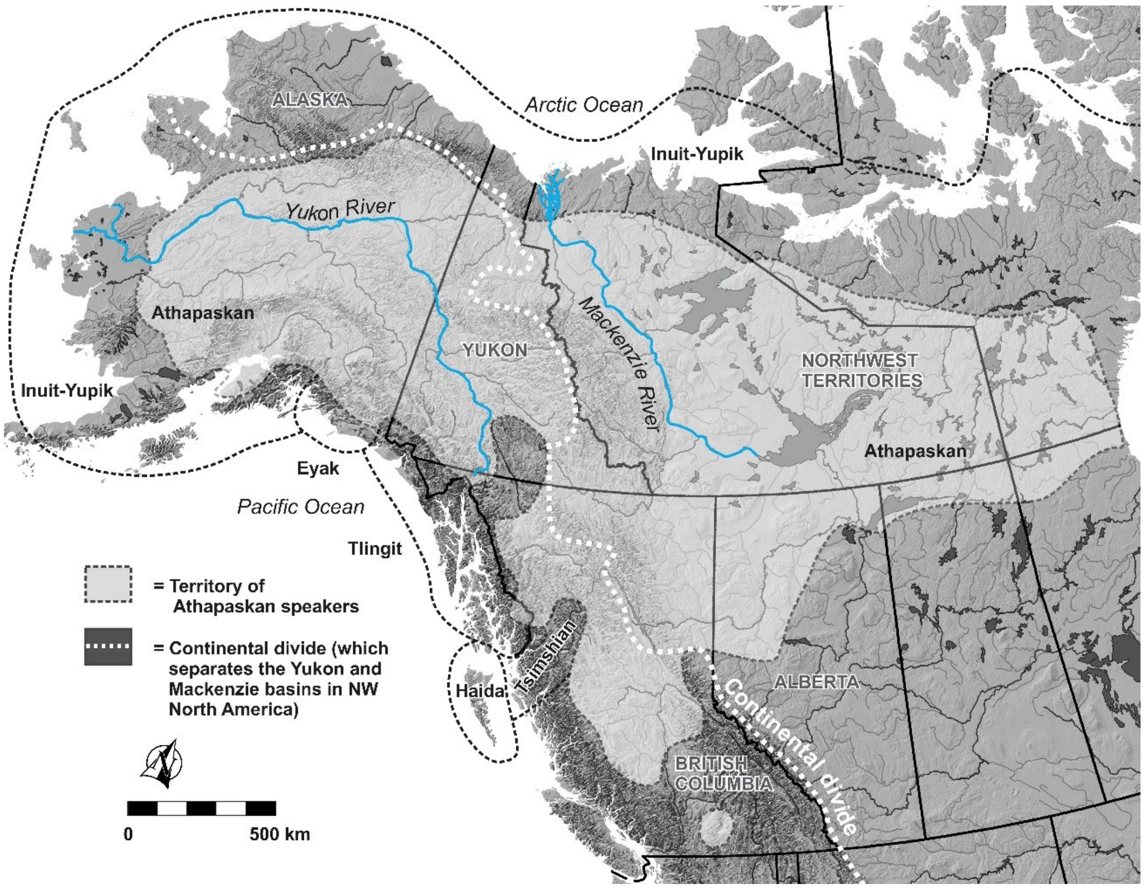

Figure 5.3 Yukon and Mackenzie rivers and boundaries of major linguistic branches/families at European contact (the eighteen and nineteenth centuries).

We use historical records of kinship and exchange in the study area to evaluate pre-contact lithic patterns in Late Holocene times. Sourced lithics, specifically Tertiary Hills Clinker (THC) from the Mackenzie Basin and obsidian from the Yukon Basin, serve as proxy indicators of human contact, kinship, and trade corridors (Kristensen et al. 2019a; Kristensen et al., 2019b). Temporal shifts in lithic networks, in relation to a tephra layer associated with the WRAe event, enable an investigation of changing patterns of human contact. We contextualise the human response with palaeoenvironmental records of the event's impact including pollen and charcoal studies. The paper concludes with an explanation of how adaptations to this natural disaster shaped the movement of people and ideas including bow and arrow technology and copper use, which altered human history in Subarctic North America.

Large-scale ecological events can devastate landscapes but the mosaic environments that result can set a stage for biological species richness and diversity that had not been possible in pre-existing habitats (Rowe, 1961; Burton et al., 2008). So too may cultural systems affected by natural disasters stimulate change: they may have triggered new modes of human contact, a fluorescence of ideas and perspectives, as well as the transmission of language, DNA, and technologies (Holling 2001). Just as biologists (Eldridge and Gould 1972; Gould and Eldridge 1993) have adopted the theory of punctuated equilibrium –long periods of stability that are broken by short bursts of environmental, genetic, and morphological change – some archaeological records may involve centuries or millennia of relative stability that have been punctuated by days or months of perturbation that ushered in profound cultural change (Gunderson and Holling 2002; Redman and Kinzig 2003; Folke 2006, Hegmon et al. 2008, Solich and Bradtmöller 2017).

5.3 The intersection of ecology, kinship, and exchange

Contrasts between ethnographic and archaeological records of the Yukon and Mackenzie basins (e.g., Osgood 1936b; MacNeish 1960; Millar 1981) generally share an inferred connection of resource surplus to the need to coordinate labour, which scholars argued fostered degrees of social complexity. Ideas about these origins of complexity owe part of their development to studies of social hierarchy, rank, and salmon surplus among neighbouring coastal nations in Alaska, Yukon, and British Columbia, which, according to early theories, then spread east to interior North America (Morice, 1890; Goldman, 1940; McKennan, 1959; Steward, 1960; de Laguna, 1972; Dumond, 1980; Townsend, 1980; Ames, 1981; Townsend, 1980; Rubel and Rosman, 1983; Bishop, 1987; Coupland, 1988, 1998; Maschner and Patton, 1996). Kinship beyond coastal British Columbia and Alaska to western N.W.T. has therefore been depicted as a complicated intersection of *in situ* development, prototypical kin patterns, local ecologies, and historical patterns of contact across linguistic divides. Kinship and exchange are here contrasted between Yukon and Mackenzie basin nations. However, in actuality, contact across the continental divide was relatively common and some Yukon nations (e.g., Kaska) had patterns more characteristic of the Mackenzie Basin and vice versa (e.g., some Gwich'in) (MacNeish, 1960; Gillespie, 1981; Ives, 1990).

5.3.1 The ecological context of kinship, contested resources, and power in the Upper Yukon Basin

The Upper Yukon Basin (that portion of the Yukon River within Yukon Territory) formed by orogeny and erosion that have since influenced biological resource dispersion. The Pacific Coast Ranges in the southwest and Mackenzie Mountains to the east bounded a series of accretionary terranes that span much of southern and central Yukon and created a landscape of spatially compressed, high topographic relief (Figure 5.4) (Fensome et al., 2014). Colluvial and fluvial erosion created steep valleys and narrow lowlands that often confine animal residence and movement. The human implication is a reduced number of optimal harvesting sites for fish and game compared to the Mackenzie Basin.

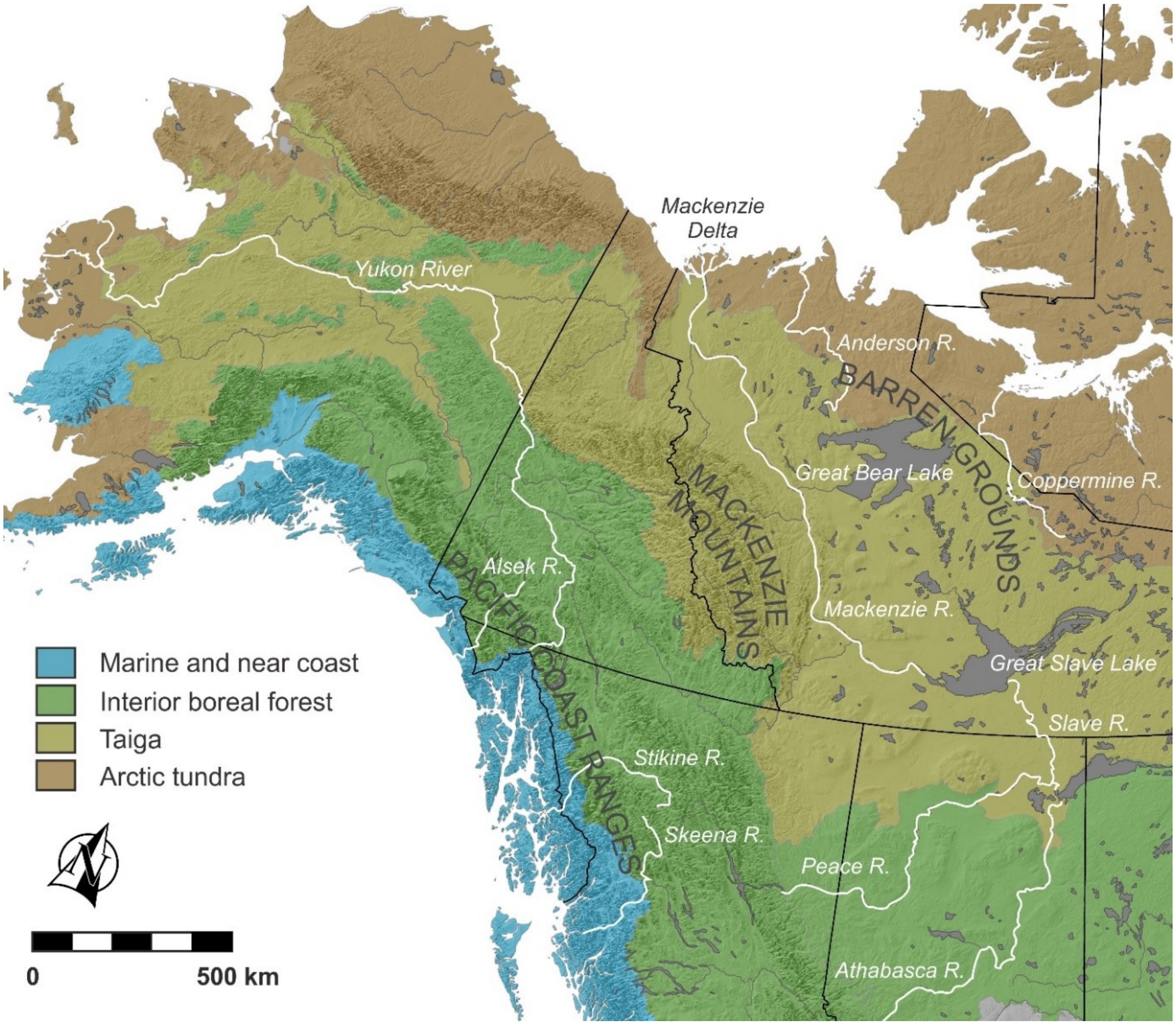

Figure 5.4 Major ecozone groupings of northwest North America (United States. Environmental Protection Agency, 2010).

Yukon has two major biological pulses of activity important to hunter-gatherers. Firstly, salmon enter the Upper Yukon Basin to spawn from July to mid-October (Scribner et al., 1998; Brown et al. 2017; Cunningham et al. 2018). While present on many river stretches, salmon runs are only accessible for large harvests during specific weeks, depending on species (chinook, chum, and coho), and at particular narrows or shoals where they could be caught by traps, net, and gaff (McClellan, 1975:185-198; Mishler and Simeone, 2004; O'Leary, 1992). Secondly, barren ground caribou, some herds of which exceeded 500,000 animals, historically migrated to central and southern Yukon each autumn to overwinter in the forests before going north again in spring to give birth to calves on the tundra (Valkenburg et al. 1994; Boertje and Gardner, 2000). Predictable migratory corridors were exploited to produce great surpluses of meat and hides (McClellan, 1975:108-118; Mishler and Simeone, 2004). Woodland caribou also provided predictable foot stores (Kuzyk et al., 1999; Farnell et al, 2004). They do not migrate long distances north-south but undergo daily and seasonal altitudinal migrations from valleys to alpine areas. In addition to these pulses, moose, sheep, goat, beaver, porcupine, marmot, hare and a variety of lake fish were valued resources across southern and central Yukon (McClellan, 1975: Workman 1978; Thomas, 2003; Legros, 2007).

Comparatively high Subarctic human population densities in the Yukon Basin and the relative fixity of major fish and game to specific locales made them *contested* resources (for which there was competition to secure access). Corporate kin groups in the Yukon River Basin, with influence from coastal nations, could exert dominance over territories of maximum exploitation and coordinate surplus harvests (McClellan 1975; Legros, 1985). These kinship systems are characterized as mostly of unilineal descent (traced through only one gender, and in northwest North America, characteristically matrilineal) (McClellan 1975; Townsend, 1980; Legros, 1982). In southern Yukon, they often involved sibs or moieties (systems of ascertaining relations typically based on two exclusive divisions in society) that reinforced socio-political divides and rank (de Laguna 1972:355; McClellan, 1975: Legros, 1981). Marriage was often exogamous (a preference or proscription to marry outside of one’s own social unit) and was closely regulated such that only certain members of sibs and moieties were permitted to marry others. Kinship fuelled class differentiation in contested landscapes and this in turn influenced how nobility or wealthy individuals (as opposed to lower classes of freemen and slaves) accrued power and interacted in systems of material exchange with neighbours (de Laguna, 1972; McClellan 1975; Legros 1985; Grinëv, 1993; Simeone, 1995; Cooper, 2012). For example, the upper classes or *dan noži?* of Tutchone Nations in southern Yukon controlled prime harvesting locales and monopolized trade relationships with coastal Tlingit (Legros 1985). Economic systems were solidified by marriage and kinship rules (de Laguna, 1972:525; Legros 1985:62; Simeone, 1995; Grinëv, 2018).

5.3.2 The ecological context of kinship, dispersed resources, and security in the Mackenzie Basin

The Mackenzie Basin is not bound as tightly by mountain chains as the Yukon Basin, nor is there an equally complex history of terrane accretion. Over millions of years, sediment beds spread east from the Mackenzie Mountains (Figure 5.4) over large and low plains where slower rivers and glaciers carved wide valleys and expansive basins that eventually drain north to the Arctic Ocean (Fensome et al., 2014). As a result, animal habitats and movements are generally less confined compared to Yukon Basin. For example, the region has a greater abundance of lakes, particularly east of the Mackenzie River. The implication for people is that fish and game were more widely dispersed (Ives, 1998).

The Mackenzie Basin has a seasonal pulse of migratory tundra caribou that move from the barren grounds south towards treelines approaching Great Bear and Great Slave lakes (Figure 5.4) (Hummel and Ray, 2008; MacKay and Andrews, 2016). The timing of tundra caribou migration was relatively predictable but, owing to its open and relatively flat topography, the prime hunting locations were less so (Pike, 1892; Ives, 1990; Gordon, 1996). In the basin west of Mackenzie River, barren ground caribou are rare and people relied more heavily on more scattered mountain caribou, upland sheep and goats, as well as valley populations of moose (Gillespie 1981; MacKay and Andrews, 2016; Andrews et al., 2012b). Salmon do not spawn in the Mackenzie River, which is nevertheless a rich source of freshwater fish. Fish were still major staples in N.W.T. (Morris, 1972; Hanks and Winter, 1991), particularly east of the Mackenzie River, but through more modest harvests of whitefish, trout, inconnu, and pike during their spawn and under the ice in winter.

Comparatively low Subarctic human population densities in the Mackenzie Basin and the fluctuations of fish and game harvesting spots made them dispersed and *coveted* resources (defined here as products over which there was little competition but great value because of the difficulty locating them). Mackenzie Basin kinship patterns helped maximize the ability to detect (or follow) dispersed game, coordinate exploitation, and perhaps most importantly, to support each other when harvesting failed (Osgood, 1933; Helm and Lurie, 1961; Helm, 1968; Ives, 1990, 1998; Gordon, 1996). Kinship systems were generally bilateral: descent was traced through both genders and corporate kin groups, such as moieties, clans, or sibs were absent. Co-resident kin groups (local groups or microbands) could be agamous or exogamous, but were more commonly highly exogamous in terms of marriage proscriptions (Helm and Lurie, 1961; Savishinsky 1974). Co-resident local groups were characteristically fluid in their kin and non-kin composition. Exogamous social networks, in particular, were persistent even as co-resident local groups cycled in and out of existence over generations (Helm 1965; Helm and Leacock, 1971; Savishinsky 1974; Ives, 1990). Kin ties were important during times of plenty for sharing the abundance that could come with freshwater fish spawns and caribou hunting; they provided a form of future security to survive periods of resource scarcity. For example, in the Mackenzie Basin, Shutagot'ine Dene are known to have moved across the continental divide to the west to live among Kaska kin and harvest salmon (Hanks and Pokotylo, 2000) but more commonly, they had strong kinship relations to people east of the Mackenzie River (Gillespie, 1981; Andrews et al., 2012b). The Mackenzie River served as a meeting ground of Shutagot'ine, Hare, Sahtu Got-ine, Dehcho (Slavey), and Tłįchǫ, among whom intermarriage was common (Gillespie, 1981). In times of stress, the Shutagot'ine lived among the Slavey and Sahtu Got-ine, particularly to hunt barren ground caribou.

5.3.3 Ecological gradients, linguistics, and exchange

The motivations and mechanisms of material exchange in the Mackenzie and Yukon basins were to some degree influenced by access to different raw materials in adjacent habitat types. The study area is bound by two distinctly different maritime habitats. The Upper Yukon Basin is bordered to the south and southwest by the Pacific Northwest Coast and its tributaries including

Alsek and Stikine rivers (Figure 5.4). This geography allowed maritime cultural influences to reach into the Pacific Coast Ranges and beyond to southern and central Yukon. To the east, the interior barren grounds and taiga ecozone of N.W.T. approach the Arctic Coast fed by the Mackenzie, Anderson, and Coppermine rivers. These Pacific, Arctic, and interior habitat proximities, or ecological gradients, were the home of distinct language families (Figure 5.3).

Along the Pacific Coast of southeast Alaska and northwest British Columbia existed the Tlingit branch of the Athapaskan-Eyak-Tlingit (AET) language family (Figure 5.3), which split from other branches in a mid-Holocene time range (Krauss, 1979; Leer et al., 2001). The Tlingit branch is thought to have lived in coastal regions until the last 200 or 300 years when an inland population of Dene or Athapaskan people adopted Tlingit language and customs (McClellan, 1953). South of the Tlingit branch is the Haida language isolate (Figure 5.3), the affinity of which to AET has been debated, although it seems likely that similarities to AET are due to modes of exchange rather than shared language ancestry (Leer 1991; Ruhlen 1994; Enrico 2003; Vajda 2010, 2018; Mithun 2018). Haida language is largely confined to coastal and near-coastal southeast Alaska and British Columbia. The Inuit-Yupik branch of the Eskimo-Aleut language family spread along the Arctic Coast and western Alaska (Dorais 2010) (Figure 5.3). Inuit-Yupik is thought to have diverged from Eskimo-Aleut around 1500-2000 years ago (Berge 2018). Inuit language then spread east with Thule migration 900-700 years ago (Friesen and Arnold 2008; Dorais 2010). In between the coastal Tlingit and Inuit-Yupik is the interior Subarctic of western North America, home of the Athapaskan branch of AET (Figure 5.3). Proto-Athapaskan is thought to have appeared around 3000 years ago in Subarctic North America (Krauss and Golla, 1981). Unique resources within the boundaries of these linguistic branches and isolates presented opportunities for exchange between them.

5.3.4 Exchanging resources between the Pacific Coast and Upper Yukon Basin

Plate tectonics and weather (e.g., rain clouds) created landscapes of sharp relief and distinct ecological change over comparatively short distances from the Pacific Ocean of southeast Alaska up the rain forest-draped mountains to the Upper Yukon Basin. For example, Yakutat Bay (a core area in a coastal Tlingit sphere) is only 100 km from Kluane Lake (an important area to the Southern Tutchone) (de Laguna, 1972; McClellan, 1975) while Lynn Canal (a core area for coastal Chilkat Tlingit) is 50 km from Tagish Lake (a core area of the interior Tagish) (McClellan, 1975:509-516). Based on ethnohistoric records, the Tlingit delivered seaweed, dentalia, baskets, clams, ochre, eulachon oil, and obsidian to the interior while the Tutchone provided fur, sinew, finished clothing, copper, porcupine quills, lichen, berries, and spruce gum to the coast (Krause 1956:108; de Laguna 1972:216, 350; Legros 2007; McClellan 1953, 1975:502-506, 512; Grinëv 2005:32). Trading parties of up to 100 Tlingit men frequented the interior to amass supplies. Intermarriage, particularly of Tlingit men to Dene women, was common as both parties sought to strengthen alliances and trade monopolies (Emmons 1911; de Laguna 1972:526; McClellan 1975:507; Tybjerg 1977; Hebda et al. 2017). In addition to the exchange of luxury goods that fuelled coastal potlatches, feasts, and other modes of gift-giving, marriage was as a conduit for the transfer of language, DNA, and technology. Economic and political drives to secure power and prestige through exotic goods were strong enough to overcome otherwise isolating ecological and linguistic barriers between Tlingit and Dene. Figure 5.5 is a schematic representation summarizing seasonal pulses of resources in the Yukon Basin (and Mackenzie) and the way that it influenced the interaction of Dene and Tlingit people. Tall parts of the black bands represent widely dispersed resources while short parts are spatially confined resources. People were generally attracted to loci, represented by the thin parts of the diagram bands, where resource aggregations could be harvested en masse (e.g., water crossings where caribou were killed or narrows where salmon were caught). Blue vertical lines represent micro- and macrobands of Dene hunter-gatherers (Ives 1990). Light blue lines in the Yukon Basin represent those members or bands that were denied access by more politically dominant Dene bands to both prime harvest locales and trade opportunities with the Tlingit (denoted by a lack of contact between the light blue microband and yellow Tlingit, as well as denied contact between the light blue microband and the narrow portion of the black resource band). The green bands represent co-residence of Tlingit traders in Dene territory and/or periods of particularly intense orientation of activities to fuel Tlingit-Dene trade. Securing access to contested resources fueled socio-political status differentiation based upon surplus harvesting of resources. This differentiation was solidified by kin ties and an economic monopoly over exchange with foreign people.

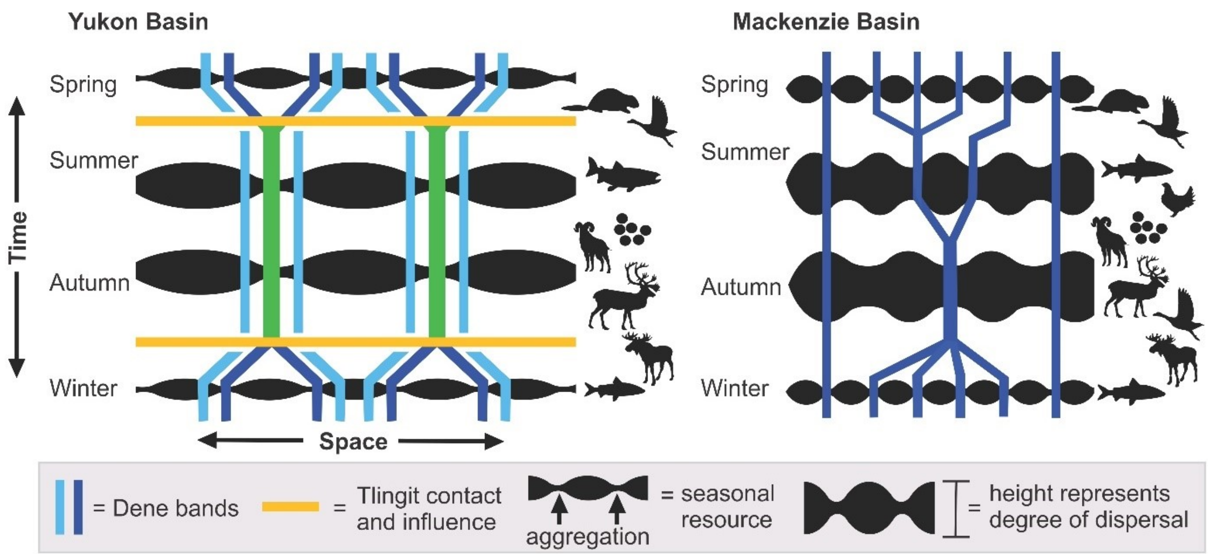

Figure 5.5 Seasonal pulses of biomass in the Yukon and Mackenzie basins. Resources types do not differ significantly across basins with the exception of salmon. However, Mackenzie Basin fish and game were more widely dispersed, which often made them difficult to intercept, capture, and store in large quantities.

5.3.5 Exchanging resources between the Arctic Coast and Mackenzie Basin forests

In contrast to the Pacific Northwest Coast, ecological gradients from the Arctic Ocean to interior boreal forests are less pronounced. Habitat divides from the coast to Arctic tundra plains to the treeline of the boreal forest are diffuse and spread over long linear distances. The Mackenzie Delta terminus at the Arctic Ocean (a core area of the Mackenzie Inuit) is 220 km from major stretches of Mackenzie River exploited by the Gwich'in (Osgood, 1936a; Krech, 1976; Betts, 2008) while Coronation Gulf (a central locale of the Copper Inuit) is 200 km from Great Bear

Lake that anchored movements of the Sahtu Got-ine and Hare (Jenness, 1922; Osgood, 1933; Savishinsky, 1974). Because of a relatively consistent climate and topography, biological resources within different Mackenzie Basin habitats (interior and coast) did not differ as much as those between the Pacific Northwest Coast and the Upper Yukon Basin. Unique coastal and interior goods in the Arctic drainage system (e.g., walrus ivory, baleen, soapstone, beaver teeth, copper, moose hide, porcupine quills) were comparatively distant between suppliers and consumers (Morrison, 1991; Jensen 2016). Political and economic desires do not appear to have bridged this geographic gap or broken the linguistic barrier of Dene (Athapaskan) and Inuit-Yupik people, at least not for prolonged periods of time required for formal kinship and economic corridors of exchange to develop (Janes 1973; Szathmary 1979; Dumond 1980; Morrison 1991; Ousley 1995; Rasic 2016). Interactions of Dene and Inuit people vacillated from periods of warfare to relative peace (Hearne, 1795:338; Birket-Smith 1930:33; Lamb, 1970: 208; Janes, 1973; Heine et al., 2007; MacKay et al., 2013) and this seemed to limit the intensity of the transfer of language, DNA, and technology.

Two research questions stem from the preceding generalisations about kinship, subsistence, and exchange. Did historic social relationships (or lack thereof) among people of the Yukon and Mackenzie basins and their neighbouring coastlines extend into the pre-contact past? And how did pre-contact social relationships influence resilience to the White River Ash east (WRAe) eruption of A.D. 846-848?

5.4 Lithic provenance and the antiquity of Yukon and Mackenzie basin networks

Technological conservatism among Subarctic hunter-gatherers has hindered the archaeological use of stone tool typologies to reconstruct social connections in Yukon and N.W.T. (Morrison 1984, 1987; Clark, 1992; Greer, 1993; Hare, 1995; Gordon, 1996; Clark and Gotthardt, 1999; Carlson and Magne, 2008). For example, spear points typically associated with Early Holocene assemblages elsewhere in North America were used in the Subarctic up to European contact to kill caribou at river crossings (Hearne 1795:35; Morrison 1984, 1987; Gordon, 1996). The Subarctic has also received comparatively little archaeological attention, which, when combined with poor preservation and challenging stratigraphy, has produced a meagre body of dated tools or items of adornment to inform studies of social dimensions (Holly 2013, 2019; MacKay et al., 2013). Lithic provenance (linking stone artifacts from archaeological sites to their geological origins) is one of the few avenues to reconstruct human relations in the Subarctic: we summarize studies in Yukon (Kristensen et al., 2019b) and N.W.T. (Kristensen et al., 2019a) to illuminate pre-contact social relationships.

5.4.1 Obsidian in the Upper Yukon Basin

Obsidian is an ideal raw material to inform how people in Yukon established and maintained networks through the Holocene because it was circulated widely, had functional attributes (the sharpest edge of any Subarctic rock type), and aesthetic qualities (a distinct luster) that heightened hunter-gatherer attraction to it to make projectile points, microblades, and knives. However, obsidian is brittle with a short use life compared to more durable cherts and quartzites (Whittaker, 1994; Cheshier and Kelly, 2006; Smith, 2015) so there were likely both utilitarian and prestige motivations for its acquisition and distribution. Obsidian outcrops occur in two known locales in southern Yukon and two major known locales in neighbouring interior Alaska and northern British Columbia, a situation which permits comparisons of local versus foreign obsidian exchange (Figure 5.6).

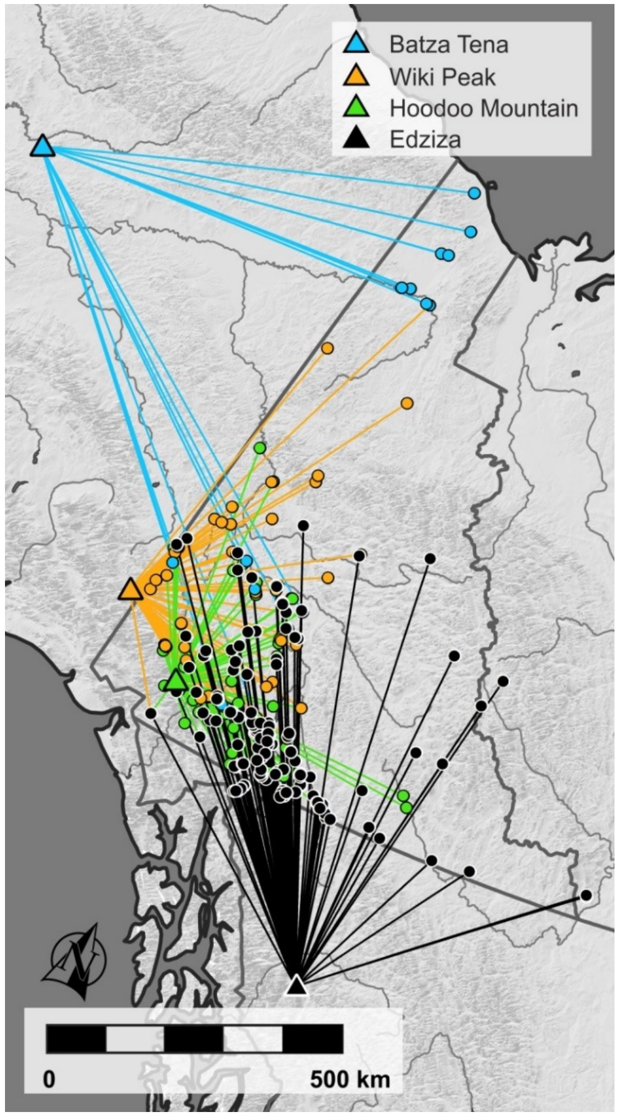

Figure 5.6 The distribution of Yukon obsidian artifacts from known source groups (from the Yukon portion of the Alaska Obsidian Database, see Reuther et al., 2011; Kristensen et al., 2019b).

Overlapping distributions of artifacts made of foreign Edziza obsidian and local Wiki Peak and Hoodoo Mountain obsidians in Yukon indicate socio-political dimensions of exchange between coastal and interior nations that infused raw materials with an importance beyond pure utility (Figure 5.6) (Kristensen et al, 2019b). Edziza obsidian primarily moved down the Stikine River to coastal Tlingit ancestors before moving north up the coast where it was incorporated into trade and kinship systems that then brought it to nations of interior Yukon. This is supported by the distribution of Yukon archaeological sites with Edziza obsidian (along tributaries that drain to the Pacific Ocean), the incorporation of Edziza obsidian into a broader coastal interaction sphere in British Columbia (Fladmark, 1984; Carlson, 1994; Reimer, 2015; Springer et al., 2018), ethnohistoric evidence of grease trails that connected interior and coastal regions (de Laguna, 1972), ethnohistoric evidence of a well-developed trade network between Tlingit and Dene people along the Stikine River (Emmons, 1911:6-7, 33; Teit, 1956:97-98), and ethnohistoric accounts that coastal Tlingit brought obsidian into southwest Yukon to trade (Krause, 1956:108; McClellan, 1975:512). Obsidian appears to have been one of many items that fueled complex exchanges of raw materials through trade, potlatches, and bride price—practices that linked coastal and interior nations deep into pre-contact eras (Kristensen et al., 2019b). McClellan (1975:512) documents a pertinent case in Tagish oral history where people received obsidian from visiting coastal Tlingit traders despite knowing of a secret local obsidian outcrop. Edziza obsidian was distributed much more widely than expected (Springer et al., 2018; Kristensen et al., 2019b) because it was incorporated into a coastal and interior exchange sphere, which fed into a social network that influenced resilience. If hunter-gatherers turned to kin ties when dealing with large-scale disturbances, the logical direction of reliance in southern Yukon was to the south and southwest towards relatives and exchange partners among coastal Tlingit. Obsidian provenance results indicate that pre-contact exchange across the Mackenzie Mountains was not particularly intense despite a closer linguistic affinity among Yukon and Mackenzie basin Dene groups than between Yukon Dene and coastal Tlingit.

5.4.2 Tertiary Hills Clinker in the Mackenzie Basin

THC is a stone material that outcrops west of Mackenzie River (Cinq-Mars, 1973) and, like obsidian, has unique attributes (sharp edges and a sugary glass texture). Kristensen et al. (2019) identified and sourced THC to create a distribution map of its movement through the Mackenzie Basin and beyond (Figure 5.7). THC moved over 1000 km south to the far reaches of the ancestral Dene sphere but does not appear to have broken a linguistic barrier to move a much shorter distance north into territory of the ancestors of Inuit or Paleo-Inuit people. Despite archaeological attention in the coastal Arctic and 10,000 years of THC exploitation across the Subarctic interior, THC has yet to be detected at any Arctic sites. We argue that a lack of socio-political motivations to exchange goods between Dene and people of the Arctic Coast, and a lack of sharp ecological gradients, explains the northern truncation of Northern Archaic and ancestral Dene social networks (Figure 5.7). THC distribution supports an early and persistent barrier separating Dene ancestors from other nations as noted by Potter (2016:550) of a boundary established by the Middle Holocene between Northern Archaic and Paleo-Inuit people (ASTt, Choris, Norton, and Ipiutak) in Alaska, which persisted through the Late Holocene. The continuous exploitation of these relatively small clinker outcrops and a lack of exchange with northern neighbours for many millennia does lend some credence to work that genetically links Dene ancestors to Northern Archaic people (Flegontov et al., 2019) with a later mid-Holocene arrival of AET in North America and subsequent development of a Dene speech community that did not introduce major disruptions to pre-existing networks beyond language.

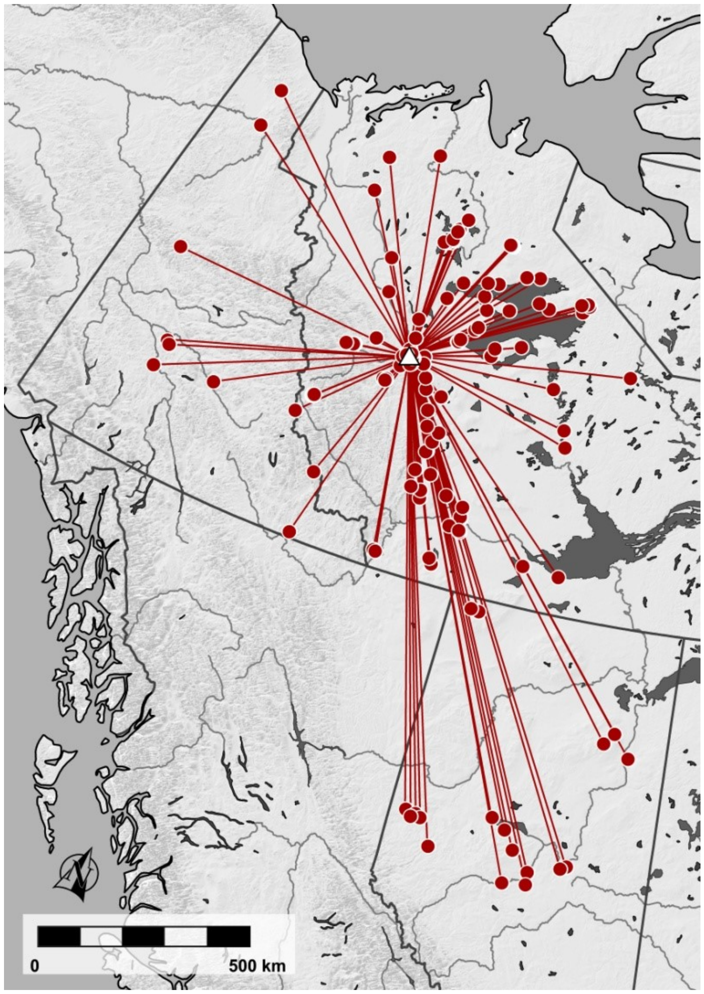

Figure 5.7 Distribution of THC artifacts in Yukon, N.W.T., and Alberta (adapted from Kristensen et al., 2019).

Ethnohistoric records note that when resources were depressed along the Mackenzie River and west into the Mackenzie Mountains, people gravitated to the barren grounds where they could rely on kin and the cooperative interception of migratory caribou (Morris, 1972; Clark, 1987; Ives 1990). THC occurrences along Mackenzie River, Great Bear Lake (Figure 5.4), and into the barren grounds bear this out (Figure 5.7). As with obsidian, pre-contact social relationships revealed by THC have implications for resilience: people of the western Mackenzie basin would logically move in directions ranging from northeast to southeast to their established kin and exchange networks in response to large-scale disturbances.

5.4.3 Comparison of pre-contact social relationships and linguistic barriers

Obsidian use was more widespread in the Yukon Basin than THC use in the Mackenzie Basin: 462 archaeological sites in Yukon have yielded sourced obsidian artifacts, of which 166 sites produced artifacts of Edziza obsidian while only 132 sites in N.W.T. have yielded artifacts of THC (each jurisdiction has roughly 4000 recorded archaeological sites). The average distance from an archaeological example of THC in N.W.T. to its source is 245 km while the average distance from an Edziza artifact in Yukon to its source is 452 km (Figure 5.8). We contend that foreign obsidian moved more widely in southern and central Yukon than locally acquired THC moved in N.W.T. because of a higher population density in Yukon and a social network driven by the exchange of prestige goods to supply trade, potlatches, and other forms of gift giving. THC movement in N.W.T. reflects a lower population density and social relationships influenced more heavily by concerns over ecological security.

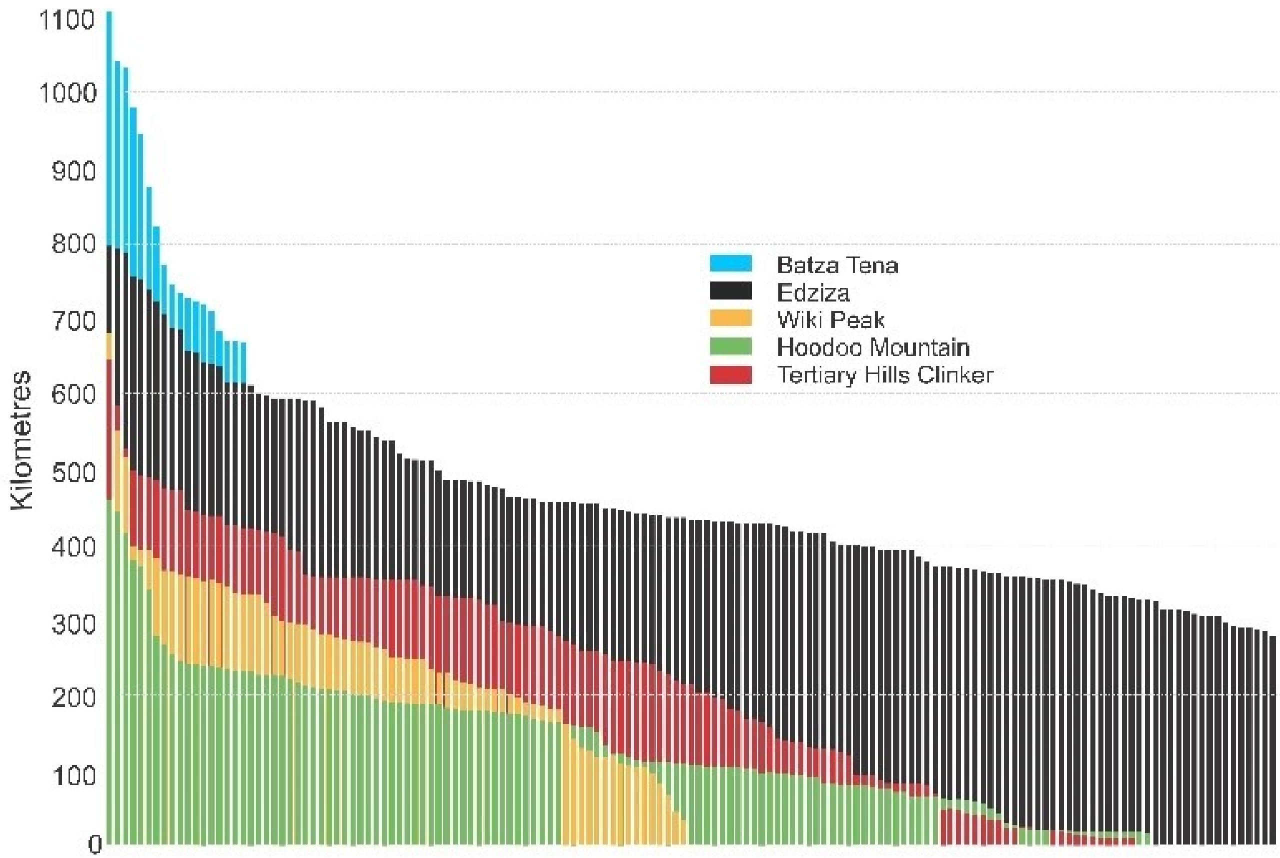

Figure 5.8 Comparison of the distances from archaeological sites with artifacts made of each raw material to their respective geological origin. Each coloured bar along the x-axis represents one archaeological site (data adapted from Kristensen et al., 2019a, Kristensen et al., 2019b).

A comparative approach reveals that social relationships stimulated by power and economic exchange could bridge linguistic divides and span large distances in pre-contact times (Figure 5.9). For example, Edziza obsidian appears to have moved among ancestors of the Salish, Tsimshian, Haida, Tlingit, and Dene (Coupland, 1988; Carlson, 1994; Brüchert, 2012; Reimer, 2015; Hackett, 2017; Springer et al., 2018). This strengthens Townsend's (1980) claim that linguistic affiliation in the historic Alaskan Rim was not as important of an influence on contact as economic modes of interaction. THC still moved widely in North America, a testament to the vast extents of Subarctic relationships, but does not appear to have moved beyond Late Holocene linguistic boundaries. To understand how relationships were influenced by the WRAe event, we present an ecological synthesis of the eruption followed by an assessment of detectable changes to lithic distribution patterns.

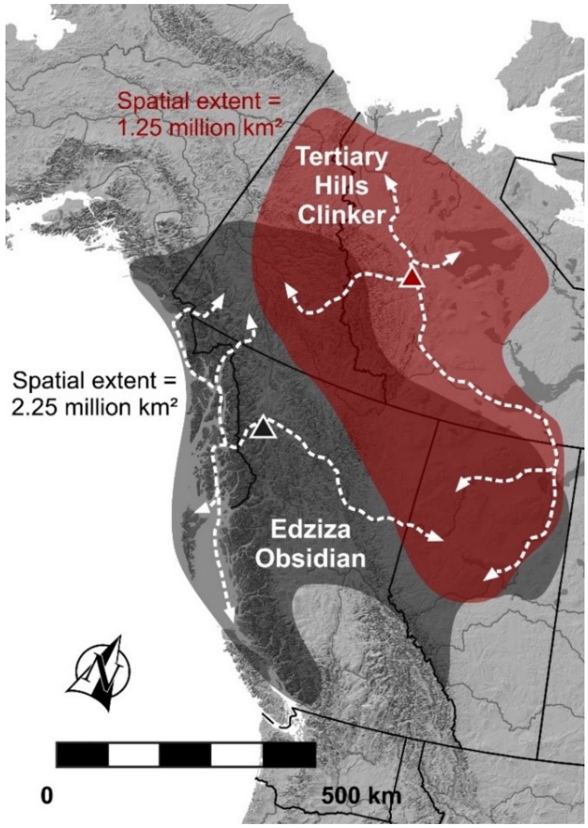

Figure 5.9 Comparison of the extent of Edziza obsidian and Tertiary Hills Clinker (from Wilson, 1989; Carlson, 1994; Kristensen and Woywitka, 2013; Kristensen et al., 2016; Hackett, 2017; Woywikta 2017; Springer et al., 2018; Kristensen et al. 2019). Triangles represent geological sources.

5.5 The ecology of White River Ash east

Kristensen et al. (in press) use pollen and charcoal records in southern and central Yukon supplemented by studies of modern eruptions to inform an understanding of impacts of WRAe up the trophic pyramid to major game species for hunter-gatherers. The pollen of most taxa show no major change following ash deposition. Some of this undoubtedly relates to degree of resolution: sediment cores are typically not sampled at a sufficient temporal resolution to link pollen changes to a specific event (see Hutchinson et al., 2019). Despite resolution issues, in southern Yukon, available data indicate that spruce (*Picea* spp.) pollen drops while sedge (Cyperaceae) pollen increases above the WRAe tephra (Kristensen et al., in press). When combined with charcoal records that indicate an increase in forest fires shortly after the ash, it seems that forested landscapes were replaced with a mosaic of closed and open plant communities. Some spruce forests gave way to sedge meadows, which may be due to changes in ground water retention and infiltration associated with tephra (Mehringer et al. 1977; Lotter and Birks, 1993; Heinrichs et al. 1999; Hughes et al., 2013; Egan et al., 2016).

The physiology and ecology of major game species of ungulates and fish were negatively affected by tephra (Figure 5.10). Caribou rely on lichen for winter forage and sedge meadows in summer through much of Yukon. Deposits of over 5 cm of tephra have been shown to significantly harm lichen and moss communities, which can take up to a century to recover from large-scale disturbances in Subarctic environments (Rupp et al., 2006; Collins, et al. 2011; Payette and Delwaide, 2018). A loss of winter forage would have stressed populations of tundra caribou and woodland caribou that wintered in the forests of southern and central Yukon. However, an increase in sedge meadows in the decades following WRAe may have hastened caribou recovery, particularly woodland caribou that resided in southern and central Yukon during summer months. The physiology of caribou, as well as moose, sheep, and goats, was probably negatively affected by tephra due to dental wear (associated with tephra abrasion), corneal abrasion, rumen blockage (due to tephra ingestion), silicosis (respiratory damage from inhalation of airborne silica), and possibly fluorosis (bone and tooth deformation associated with toxic fluoride released during eruptions)(Hubbard 1938:57; Thorarinsson, 1979:146; Araya et al., 1993; Gregory and Neall, 1996; Cronin et al., 2003; VanderHoek 2009:166; Wilson et al., 2011; Flueck, 2014, 2016; Craig et al., 2016). Tundra caribou may have altered their migratory paths and winter feeding grounds to avoid the WRAe tephra and its impacts but resident woodland caribou had fewer options. Woodland caribou DNA research suggests a partial population replacement after the WRAe ash fall (Kuhn et al., 2010), which confirms the severity of this event for major game animals in southern Yukon. We conclude that caribou populations may have taken 100 years to become a robust and predictable resource again (Figure 5.10).

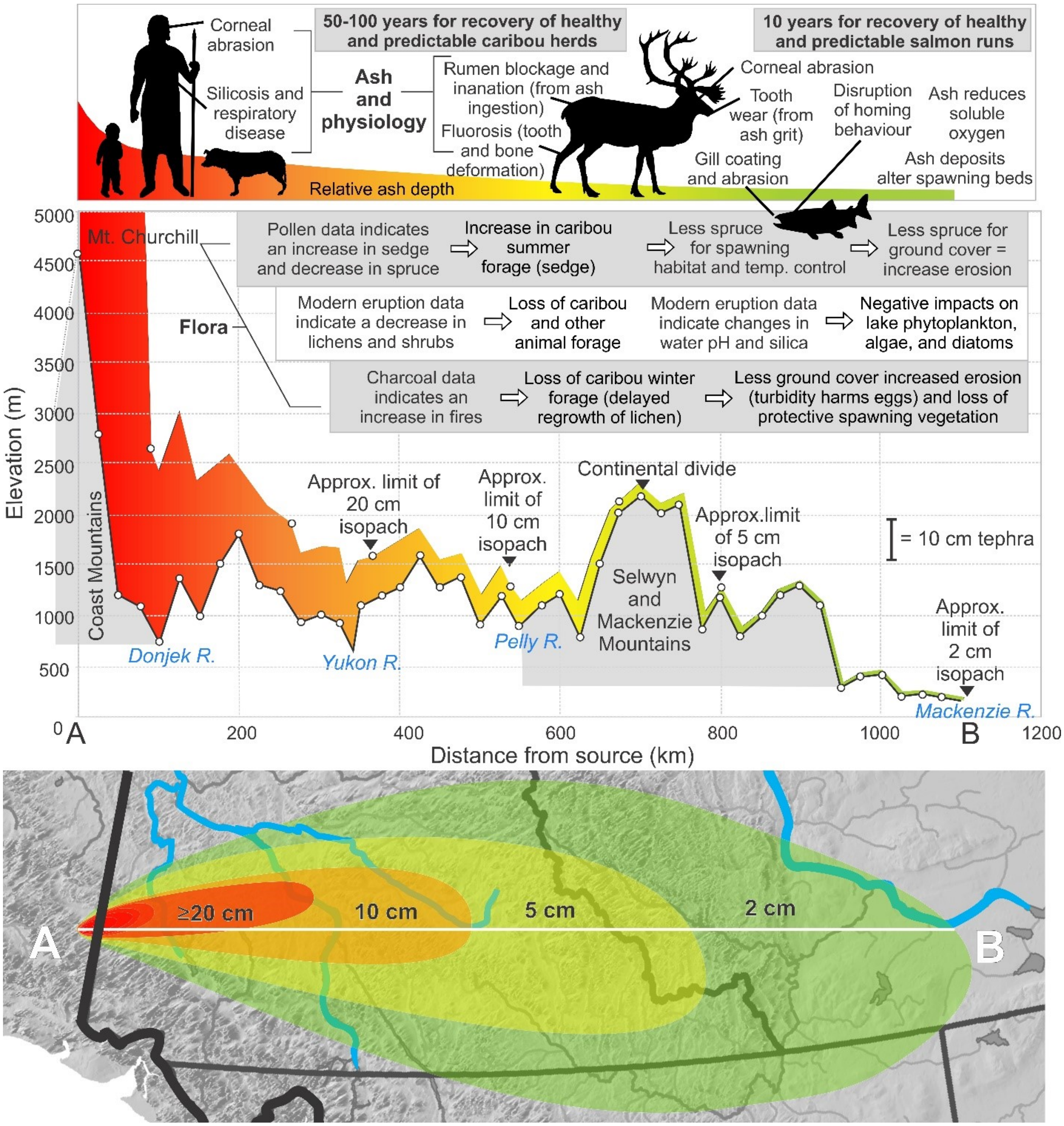

Figure 5.10 Schematic summary of tephra impacts on flora, fauna, and humans in the WRAe footprint. Note that the vertical scale of tephra depth in the middle line graph differs from that of the x-axis (elevation) for visualization purposes.

Fish are negatively affected by tephra because it coats gills, harms the ability of anadromous fish to relocate ancestral spawning tributaries, and because influxes of ash alter spawning bed morphology (Eicher and Rounsefell, 1957; Kurenkov, 1966; Whitman et al., 1982; Newcombe and Flagg, 1983; Leider 1989; Ayris and Delmelle, 2012; Lallement et al., 2016). A decrease in spruce may have removed riverside vegetation and woody debris that harboured salmon fry and regulated water temperatures crucial to successful incubation (Martin et al., 1986). Resident lake fish may have been harmed by changes in silica and pH levels in water, which altered communities of phytoplankton, algae, chironomids, amphipods, and diatoms (Kurenkov, 1966; Abella, 1988; Hutchinson et al., 2019). However, unlike ungulates, we predict that anadromous fish populations recovered within ten years thanks in part to salmonid life cycles (roughly five years) and zooplankton and phytoplankton blooms associated with ash input (Bisson et al., 1988; Bisson et al., 2005; Parsons and Whitney, 2012), although it may have taken longer for hunter-gatherers to re-establish the successful spots where fish were harvested in large quantities (Figure 5.10).

Two variables may have mitigated ecological impacts of WRAe. If the ash fell in late fall or winter (Hanson, 1965; Lerbekmo and Campbell, 1969; West and Donaldson, 2002; West, 2007), much of it may have flushed out of the ecosystem during the ensuing spring. Secondly, sharp topographic relief over much of southern and central Yukon likely created variable microhabitats where pronounced erosion limited the residence time of ash. Homogenous and sensitive habitats (in terms of topography, permafrost aggradation, and species composition), like alpine meadows, may have been more negatively affected.

Ecological reconstructions point to the likelihood that populations of hunter-gatherers temporarily abandoned portions of the WRAe footprint for one to several human generations. However, small social units may have revisited ancestral homelands periodically in the ensuing years to monitor resource recovery. Despite a greater distance from the volcanic origin (and a subsequently thinner ash deposit), people of the Mackenzie Mountains in the Middle and Upper Mackenzie basins were probably negatively affected through a decreased ability to predict ungulates (mainly caribou) and slower rates of ecological succession in alpine areas. Finer ash deposits (characteristic of distal tephra fallout) are more likely to be inhaled and ingested (Thorarinsson, 1979; Óskarsson, 1980), are more likely to alter pH because they adsorb volatiles (Smith et al., 1993; Payne and Blackford, 2008) and form more compact horizons (particularly when interacting with snow) that hinders regrowth (Antos and Zobel, 2005): increasing distance from the volcano does not directly decrease impacts on plant and animal physiology.

Because salmon and caribou enter southern Yukon from the north, it would be challenging for displaced people to migrate north (as suggested by Derry 1975 based on stone tool typology) into a region in which migratory game animals were still negatively effected during their seasonal residence in southern and central Yukon. For example, salmon would be negatively affected on the Yukon River well beyond the tephra footprint because of the delivery of ash downstream by erosion. By similar logic, it is ecologically unlikely that people of southern Yukon moved east into and across the Mackenzie Mountains, as suggested by Moodie et al. (1992) based on their review of some oral histories of origins and explosive events, because that route would involve encroaching into alpine territories of people who were also coping with resource stress. The remaining sources of refugia for Yukon hunter-gatherers are southwest to the Pacific Coast and south or southeast into the northern boreal forests of British Columbia.

From an ecological standpoint, people of the Mackenzie Mountains presumably had a broader range of options to seek refuge if they temporarily vacated ancestral homelands while waiting for tephra to flush through the comparatively high altitude ecosystem, and for plant and animal communities to re-establish. Ancestors of the Dene people in the Mackenzie Basin may have temporarily moved either south, east towards the barren grounds (east of Mackenzie River), or north.

5.6 White River Ash east, social relationships, and resilience

Changes in the distribution of Edziza obsidian after WRAe indicate that hunter-gatherer groups temporarily left southern Yukon and returned with a strengthened network of exchange with allies to the southwest (Kristensen et al., 2019b). Edziza obsidian appears to be circulated with greater frequency to southern Yukon (south of, and within, the ash footprint) but less frequently north of the footprint (Figure 5.1). Wiki Peak obsidian moves to a greater extent north of the WRAe footprint after the eruption (Figure 5.1). A lack of a drastic changes in Hoodoo Mountain obsidian movement (a local source) after the eruption suggests that fluctuations induced by the WRAe event were short-lived and that people returned with a modified social network. People may have abandoned landscapes, but on an archaeological time scale (i.e., one to a few human generations), most of them quickly returned. This accords with a roughly century long hiatus of ice patch artifacts in southern Yukon (Hare et al., 2012) and Mullen's (2012) work on radiocarbon dates and population history following WRAe that favour a relatively short term exodus or population decline within the WRAe footprint. Figure 5.11 summarizes changes to obsidian distribution before and after the WRAe event. On these grounds, and with ethnohistoric backing concerning kinship and economy, and our palaeoenviornmental synthesis, we hypothesise that the eruption fostered co-residence of Dene hunter-gatherers among Tlingit kin on the coast for several human generations.

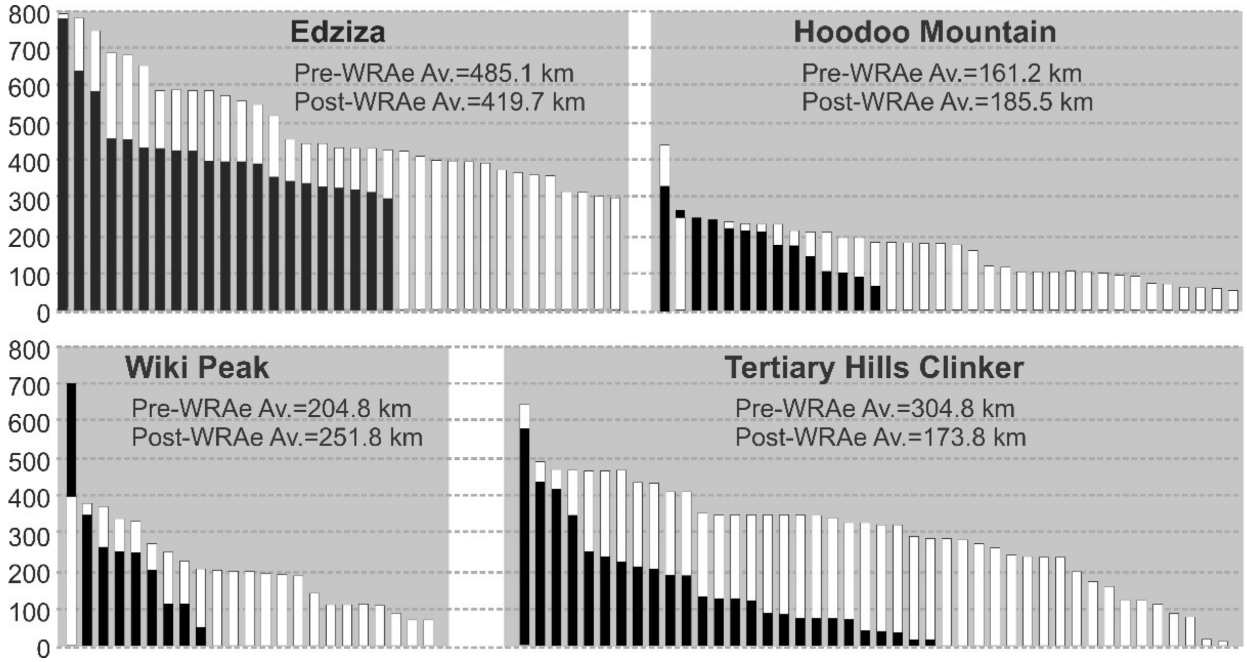

Figure 5.11 Obsidian and THC distance drop-off curves before and after WRAe. Edziza obsidian became more spatially confined to southern Yukon while Wiki Peak expanded its distribution in central Yukon. The movement of Tertiary Hills Clinker notably contracted.

East of the Mackenzie Mountains, THC underwent a more drastic change to its circulation (Figure 5.11). Kristensen et al. (2019a) argue that WRAe impacts weakened relationships across the Mackenzie Mountains and that hunter-gatherers in western N.W.T. moved east to rely on kin towards Mackenzie River and the barren grounds. This appears to have disrupted broader social relationships as THC does not move into the Yukon or Alberta with the same frequency as prior to the eruption. The results support Morrison's (1984) assessment that Late Pre-contact sites (1200 BP to 200 BP) in the Mackenzie Basin (in comparison to Middle Pre-contact sites) tend to cluster more tightly along the Mackenzie River and neighbouring fish lakes. The pre-WRAe distribution of THC into northwest and central Alberta does suggest that ancestral Dene social units in southwest N.W.T. may have fled south and southeast along existing kinship and/or exchange corridors towards large parkland/prairie isolates in the Peace and Slave-Athabasca river regions.

Ecological reconstructions, ethnohistoric records, and lithic provenance data in the Pacific and Arctic drainage basins paint a coherent picture. The WRAe eruption created a mosaic of successions of ecological disturbances with detectable impacts on social relationships. People rely on kin during times of stress. While Subarctic kinship has a complicated history, its local manifestations are partially influenced by socio-political motivations, economy, and resource dispersal including differential material access across ecological gradients. We hypothesize that human responses in both basins were forms of network-mediated migration when social relationships and economic variables influenced the directions that hunter-gatherers moved away from their traditional territories (Butterworth, 1962; Kearney, 1986; Wilson, 1994; Brettell, 2000). The resulting social network influenced by power and economic interests led Yukon Basin hunter-gatherers to move southwest after the WRAe event to rely on coastal kin while western Mackenzie Basin hunter-gatherers relied on a social network shaped in part by security, and temporarily moved east after the eruption to the Mackenzie River and barren grounds. Hunter-gatherers in the eastern portion of the tephra footprint may well have sought refuge to the south and southeast to the ecologically rich Peace Region of northeast British Columbia and northwest Alberta but post-WRAe archaeological records (including lithic provenance research on obsidian and THC) in these jurisdictions are currently too poorly understood to inform that route. However, a number of archaeological signatures in Yukon, including those related to bows and arrows and metallurgy, after the WRAe event, suggest that social relationships with coastal nations and modes of resilience had larger impacts on the movement of people, ideas, and technologies.

5.7 WRAe, technological exchange, and linguistic barriers

Two innovations appear in Yukon during the Late Holocene. The bow and arrow offered advantages over previous methods of killing game using a spear, lance, or atlatl (dart thrower) (Churchill, 1993; Shott, 1993; Whittaker et al., 2017) while copper utilisation introduced a new raw material and manufacturing process to make decorative goods, utilitarian knives, and projectile points that were used as trade items, elements of prestige acquisition, and for honouring the dead (Cooper 2012, 2016; Thompson and Doonan 2018). Because of the complicated skill sets involved in bow use/maintenance and copper use, they are assumed to have diffused across Canada. Both technologies appear in southern and central Yukon shortly after the WRAe event (Cooper 2012; Hare et al. 2012).

5.7.1 The bow and arrow

Archaeologists have attempted to detect and date bow technology through two means; 1) metric analyses of stone projectile points associated with radiocarbon dated material, and 2) radiocarbon dating preserved wooden bows and arrow shafts. Metric indices are based on an assumption that combinations of stone point dimensions change from darts to arrows (Thomas, 1978; Flenniken and Raymond, 1986; Shott, 1997; Hildebrandt et al. 2012). South of the study area, various indices suggest that the bow and arrow reached coastal British Columbia and the Interior Plateau 3500 years ago (Morrissey 2009; Rorabaugh and Fulkerson 2015). Carlson (2008) argued based on point sizes for a later introduction of the bow and arrow to the Salish Sea area by 1600 BP. Rousseau (2008) argued that the bow was present on the neighbouring Interior Plateau of British Columbia by 1800 BP based on changes in point size and shape, while Chatters (2004) suggested an earlier spread in interior British Columbia by 2000-2400 BP. On the Northern Plains, metric analyses suggest the bow and arrow may have been present as much as 3600 years ago, coming into common use during the Avonlea Phase about 1800 years ago (Dyck and Morlan 1995; Walde 2014). Using more subjective assessments of transitions in point sizes, Reeves (1983) argued for the replacement of darts by arrows on the Northern Plains from 1500-1200 BP. Blitz (1988) put the transition at 1700 BP and Duke (1991) suggested that the bow first appeared on the Northern Plains at 3500 BP.

On the northern margin of the study area, the first members of the Arctic Small Tool tradition appear to have brought the bow and arrow to Arctic North America by 4800 BP based mostly on projectile point sizes and shapes (Stanford 1976; Anderson 1984, 1988; McGhee 1984a, 1984b 1996; Maschner and Mason 2013; Lepola 2015). After spreading across coastal Arctic by 4000 BP, the bow disappeared during the Dorset Paleo-Inuit phase (roughly 2500-500 BP) before re-emerging with the Thule people and their descendants (Inuit) who spread across the Arctic from west to east from 800 to 200 BP (McGhee 1984a, 1996:144; Alix 2001; Friesen 2013; Jensen 2016; Tremayne and Rasic 2016).

Within the study area, the bow and arrow is associated with a transition from Taye Lake to Aishihik phases at roughly 1200 BP in the Yukon, based on changes in projectile point morphology (Workman 1978; Hare 1995). In the Mackenzie Basin, Morrison (1984) connects the bow and arrow to the appearance of small side-notched points around 1200 BP that he argued derived from the Northern Plains. Models of the spread of the bow and arrow based on metric analyses may be flawed by the difficulty of transferring interior hunting systems to the coast where people used harpoons (Erlandson et al., 2014) and the basis of metric studies on ethnographic specimens that may not be reflective of pre-contact situations (Thomas, 1978; Hildebrandt and Ruby, 2004; Hildebrandt and King, 2012). Limitations, varying methods, and widely variable dates aside, metric studies point to the presence of the bow on the Pacific Northwest Coast and Northern Plains prior to its movement to Yukon and N.W.T. (Figure 5.12).

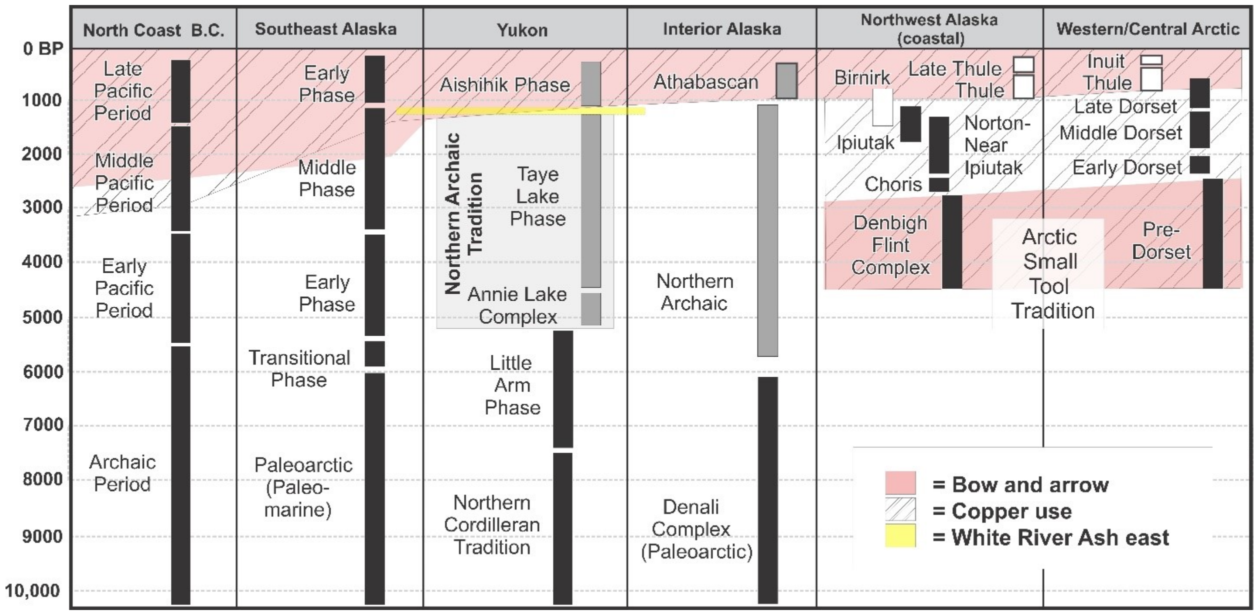

Figure 5.12 Culture-history chart depicting bow and arrow and copper technologies (phases and traditions adapted from Hare, 1995; McGhee, 1996; Ames and Maschner, 1999; Potter, 2016; Anderson and Freeburg, 2013; Letham et al., 2015).

Organics preserved in permafrost or alpine ice offer a means of directly dating the spread of bow technology. Frozen arrow shafts (i.e., specimens that are nocked) and a bow fragment from interior alpine ice patches in Yukon, Northwest Territories, Alaska, and central British Columbia point to rapid adoption of the bow only after 1200 BP (Dixon et al., 2005; Keddie and Nelson, 2005; Andrews et al., 2012; Hare et al., 2012; VanderHoek et al., 2012; Grund and Huzurbazar, 2018). The preserved organics from these high altitude hunting sites reveal precise chronologies and inform the movement of technologies. For example two wooden artifacts from southwest Yukon have likely coastal origins based on the tree species: a bow made of maple wood is dated to 1180+/-40 BP (uncalibrated) (Hare et al., 2012) and an arrow made of hemlock is dated to 410+/-100 yr BP (calibrated) (Alix et al., 2012). Elsewhere, several presumed arrowheads of bone in northwest Alaska yielded dates from 860-380 BP (Murray et al., 2003) while antler arrowheads and a bow limb are associated with components dated to 1000-800 BP in northwest

Alaska (Hoffecker et al., 2012; Mason and Bowers, 2009:31). Human burials with presumed barbed arrow points are from the Ipiutak phase in northwest Alaska (1850-1050 BP) (Mason, 2009, 2016) and miniature bow fragments have been found in dated assemblages from roughly 1000 BP in northwest Alaska (Hoffecker et al., 2012), and in early Thule houses at Sisualik (Giddings and Anderson, 1986) and at Deering (Alix, 2009). Wooden bow remains are common at early Thule sites across the North American Arctic (McGhee, 1984b, 1996; Alix, 2001). Though not directly dated, the oldest record is currently a bow fragment assumed to be associated with a dated component from 3900-3400 BP in West Greenland (a Saqqaq site) (Gotfredsen and Møbjerg, 2004; Grønnow, 2012, 2017)[3].

To summarise, dating the movement of the bow on the Pacific Northwest Coast, Arctic, and Subarctic is unresolved, but reliable and direct radiocarbon dates indicate that the transition in interior Alaska, Yukon, and N.W.T. occurred *after* 1200 BP (Figure 5.12). It appears that the bow was present in neighbouring coastal southeast Alaska and northwest British Columbia before 2000 BP, was present on the Arctic Coast of Yukon and Northwest Territories by 800 BP, and was present on the Northern Plains by 1800 BP (Figure 5.12). If this model holds, the bow existed for up to 500-600 years in coastal Alaska and on the Northern Plains before adoption in neighbouring Yukon and western Northwest Territories. Obsidian data support a connection of coastal Alaska and interior Yukon people for millennia prior to WRAe: why is bow adoption in those two regions not synchronous? Dene ancestors may have been aware of the bow and arrow on their margins along the Pacific Northwest Coast or with ASTt neighbours for centuries, but preferred the reliable atlatl and lance (Ives, 2010:328). However, the seemingly sharp transition from darts to arrows in Yukon on the heels of tephra deposition (Hare et al., 2012) is suggestive. We argue that the WRAe event at roughly 1100 BP brought interior Dene ancestors into a period of prolonged contact with Tlingit kin on the Northwest Coast that permitted ample exposure to the benefits of bow and arrow technology and perhaps more importantly, it afforded an exchange of the complicated knowledge required to manufacture and maintain them. A pre-existing

[3] Theories that place the bow and arrow into the Early Holocene both south (Ames et al., 2010) and northwest of the study area (Rasic and Slobodina, 2008; Ackerman, 2011; Dixon, 2011; Maschner and Mason, 2013) are still much debated and are not discussed here.

economic exchange system did not guarantee the transfer of technologies but co-residence for one to several generations might have.

Ancestors of the Subarctic Dene then used the bow for several centuries before Thule bow users moved along the northern margin of Dene territory beginning around 800 or 700 BP (Figure 5.12). It is expected that bow technology would spread quickly in a social network where the success of neighbours had immediate benefits to social units that shared innovations. Tertiary Hills Clinker, ecological variables, and ethnohistoric records suggest that bow technology moved relatively independently in the Subarctic taiga vs. Arctic coast because interactions across linguistic boundaries were minimal. By extension, the demise of Norton/Ipiutak and Dorset people may be linked to the encroachment of Thule bow users from the west and Dene bow users to the south.

5.7.2 Copper use

The chronology of copper use in southern Yukon largely mirrors that of the bow and arrow (Cooper 2012) (Figure 5.12). Copper has become a distinguishing character of the phases and traditions that post-date WRAe (Workman 1978; Potter 2016) and, as in the case of the bow and arrow, it appears that copper utilisation existed on the Pacific Northwest Coast and Arctic Coast centuries and perhaps a millennium prior to its spread into interior Yukon and N.W.T. (Figure 5.12). Copper was noted at a burial at Prince Rupert Harbour dated to 2565 BP (Ames 2005) and is presumed to have been utilised on the Pacific Northwest Coast through the second millennium BP before a proliferation of copper use and exchange along the coast in the first millennium BP (Cooper 2012). On the Arctic Coast, copper has been linked to Pre-Dorset through Late Dorset occupations (Franklin et al. 1981; McCartney 1988; Rowley and Rowley 1997; Lemoine et al. 2003). Copper use is well established among the Thule where it was used for tools and status goods in a system of prestige acquisition (McCartney 1991; Whitridge 2002; Cooper 2016).

The most productive areas of raw copper collection were imbedded in Athapaskan territory (Cooper 2007, 2012) and just like the bow and arrow, it is not clear why a pre-existing relationship between people of coastal Alaska and interior Yukon did not spur an earlier fluorescence of an interior copper industry. Again, prolonged contact between interior and coastal people induced by the WRAe eruption may have brought together people who had knowledge of copper outcrops (Dene ancestors) with people who had an intense interest in acquiring foreign goods of trade value (Tlingit ancestors)—new systems of knowledge and technological exchange were forged. The existence of interior Dene social units among ancestors of Tlingit people for one or more generations may have spurred an economic system wherein copper utilisation found new vigour and was then more prominently situated within coastal potlatch and trade systems (de Laguna, 1972:606-610; Cooper, 2012). A modest but detectable increase in pre-contact copper utilisation was later dwarfed by the historic expansion of copper use on the coast following the appearance of European ships with copper plates.

According to this scenario, groups of ancestral northern Tlingit in Southeast Alaska were exposed to copper technology for centuries preceding the WRAe eruption but, because they were on the margins of a copper industry based further south in the Pacific Northwest or further north on the Bering Strait, they received sparse amounts of prestige copper adornment items through down-the-line exchange. The movement of Dene social units into a Tlingit sphere following the eruption created new opportunities with two material outcomes visible in the archaeological record. Coastal groups in Southeast Alaska gained newfound access to sources of native copper that were then used for local manufacture of adornment items. Dene social groups in the Subarctic interior gained exposure to the potential of copper metallurgy and utilised local sources to manufacture and exchange functional items like knives, awls, and projectile points (Cooper 2016). This accords well with oral histories of both interior Dene and coastal northern Tlingit that credit Dene ancestors with the innovation of copper mining that then spread copper production to coastal Alaska (de Laguna et al., 1964; McClellan, 1975; Cooper 2016).

5.8 Economic exchange, Athapaskan movement, and White River Ash east

We argue that the WRAe event spurred the residence of a relatively large Dene social unit (perhaps 200 to 500 people) among coastal allies, which stimulated new forms of interaction. A notable increase in copper utilisation both among Northwest Coast and interior Subarctic people after the eruption points to a means by which such a large social unit may have justified its presence in foreign lands. Dene ancestors may have found prosperity by creating or at least occupying key positions in an economic system of exchange with socio-political implications. Copper therefore became a medium for Dene people to develop an economic specialisation or niche that in turn, won Dene social units a valuable position (or at least tolerance) within coastal communities. The copper industry represents a seed from which grew a newly intensified system of coastal-interior interaction. The increase in Edziza obsidian in southern Yukon following the WRAe may represent growth from this seed. Other lines of evidence outlined below point to strengthened relationships of interior and coastal people in the study area following WRAe.

5.8.1 A coastal Dene presence in northwest British Columbia

Linguists have demonstrated that Dene people migrated from the north down to southern British Columbia, Washington, and California, although the motivation and timing are debated (Krauss and Golla, 1981; Snoek, 2015). Our research suggests that the stimulus of initial movement to northwest British Columbia may relate to positive interaction of Dene people with non-Dene kin to facilitate exchange between coastal and interior nations, and, in the process, further the socio-political advancement of both. Following the WRAe eruption, conditions were ripe for the development of Dene groups that replicated the success of coastal-interior exchange in southeast Alaska and southwest Yukon (invigorated by copper) by transplanting it down the northern Pacific Northwest Coast. In several regions, Dene people may have bridged barriers or strengthened pre-existing relationships between resident coastal nations and their interior Dene neighbours. For example, Dene social units may have spread southward by fostering exchange between Tsimshian and Haida people and their neighbours.

Ethnohistoric records tell of hierarchical coastal political landscapes that were frequently characterized by warfare and aggression along the Pacific Northwest. At first glance, this may not appear to have been an inviting landscape for Dene migrants, but a socio-political realm more conducive to slavery. On the contrary, political tension and social motivations for prestige amidst a land of ecological plenty, may have created ideal conditions for the entry of a group of non-threatening ‘others’ to the coast. Coastal nations, like the Tlingit, were known to hold their Dene neighbours in the Yukon in lower regard concerning social status (de Laguna 1972; McClellan, 1975) and were considered dominant partners despite close economic interactions and intermarriages. Therefore, co-residence of Dene social units in coastal communities, or enhanced proximity of some form, would not be considered a threat to existing dynamics. Rather, powerful coastal nations could have strengthened their forces by creating new economic opportunities, solidifying relationships with Dene migrants, and establishing allies to enhance power. While this dynamic may have involved some type of subjugation, the entry of a relatively large social unit of Dene migrants (e.g., 300 people) would have made outright slavery and total absorption unlikely. A particularly harsh response of coastal residents to Dene migrants (be it through violence or slavery) would endanger important trade and kin networks with people of the Yukon that had existed for millennia. Tolerance, but with a degree of subjugation, in fact, may have encouraged a degree of isolation of migrants within a host society that promoted the retention of an ethnic identity with linguistic conservatism. In summary, the coast had an ecology capable of supporting a large group of migrants, as well as a socio-political landscape in which ‘others’ could find value.

Edziza obsidian may reveal footprints of Dene people because the outcrops lay within Athapaskan territory. Late Holocene examples of Edziza obsidian have been recovered from archaeological sites in the traditional territories of the Tsimshian in Prince Rupert Harbour (Coupland, 1988; Carlson, 1994), interior British Columbia territories of Babine (Hackett, 2017) and Chilcotin nations (Carlson, 1994; Brüchert, 2012), Haida Gwaii (Carlson, 1994), the central mainland coast of British Columbia (Carlson, 1994), and even to Salish territory as far south as the lower Fraser River in southern British Columbia (Reimer, 2015; Springer et al., 2018). The northern Tlingit also traded copper as far south as Vancouver Island (Emmons, 1991:177), which is an indication of the vast extent of coastal exchange. While Edziza obsidian and other raw materials may have moved south through hands of coastal nations, their ultimate sources reflect at least a distant relationship to Dene people. Historically documented grease trails (that moved eulachon oil and other coastal goods to interior British Columbia and Yukon) linked coastal nations to interior Dene (Boas, 1916; Garfield, 1951; de Laguna, 1972:15, 350; Patton et al., 2019) and they may represent channels through which a Dene presence in northern coastal British Columbia found value.

Economic and socio-political incentives may have pulled Dene social units to coastal settings but an additional social factor may have prevented or at least dissuaded their return, i.e., a push factor to supplement the pull (Anthony, 1990). The *dan noži?* of the nineteenth century were a wealthy class of Tutchone people who controlled productive hunting and fishing grounds in southern Yukon and maintained trade monopolies with coastal Tlingit (Legros, 1985). Below them in a hierarchy of wealth and power were classes of people who may have sought economic opportunities through interactions with coastal peoples to free themselves from different degrees of hierarchical control. If the WRAe event temporarily pushed interior people out of the tephra footprint, perhaps individuals and groups below the elites were the least likely to return. Townsend (1980) wrote of the Alaskan Rim that, with a fixed system of status transfer and inheritance, enterprising individuals of lower rank and their immediate kin occasionally sought new avenues to prestige through out-migration.

Archaeologists have documented a time of change and upheaval on the Northern Pacific Northwest Coast with increased conflict between coastal nations, new burial practices, and subsistence pursuits that are roughly coeval with the WRAe eruption at 1100 BP (Coupland, 1998; Martindale and Marsden, 2003; Edinborough et al., 2017). In this shifting socio-political landscape, Dene social groups and Tlingit allies may have found mutual benefit in their co-existence on the coast. Economic alliances may have offered benefits during periods of warfare. The relatively recent development of the Inland Tlingit provides an example of how this mutual benefit may develop. Dene social units in northern British Columbia and southern Yukon gradually adopted Tlingit language associated with a host of social and economic relationships that more-or-less fused Tlingit and Dene traits (McClellan, 1953). This relationship developed *in situ* in the interior but it may inform how hypothetical Dene groups that arrived on the coast interacted to positive effect with Tlingit kin and allies.

Radiocarbon dates, oral history, and linguistics may also point to demographic changes associated with Dene and Tlingit interaction on the northern and central Pacific Northwest Coast. Marsden (2001) summarizes oral accounts of the previously noted period of upheaval and abandonment of the mouth of Skeena River by Tsimshian people due to conflict with the expanding Tlingit over one millennia prior to European contact. Edinborough et al. (2017) use radiocarbon dates and simulation models to verify this period of demographic change on the Skeena River to 1200-1100 cal yrs BP, which closely coincides with aftermath of the WRAe event. Although we are not implying that WRAe caused Tlingit intrusion on the Skeena River, it is foreseeable that allied Dene and Tlingit social units may have capitalized on new relationships to navigate through tumultuous social landscapes.

Our analysis of the Edziza obsidian data would suggest that there were exchange links between the Tlingit region and interior southwest Yukon prior to WRAe, and that these ties were re-established with even greater strength in the post-WRAe time frame, eventually culminating in Inland Tlingit populations that fused Tlingit and interior Dene cultural identities. Some of the factors involved in our study region may well be of comparative analytical value with respect to further explorations of the timing and nature of the Pacific Coast Athapaskan (Dene) departure from Canada. While there is current uncertainty regarding the timing of Pacific Coast Athapaskan expansion southward, linguists believe it appreciably pre-dated Apachean and other Canadian Dene expansion (e.g., Krauss and Golla, 1981; Snoek, 2015).

We posit three supporting elements of Dene movement to the northern Pacific Northwest Coast of British Columbia: 1) An **origin** in southern Yukon; 2) an initial **movement stimulus**—the WRAe eruption that fostered a new market for copper and intensified modes of coastal-interior exchange; and, 3) a persistent **motivation** for prolonged co-existence—Dene people developed an economic and socio-political identity that could thrive by facilitating exchange between coastal communities and their interior neighbours (Figure 5.13). In the relatively densely populated landscapes of coastal and Plateau British Columbia, into which Dene entered (Sapir, 1936; Krauss and Golla, 1981; Snoek, 2015), trade-oriented social units may have found niches in which to co-exist (Wilson, 2011; Magne, 2012:368). These Dene units would be characterized by high mobility and a propensity for positive interaction with other nations, two traits conducive to persistent movement. Writing of the Dene presence in coastal California, Jackson (1989) noted that these migrant groups were likely conduits of innovations and economic relations. An increase in ceremonial obsidian bifaces is associated with the introduction of Dene to northwest California who may have influenced the movement of goods between existing high-status politico-economic mediators (Jackson and Ericson, 1994) while sourcing work highlights a preference among Californian Dene coastal traders for obsidian from distant sources acquired through linguistic relatives (Whitaker et al., 2008). These lines of evidence point to an outgrowth or an antecedent expression of an economic system that may have flourished on the northern Pacific Northwest Coast following WRAe.

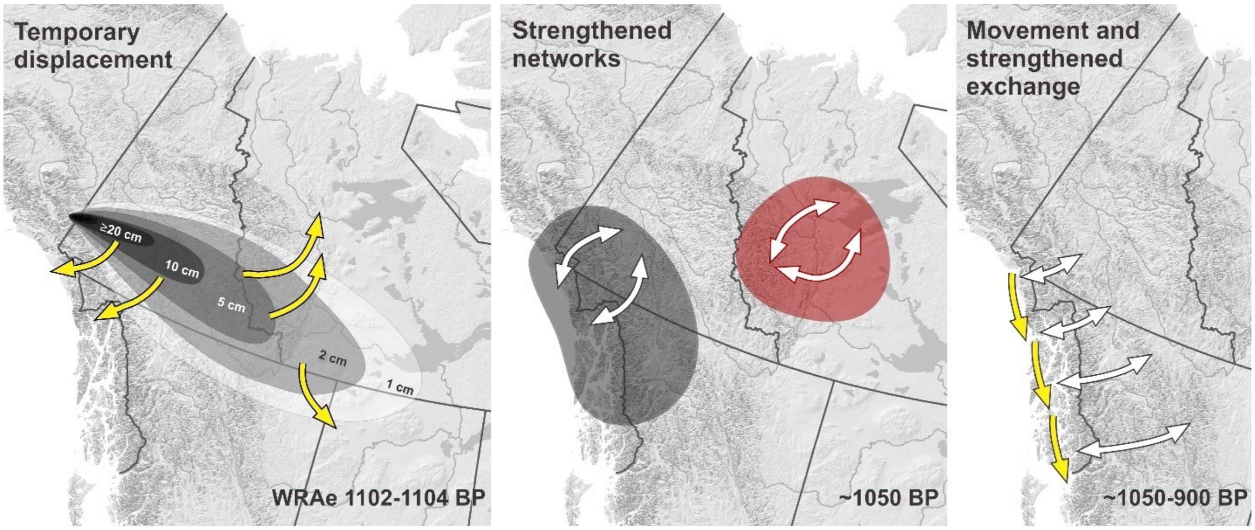

Figure 5.13 Chronological schematic of human displacement (yellow arrows) and social or economic relationships (white arrows) following the WRAe eruption.

The Pacific diaspora of Dene people is estimated to have occurred earlier in the Holocene than WRAe by linguists (see Snoek, 2015) although uncertainties persist about the exact chronology, trajectories of linguistic diversity, and social isolating mechanisms that conserve linguistic components of interest (Nettle, 1999; Epps, 2016; Coehlo et al., 2019). There is growing consensus that the Pacific Coast Athapaskan languages are more closely related to Dene speakers west of the continental divide, but they do not share an origin from a coastal group—that is, Pacific Coast Athapaskan speakers derive from one or more interior Athapaskan speech communities in British Columbia, Yukon, or Alaska (Golla, 2011:257; Snoek, 2015). The WRAe event has been linked more closely in terms of chronology to a proposed interior migration of Dene people into northeast British Columbia, Alberta, and further south to the American Southwest and Great Basin (Ives, 1990, 1998, 2003, 2010; Snoek, 2015). Archaeological and linguistic timeframes for Apachean dispersal remain imperfectly resolved, but are consistent with the timing and impact of the WRAe. Genetic and linguistic evidence suggest that the founding Apachean population was quite small and linguistically cohesive, making it plausible that WRAe could have been a trigger for the departure of Apachean ancestors from the Canadian Subarctic (cf. Achilli et al., 2013; Billinger and Ives 2015; Malhi et al., 2003, 2008; Monroe et al., 2013). The model presented here involving ethnohistoric records, palaeoenvironmental studies, and lithic provenance work in Subarctic Canada forms a framework against which to test new lines of evidence. Ecological and archaeological data demonstrate that the WRAe event was indeed capable of inducing significant local change.

5.9 Societal implications

The study of WRAe in the Canadian Subarctic has several implications for modern disaster studies. Firstly, palaeoenvironmental research can provide accurate chronological records of the frequency of large-scale disturbances that may or may not be preserved in oral histories (Kristensen and Beaudoin, 2015). Reliable chronologies of ecologically recurrent events enhance the ability to predict them.

Secondly, social relationships are perhaps the most critical component of resilience. We can predict the impact of ecological disturbances on modern populations through understandings of established kin and economic networks. The ease with which past groups picked up and moved partially influenced their response and the ability to return. With fixed infrastructure and permanent residence, modern societies face a much different range of options and opportunities when responding to modern ecological disturbances. However, social and economic relationships, including those built through media and capitalist ventures will continue to shape how people perceive and respond to future disasters. Modern economies will persist, collapse, or evolve depending on pre-existing relationships to major trade partners. People will continue to rely on neighbours and familial connections to weather disturbances, and their return (or permanent departure) will be shaped in part by economic opportunism.

5.10 Conclusion: Large scale disturbances and cultural fluorescence

We argue that the primary means of pre-contact hunter-gatherer resilience to the Late Holocene White River Ash east volcanic eruption was a pre-existing social relationship that consisted of patterns of kinship and economic exchange. Social relationships over the past few millennia differed among Yukon and Mackenzie basin hunter-gatherers in accordance with historical trajectories of socio-political development, exchange, and local ecological conditions and habitat gradients from the Pacific Northwest Coast into the Subarctic interior and toward the Arctic Coast. We synthesise Late Holocene palaeoenvironmental records, archaeometry, and ethnohistory of hunter-gatherers in the neighbouring upper Yukon and Mackenzie river basins to contrast social relationships and responses to the WRAe event. We argue that Yukon Basin relations were geared towards exertions of power over contested resources versus Mackenzie Basin adaptations that strove for affordances of security to intercept coveted resources. Numerous exceptions existed to this broad generalization but the means that hunter-gatherers employed to maintain or redress ecological imbalances influenced respective trajectories of resilience to ecological disturbances.

After the WRAe eruption of A.D. 846-848, people in the Mackenzie Basin west of Mackenzie River appear to have migrated east towards familiar kinship networks approaching the barren grounds to hunt caribou (Kristensen et al., 2019), based on stone tool provenance records. This movement was short-lived and represents an adaptive pattern that probably characterised the Mackenzie Basin for much of the Holocene. People may have also moved south and southeast into northern British Columbia and Alberta. Kinship helped redress ecological imbalances through social fluidity (Ives, 1990), which may have fostered temporary absorption of displaced people by immediate neighbours.

An exchange system and corridor from the Pacific Northwest Coast to the interior Subarctic provided a channel of kinship and reliance that hunter-gatherers in the Yukon Basin fell back on during a largely temporary abandonment of southern and central Yukon following WRAe tephra dispersal. The co-residence of Dene social units among Tlingit kin, or some form of enhanced proximity, following the eruption witnessed the transmission of the complicated skill set and knowledge base of bow and arrow technology. We argue that it also ushered a fluorescence of copper use by bringing together manufacturers, suppliers, and consumers of copper ore and goods. One impact of strengthened modes of economic exchange between coastal and interior people was the creation of a new economic and socio-political niche for Dene people to occupy in a growing and complex sphere of coastal trade and warfare that extended along the Pacific Northwest Coast. Displaced Dene social units that chose not to return to an interior Yukon kinship network that was geared towards maintaining ecological imbalances, may have risen to new levels of prominence on or near the Pacific Northwest Coast by facilitating exchange between coastal peoples and their interior Dene neighbours. These social units may have influenced development of the Inland Tinglit, expansion of the Pacific Coast Athapaskan speakers, and/or what would become the various Dene nations at European contact who resided in near coastal northwest British Columbia.

The hypotheses presented here can be further advanced by seeking palaeoenvironmental and archaeological data with high enough temporal resolution to detect human responses in the years and decades following the WRAe event. Pollen and charcoal data from sub-centimetre sampling intervals are viable and will refine our understanding of immediate responses of vegetation to tephra dispersal (as shown by Hutchinson et al., 2019). Because WRAe is a visible and convenient stratigraphic marker in much of the Yukon, its presence can hinder more refined dating chronologies of late Holocene material. That is, archaeologists are apt to submit samples for dating more distant from the tephra in the stratigraphic column, which tends to be material from the early to middle Holocene. As a result, occupations that closely approach the tephra receive less chronological interest, which hinders the ability of archaeologists to detect behavior patterns of groups who occupied sites directly before and after the eruption. Radiocarbon dates of archaeological material immediately below and above the stratigraphic position of WRAe tephra will further elucidate human responses with greater chronological precision. Detecting the presence of Dene ancestors in Southeast Alaska may remain elusive because, as elsewhere in

North America, Dene migrants appear to have quickly adopted material toolkits of their surrounding communities. Instead, the evidence may lie in altered exchange networks that witnessed new modes or intensities of trade of coastal and interior goods. The newfound movement of coastal products to interior markets after the WRAe, like pre-contact jade that was transmitted from coastal communities across the Rocky Mountains to Alberta and Saskatchewan (Kristensen et al., 2016), may be harbingers of new coastal relationships for Dene people. Grease trails, that linked interior Dene communities to coastal exchange partners, may have similarly expanded, or witnessed intensified use, after roughly 850 A.D.

Archaeologists can reconstruct complex social and political landscapes of pre-contact Subarctic hunter-gatherers through syntheses of palaeoenvironmental, archaeological, and ethnohistoric records. In accordance with network-mediated migration theory (Butterworth, 1962; Kemper, 1977; Kearney, 1986; Massey et al., 1987; Wilson, 1994; Brettell, 2000), ecological and social conditions influenced resilience to large-scale ecological disasters. Volcanic eruptions were both destructive and creative; they presented opportunities for the transmission of technologies, new modes of economic exchange, and the socio-political rise of resourceful groups of hunter-gatherers.

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APPENDIX A – Obsidian provenance results

AOD Number	Site Number	Catalog Number	Source Name	Source Group	Instrument	Pre or post WRA
AOD-00181	A-2-1		Hoodoo Mountain	J	MURR-INAA	
AOD-00229	JdVa-2		Hoodoo Mountain	M	MURR-INAA	
AOD-00230	JeVb-14		Hoodoo Mountain	M	MURR-INAA	
AOD-00231	JfVi-4		Wiki Peak	A	WU-INAA	
AOD-00232	JhVp-1		Edziza	E1 (outlier)	MURR-INAA	
AOD-00233	JjVi-7	JjVi-7-0848	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00234	JjVi-7	JjVi-7-0344	Wiki Peak	A	WU-INAA	Pre
AOD-00235	JjVi-7	JjVi-7-0051	Group Y4	Y4	MURR-INAA	
AOD-00236	JjVi-7		Hoodoo Mountain	M	WU-INAA	
AOD-00313	JjVi-8	JjVi-8-0032.2	Hoodoo Mountain	J	MURR-INAA	
AOD-00314	JjVi-8	JjVi-8-0040.1	Hoodoo Mountain	J	MURR-INAA	Pre
AOD-00315	JjVi-8	JjVi-8-0050.1	Hoodoo Mountain	J	WU-INAA	Pre
AOD-00316	JjVi-8	JjVi-8-0071	Edziza	E	MURR-INAA	Post
AOD-00317	JjVi-8	JjVi-8-0099	Wiki Peak	A	WU-INAA	Pre
AOD-00319	JjVi-8	JjVi-8-0154	Hoodoo Mountain	M	MURR-INAA	Post
AOD-00320	JjVi-7	JjVi-7-0174	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00322	JjVi-7	JjVi-7-0396	Group Y1	Y1	MURR-INAA	Pre
AOD-00323	JjVi-7	JjVi-7-0451	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00325	JjVi-7	JjVi-7-0577	Hoodoo Mountain	J	WU-INAA	
AOD-00326	JjVi-7	JjVi-7-0583	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00327	JjVi-7	JjVi-7-0606	Hoodoo Mountain	J	WU-INAA	
AOD-00329	JjVi-7	JjVi-7-0994	Hoodoo Mountain	J	MURR-INAA	Pre
AOD-00330	JjVi-7	JjVi-7-1034a	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00346	JjVi-7	JjVi-7-0515a	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00347	JjVi-7	JjVi-7-0515b	Hoodoo Mountain	J	MURR-INAA	Pre
AOD-00381	JjVi-7	JjVi-7-0296.1	Hoodoo Mountain	M	MURR-INAA	Post
AOD-00382	JjVi-7	JjVi-7-0296.2	Hoodoo Mountain	M	MURR-INAA	Post
AOD-00383	JjVi-7	JjVi-7-0405.1	Wiki Peak	A	WU-INAA	Pre
AOD-00384	JjVi-7	JjVi-7-0413.1	Edziza	E	MURR-INAA	Pre
AOD-00385	JjVi-7	JjVi-7-0413.2	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00386	JjVi-7	JjVi-7-0418.1	Wiki Peak	A	WU-INAA	Pre
AOD-00387	JjVi-7	JjVi-7-0418.2	Group Y1	Y1	MURR-INAA	Pre
AOD-00388	JjVi-7	JjVi-7-0456.1	Group Y3	Y3	MURR-INAA	Pre
AOD-00389	JjVi-7	JjVi-7-0456.2	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00390	JjVi-7	JjVi-7-0641.1	Wiki Peak	A	WU-INAA	Pre
AOD-00391	JjVi-7	JjVi-7-0641.2	Group Y2	Y2	MURR-INAA	Pre
AOD-00392	JjVi-8	JjVi-8-0109.1	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00393	JjVi-8	JjVi-8-0109.2	Hoodoo Mountain	M	MURR-INAA	Pre
AOD-00394	JjVi-8	JjVi-8-0093.1	Wiki Peak	A	WU-INAA	Pre
AOD-00395	JjVi-8	JjVi-8-0093.2	Edziza	E	MURR-INAA	Pre
AOD-00988	JbUn-10	YAOS-06-03	Edziza	E	Quan X-EC	
AOD-00989	KaVn-2	YAOS-06-07	Wiki Peak	A	Quan X-EC	Pre
AOD-00990	LcVg-16	YAOS-06-08	Wiki Peak	A	Quan X-EC	
AOD-00991	KbTx-3	YAOS-06-11	Hoodoo Mountain	M	Quan X-EC	
AOD-00992	JiTj-2	YAOS-06-13	Edziza	E	Quan X-EC	
AOD-00993	JbUl-A	YAOS-06-15	Edziza	E	Quan X-EC	
AOD-00994	JfUt-11	YAOS-06-18	Edziza	E	Quan X-EC	Pre
AOD-00995	JkUx-5	YAOS-06-19	Hoodoo Mountain	M	Quan X-EC	
AOD-00996	JdUs-2	YAOS-06-27	Edziza	E	Quan X-EC	
AOD-00997	JcUr-3	YAOS-06-28	Edziza	E	Quan X-EC	
AOD-00998	JkVa-1	YAOS-06-29	Unassigned	Unassigned	Quan X-EC	Pre
AOD-00999	JjVu-4	YAOS-06-30	Hoodoo Mountain	M	Quan X-EC	Pre
AOD-01000	JeVc-23	YAOS-06-31	Unassigned	Unassigned	Quan X-EC	
AOD-01001	KaVa-8	YAOS-06-32	Unassigned	Unassigned	Quan X-EC	
AOD-01002	KdVa-8	YAOS-06-33	Edziza	E	Quan X-EC	Post
AOD-01003	KdVa-8	YAOS-06-34	Batza Tena	B	Quan X-EC	
AOD-01004	KeVd-3	YAOS-06-35	Edziza	E	Quan X-EC	Pre
AOD-01005	KbTx-6	YAOS-06-36	Edziza	E	Quan X-EC	
AOD-01006	JeVc-20	YAOS-06-37	Hoodoo Mountain	M	Quan X-EC	
AOD-01007	KbTx-4	YAOS-06-38	Batza Tena	B	Quan X-EC	
AOD-01008	JbUq-17	YAOS-06-39	Unassigned	Unassigned	Quan X-EC	
AOD-01009	JbUn-10	YAOS-06-40	Hoodoo Mountain	M	Quan X-EC	
AOD-03269	KdVo-6	KdVo-6-1688	Wiki Peak	A	Bruker Tracer III no 467	Pre

AOD-03270	KdVo-6	KdVo-6-1689	Edziza	E	Bruker Tracer III no 467	Pre
AOD-03271	KdVo-6	KdVo-6-1481	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03272	KdVo-6	KdVo-6-1482	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03273	KdVo-6	KdVo-6-1483	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03274	KdVo-6	KdVo-6-1484 - 85	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-03275	KdVo-6	KdVo-6-1691	Wiki Peak	A	Bruker Tracer III no 467	
AOD-03276	KdVo-6	KdVo-6-1324	Wiki Peak	A	Bruker Tracer III no 467	
AOD-03277	KdVo-6	KdVo-6-0153.10	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03278	KdVo-6	KdVo-6-0153.11	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03279	KdVo-6	KdVo-6-0153.12	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-03280	KdVo-6	KdVo-6-0153.13	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03281	KdVo-6	KdVo-6-0153.14	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03282	KdVo-6	KdVo-6-0756	Wiki Peak	A	Bruker Tracer III no 467	Post
AOD-03283	KeVo-1	KeVo-1-21	Edziza	E	Bruker Tracer III no 467	
AOD-03284	KeVo-1	KeVo-1-22	Group AH	AH	Bruker Tracer III no 467	
AOD-03285	KeVo-1	KeVo-1-26	Wiki Peak	A	Bruker Tracer III no 467	
AOD-03286	KeVo-1	KeVo-1-K12	Wiki Peak	A	Bruker Tracer III no 467	
AOD-03360	Taatsaan	2006-Loc-3	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-03361	KdVo-6	KdVo-6-0092	Wiki Peak	A	Bruker Tracer III no 467	Post
AOD-03362	KdVo-6	KdVo-6-0126	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03363	KdVo-6	KdVo-6-0149	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03364	KdVo-6	KdVo-6-0153.01	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03365	KdVo-6	KdVo-6-0153.02	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03366	KdVo-6	KdVo-6-0153.03	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-03367	KdVo-6	KdVo-6-0153.04	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03368	KdVo-6	KdVo-6-0153.05	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03369	KdVo-6	KdVo-6-0153.06	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03370	KdVo-6	KdVo-6-0153.07	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03371	KdVo-6	KdVo-6-0153.08	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03372	KdVo-6	KdVo-6-0153.09	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03373	KdVo-6	KdVo-6-0258	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03374	KdVo-6	KdVo-6-0321	Wiki Peak	A	Bruker Tracer III no 467	Post
AOD-03375	KdVo-6	KdVo-6-0358	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-03376	KdVo-6	KdVo-6-0360	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03377	KdVo-6	KdVo-6-0438a	Wiki Peak	A	Bruker Tracer III no 467	Post
AOD-03378	KdVo-6	KdVo-6-0727	Wiki Peak	A	Bruker Tracer III no 467	Post
AOD-03379	KdVo-6	KdVo-6-0746	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03380	KdVo-6	KdVo-6-0750	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03381	KdVo-6	KdVo-6-0789	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-03694	KdVo-6	KdVo-6-1687	Wiki Peak	A		Pre
AOD-03695	KdVo-6	KdVo-6-1417	Wiki Peak	A		Pre
AOD-03696	KdVo-6	KdVo-6-0153.15	Wiki Peak	A		Pre
AOD-03697	KdVo-6	KdVo-6-0153.16	Wiki Peak	A		Pre
AOD-03698	KdVo-6	KdVo-6-0153.17	Wiki Peak	A		Pre
AOD-03699	KdVo-6	KdVo-6-0153.18	Wiki Peak	A		Pre
AOD-03700	KdVo-6	KdVo-6-0153.19	Wiki Peak	A		Pre
AOD-03701	KdVo-6	KdVo-6-0153.20	Wiki Peak	A		Pre
AOD-03702	KdVo-6	KdVo-6-0153.21	Wiki Peak	A		Pre
AOD-03703	KdVo-6	KdVo-6-0153.22	Wiki Peak	A		Pre
AOD-03704	KdVo-6	KdVo-6-0153.23	Wiki Peak	A		Pre
AOD-03705	KdVo-6	KdVo-6-0153.24	Wiki Peak	A		Pre
AOD-03706	KdVo-6	KdVo-6-0153.25	Wiki Peak	A		Pre
AOD-03707	KdVo-6	KdVo-6-0153.26	Wiki Peak	A		Pre
AOD-03708	KdVo-6	KdVo-6-0153.27	Wiki Peak	A		Pre
AOD-03709	KdVo-6	KdVo-6-0153.28	Wiki Peak	A		Pre
AOD-03710	KdVo-6	KdVo-6-0153.29	Wiki Peak	A		Pre
AOD-03711	KdVo-6	KdVo-6-0153.30	Wiki Peak	A		Pre
AOD-03712	KdVo-6	KdVo-6-0153.31	Wiki Peak	A		Pre
AOD-03713	KdVo-6	KdVo-6-0153.32	Wiki Peak	A		Pre
AOD-03714	KdVo-6	KdVo-6-0153.33	Wiki Peak	A		Pre
AOD-03715	KdVo-6	KdVo-6-0153.34	Wiki Peak	A		Pre
AOD-03716	KdVo-6	KdVo-6-0153.35	Wiki Peak	A		Pre
AOD-03717	KdVo-6	KdVo-6-0153.36	Wiki Peak	A		Pre
AOD-03718	KdVo-6	KdVo-6-0153.37	Wiki Peak	A		Pre
AOD-03719	KdVo-6	KdVo-6-0153.38	Wiki Peak	A		Pre
AOD-03720	KdVo-6	KdVo-6-0153.39	Wiki Peak	A		Pre
AOD-03721	KdVo-6	KdVo-6-0153.40	Wiki Peak	A		Pre
AOD-03722	KdVo-6	KdVo-6-0153.41	Wiki Peak	A		Pre
AOD-03723	KdVo-6	KdVo-6-0153.42	Wiki Peak	A		Pre
AOD-03724	KdVo-6	KdVo-6-0153.43	Wiki Peak	A		Pre
AOD-03725	KdVo-6	KdVo-6-0153.44	Wiki Peak	A		Pre
AOD-03726	KdVo-6	KdVo-6-0153.45	Wiki Peak	A		Pre
AOD-03727	KdVo-6	KdVo-6-0153.46	Wiki Peak	A		Pre
AOD-03728	KdVo-6	KdVo-6-0153.47	Wiki Peak	A		Pre
AOD-03729	KdVo-6	KdVo-6-0153.48	Wiki Peak	A		Pre

AOD-03730	KdVo-6	KdVo-6-0153.49	Wiki Peak	A		Pre
AOD-03731	KdVo-6	KdVo-6-0153.50	Wiki Peak	A		Pre
AOD-03732	KdVo-6	KdVo-6-0153.51	Wiki Peak	A		Pre
AOD-03733	KdVo-6	KdVo-6-0153.52	Wiki Peak	A		Pre
AOD-03734	KdVo-6	KdVo-6-0153.53	Wiki Peak	A		Pre
AOD-03735	KdVo-6	KdVo-6-0153.54	Wiki Peak	A		Pre
AOD-03736	KdVo-6	KdVo-6-0153.55	Wiki Peak	A		Pre
AOD-03737	KdVo-6	KdVo-6-0153.56	Wiki Peak	A		Pre
AOD-03738	KdVo-6	KdVo-6-0153.57	Wiki Peak	A		Pre
AOD-03739	KdVo-6	KdVo-6-0153.58	Wiki Peak	A		Pre
AOD-03740	KdVo-6	KdVo-6-0153.59	Edziza	E		Pre
AOD-03741	KdVo-6	KdVo-6-0153.60	Wiki Peak	A		Pre
AOD-03742	KdVo-6	KdVo-6-0312	Wiki Peak	A		Pre
AOD-03743	KdVo-6	KdVo-6-0312.01	Wiki Peak	A		Pre
AOD-03744	KdVo-6	KdVo-6-0312.02	Wiki Peak	A		Pre
AOD-03745	KdVo-6	KdVo-6-0367	Wiki Peak	A		Pre
AOD-03746	KdVo-6	KdVo-6-0368	Wiki Peak	A		Pre
AOD-03747	KdVo-6	KdVo-6-0401	Wiki Peak	A		Post
AOD-03748	KdVo-6	KdVo-6-0438B	Wiki Peak	A		Post
AOD-03749	KdVo-6	KdVo-6-0540	Wiki Peak	A		Pre
AOD-03750	KdVo-6	KdVo-6-0553.01	Hoodoo Mountain	M?		Pre
AOD-03751	KdVo-6	KdVo-6-0553.02	Hoodoo Mountain	M?		Pre
AOD-03752	KdVo-6	KdVo-6-0553.03	Wiki Peak	A		Pre
AOD-03753	KdVo-6	KdVo-6-0553.04	Wiki Peak	A		Pre
AOD-03754	KdVo-6	KdVo-6-0599	Wiki Peak	A		Pre
AOD-03755	KdVo-6	KdVo-6-0669	Hoodoo Mountain	M		Pre
AOD-03756	KdVo-6	KdVo-6-0706	Wiki Peak	A		Pre
AOD-03757	KdVo-6	KdVo-6-0781	Wiki Peak	A		Pre
AOD-03758	KdVo-6	KdVo-6-0991	Unassigned - W?	Unassigned		Pre
AOD-03759	KeVo-1	TPK9	Edziza	E		Pre
AOD-03792	KdVo-5	KdVo-5-143	Hoodoo Mountain	M		
AOD-03793	KdVo-5	KdVo-5-157	Unassigned	Unassigned		
AOD-03794	KdVo-5	KdVo-5-162	Unassigned	Unassigned		
AOD-03795	KdVo-5	KdVo-5-164	Unassigned	Unassigned		
AOD-03796	KdVo-5	KdVo-5-190	Unassigned	Unassigned		
AOD-03797	KdVo-5	KdVo-5-217	Hoodoo Mountain	M		
AOD-03798	KdVo-5	KdVo-5-325	Group Y2	Y2		
AOD-03959	JeVn	YUK16a	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-03960	JjVi-7	JjVi-7-0063	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-03961	JjVi-8	JjVi-8-0050.2	Hoodoo Mountain	J	Bruker Tracer III no 467	Pre
AOD-03962	JjVi-7	JjVi-7-0898	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-03963	JjVi-7	JjVi-7-0306	VOID	VOID	Bruker Tracer III no 467	Pre
AOD-03964	JjVi-7	JjVi-7-0577	Hoodoo Mountain	J	Bruker Tracer III no 467	Pre
AOD-03965	JjVi-7	JjVi-7-0439	Group Y3	Y3	Bruker Tracer III no 467	Pre
AOD-03966	JjVi-8	JjVi-8-0040.2	Hoodoo Mountain	J	Bruker Tracer III no 467	Pre
AOD-03967	JjVi-7	JjVi-7-0980	Hoodoo Mountain	J	Bruker Tracer III no 467	Pre
AOD-03968	JjVi-8	JjVi-8-0032.1	Hoodoo Mountain	J	Bruker Tracer III no 467	Pre
AOD-03969	JjVi-7	JjVi-7-0891	Group Y1	Y1	Bruker Tracer III no 467	Pre
AOD-03970	JjVi-7	JjVi-7-0808	Wiki Peak	A	Bruker Tracer III no 467	Post
AOD-03971	JjVi-7	JjVi-7-1034b	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-03972	JjVi-1	JjVi-1 Xi-B-147	Hoodoo Mountain	J	Bruker Tracer III no 467	
AOD-03973	JjVi-1	JjVi-1-12	Hoodoo Mountain	J	Bruker Tracer III no 467	
AOD-04177	NiVk-1	NiVk-1-a	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04178	NiVk-1	NiVk-1-b	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04179	NiVk-1	NiVk-1-288-16	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04180	NiVk-1	NiVk-1-269-3a(402)	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04181	NiVk-1	NiVk-1-833	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04182	NiVk-1	NiVk-1-834	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04183	NiVk-1	NiVk-1-846	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04184	NiVk-1	NiVk-1-896	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04185	NiVk-1	NiVk-1-919	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04186	NiVk-1	NiVk-1-920	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04187	NiVk-1	NiVk-1-921	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04188	NiVk-1	NiVk-1-992	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04189	NiVk-1	NiVk-1-993	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04190	NiVk-1	NiVk-1-1000	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04191	NiVk-1	NiVk-1-1005	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04192	NiVk-1	NiVk-1-1007	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04193	NiVk-1	NiVk-1-1027	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04194	NiVk-1	NiVk-1-1309	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04195	NiVk-1	NiVk-1-1364	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04196	NiVk-1	NiVk-1-1365	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04197	NiVk-1	NiVk-1-1366	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04198	NiVk-1	NiVk-1-1426	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04199	NiVk-1	NiVk-1-1445	Batza Tena	B	Bruker Tracer III-V no 510	Pre

AOD-04200	NiVk-1	NiVk-1-1490	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04201	NiVk-1	NiVk-1-1501	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04202	NiVk-1	NiVk-1-2176	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04203	NiVk-1	NiVk-1-2188	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04204	NiVk-1	NiVk-1-2203	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04205	NiVk-1	NiVk-1-2225	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04206	NiVk-1	NiVk-1-2272	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04207	NiVk-1	NiVk-1-2279	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04208	NiVk-1	NiVk-1-2288	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04209	NiVk-1	NiVk-1-2313	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04210	NiVk-1	NiVk-1-2545	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04211	NiVk-1	NiVk-1-2616	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04212	NiVk-1	NiVk-1-3200	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04213	MjVl-1	MjVl-1-1f	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04214	MjVl-1	MjVl-1-991	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04215	MjVl-1	MjVl-1-1783	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04216	MjVl-1	MjVl-1-1784	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04217	MjVl-1	MjVl-1-1785	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04218	MjVl-1	MjVl-1-1786	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04219	MjVl-1	MjVl-1-1792	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04220	MjVl-1	MjVl-1-1804	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04221	MjVl-1	MjVl-1-2031	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04222	MjVl-1	MjVl-1-2320	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04223	MjVl-1A	MjVl-1A-276	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04224	MjVl-1A	MjVl-1A-269f	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04225	MjVl-1A	MjVl-1A-190D	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04226	MjVl-1A	MjVl-1A-190E	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04234	MjVg-1	MjVg-1-178	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04235	MjVg-1	MjVg-1-318	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04236	MjVg-1	MjVg-1-884	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04237	MjVg-1	MjVg-1-925	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04238	MjVg-1	MjVg-1-1100	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04239	MjVg-1	MjVg-1-1158	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04240	MjVg-1	MjVg-1-1422	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04241	MjVg-1	MjVg-1-1421	BY variant or E1?	Unassigned	Bruker Tracer III-V no 510	Post
AOD-04242	MjVg-1	MjVg-1-1426	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04243	MjVg-1	MjVg-1-1687	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04244	MjVg-1	MjVg-1-1737	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04245	MjVg-1	MjVg-1-1805	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04246	MjVg-1	MjVg-1-2102	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04247	MjVg-1	MjVg-1-2288	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04248	MjVg-1	MjVg-1-3332	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04249	MjVg-1	MjVg-1-3345	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04250	MjVg-1	MjVg-1-3821	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04251	MjVg-1	MjVg-1-3863x	Group H	H	Bruker Tracer III-V no 510	Post
AOD-04252	MjVg-1	MjVg-1-3997	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04253	MjVg-1	MjVg-1-4144	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04254	MjVg-1	MjVg-1-4505	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-04255	MjVg-1	MjVg-1-4917a	Unassigned	Unassigned	Bruker Tracer III-V no 510	Post
AOD-04256	MjVg-1	MjVg-1-4917b	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04257	MjVh-3	MjVh-3-3	Batza Tena	B	Bruker Tracer III-V no 510	Post
AOD-04258	MjVh-5	MjVj-5-9	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-04259	MjVk-1	MjVk-1-12	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-04260	MjVk-4	MjVk-4-11a	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04261	MjVk-5	MjVk-4-371a	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04262	MjVk-6	MjVk-4-371b	Group N	N	Bruker Tracer III-V no 510	Post
AOD-04263	JjVi-1	JjVi-1-204	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04264	KaTx-6	KaTx-6-12a	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04265	KgTi-1	KgTi-1-11a	Edziza	E	Bruker Tracer III-V no 510	
AOD-04266	KgTi-1	KgTi-1-11b	Group AH	AH	Bruker Tracer III-V no 510	
AOD-04267	KbTx-3	KbTx-3-7	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04268	KbTx-6	KbTx-6-22a	Edziza	E	Bruker Tracer III-V no 510	
AOD-04269	KbTx-6	KbTx-6-22b	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04270	KaVd-1	KaVd-1-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-04271	KbVa-2	KbVa-2-5	Edziza	E	Bruker Tracer III-V no 510	
AOD-04272	KbVa-3	KbVa-3-25a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04273	KbVa-3	KbVa-3-25b	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04274	KbVa-4	KbVa-4-9	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04280	JeVc-2	XI-B-27	Edziza	E	Bruker Tracer III-V no 510	
AOD-04281	XI-B	XI-B-47	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04283	JiVs-2	XI-B-56	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04284	JiVs-2	XI-B-62	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04285	JiVs-2	XI-B-63	Edziza	E	Bruker Tracer III-V no 510	
AOD-04286	JiVs-2	XI-B-64	Unassigned - M1?	Unassigned	Bruker Tracer III-V no 510	
AOD-04287	JiVs-2	XI-B-83	Edziza	E	Bruker Tracer III-V no 510	

AOD-04288	KaVa-?	XI-B-142	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04289	KaVa-?	XI-B-143	Edziza	E	Bruker Tracer III-V no 510	
AOD-04290	JiVi-1	XI-B-144	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04291	JiVi-3	XI-B-170a	Unassigned - M?	Unassigned	Bruker Tracer III-V no 510	
AOD-04292	JiVi-3	XI-B-170b	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04293	JiVi-3	XI-B-170c	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-04294	JiVi-3	XI-B-170d	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04295	JiVi-3	XI-B-170e	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04296	JiVi-3	XI-B-170f	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04297	JiVi-3	XI-B-172	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04298	JiVi-3	XI-B-173	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04299	JaUe-1	XI-B-255	Edziza	E	Bruker Tracer III-V no 510	
AOD-04300	JaUe-1	XI-B-256a	Edziza	E	Bruker Tracer III-V no 510	
AOD-04301	JaUe-1	XI-B-256b	Edziza	E	Bruker Tracer III-V no 510	
AOD-04302	JaUw-1	XI-B-372	Group AH	AH	Bruker Tracer III-V no 510	
AOD-04303	MkVm-3	XI-B-388	Group H	H	Bruker Tracer III-V no 510	
AOD-04304	JeVc-3?	XI-B-397	Edziza	E	Bruker Tracer III-V no 510	
AOD-04306	IX-E	IX-E-88	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-04307	JcRw-2	XI-C-134	Edziza	E	Bruker Tracer III-V no 510	
AOD-04308	JcRx-2	XI-C-419a	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-04309	JcRx-2	XI-C-419b	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-04313	JdTv-1	JdTv-1-37	Edziza	E	Bruker Tracer III-V no 510	
AOD-04314	JdTv-1	JdTv-1-41	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04315	JdTv-1	JdTv-1-46a	Edziza	E	Bruker Tracer III-V no 510	
AOD-04316	JdTv-1	JdTv-1-46b	Edziza	E	Bruker Tracer III-V no 510	
AOD-04317	JdTv-1	JdTv-1-53	Edziza	E	Bruker Tracer III-V no 510	
AOD-04318	JdTv-1	JdTv-1-36	Edziza	E	Bruker Tracer III-V no 510	
AOD-04319	JdTv-1	JdTv-1-3	Edziza	E	Bruker Tracer III-V no 510	
AOD-04320	JaSu-1	JaSu-1-105	Edziza	E	Bruker Tracer III-V no 510	
AOD-04321	JaUk-5	JaUk-5-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-04322	JaUk-12	JaUk-12-1	Edziza	E1	Bruker Tracer III-V no 510	
AOD-04323	JaUk-19	JaUk-19-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-04324	JaUk-23	JaUk-23-84	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-04325	JaUo-6	JaUo-6-6	Edziza	E	Bruker Tracer III-V no 510	
AOD-04326	JaUp-1	JaUp-1-6a	Edziza	E	Bruker Tracer III-V no 510	
AOD-04327	JaUu-3	JaUu-3-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-04328	JaUv-5	JaUv-5-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04329	JaUv-13	JaUv-13-5	Edziza	E	Bruker Tracer III-V no 510	
AOD-04330	JbUg-7	JbUg-7-6	Group AH	AH	Bruker Tracer III-V no 510	
AOD-04331	JbUf-1	JbUf-1-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-04332	JbUq-24	JbUq-24-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04333	JbUi-2	JbUi-2-1a	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-04334	JbUi-2	JbUi-2-1b	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-04335	JbUi-10	JbUi-10-1	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-04336	JbUm-1	JbUm-1-52	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-04337	JbUn-11	JbUn-11-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-04338	JbUo-1	JbUo-1-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-04339	JbUq-1	JbUq-1-1a	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-04340	JbUq-1	JbUq-1-1b	Edziza	E	Bruker Tracer III-V no 510	
AOD-04341	JbUq-1	JbUq-1-3	Edziza	E	Bruker Tracer III-V no 510	
AOD-04342	JbUq-1	JbUq-1-4a	Edziza	E1	Bruker Tracer III-V no 510	
AOD-04343	JbUq-1	JbUq-1-4bx	Edziza	E1	Bruker Tracer III-V no 510	
AOD-04344	JbUq-7	JbUq-7-10	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-04345	JbUr-19	JbUr-19-1x	Hoodoo Mountain	J1	Bruker Tracer III-V no 510	
AOD-04346	JbUt-5	JbUt-5-2	Edziza	E	Bruker Tracer III-V no 510	
AOD-04347	JbUt-7	JbUt-7-2a	Edziza	E	Bruker Tracer III-V no 510	
AOD-04348	JbUt-7	JbUt-7-2b	Edziza	E	Bruker Tracer III-V no 510	
AOD-04373	JdTv-1	JdTv-1-87	Edziza	E	Bruker Tracer III-V no 510	
AOD-04374	JaUk-14	JaUk-14-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06285	JkVa-1	JkVa-1-57	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-06286	JkVa-1	JkVa-1-126	Group Y3	Y3	Bruker Tracer III-V no 510	Pre
AOD-06287	JaTr-3	JaTr-3-2	Edziza	E	Bruker Tracer III-V no 510	
AOD-06288	JaTe-4	JaTe4-2	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06289	JaUd-10	JaUd-10-3	Edziza	E	Bruker Tracer III-V no 510	
AOD-06290	JaVd-10	JaVd-10-2	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-06291	JbUq-9	JbUq-9-7	Edziza	E	Bruker Tracer III-V no 510	
AOD-06292	JbTf-1	JbTf-1	Group AH	AH	Bruker Tracer III-V no 510	Post
AOD-06293	JbUq-17	JbUq-17-44.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06294	JbUq-17	JbUq-17x	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06295	JbUq-17	JbUq-17-45	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06296	JbUq-17	JbUq-17	Unassigned	Unassigned	Bruker Tracer III-V no 510	Pre
AOD-06297	JbUq-17	JbUq-17-46	Edziza	E	Bruker Tracer III-V no 510	
AOD-06298	JbUq-17	JbUq-17xx	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-06299	JbUq-17	JbUq-17-44.2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06300	JcUr-7	JcUr-7-299	Edziza	E	Bruker Tracer III-V no 510	

AOD-06301	JcUj-7	JcUj-7	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06302	JcUj-7	JcUj-7	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06303	JcUj-7	JcUj-7	Unassigned	Unassigned	Bruker Tracer III-V no 510	Post
AOD-06304	JcUj-7	JcUj-7	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06305	JcUj-7	JcUj-7	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06306	JcUj-7	JcUj-7	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-06307	JcUj-2	JcUj-2	Group AH	AH	Bruker Tracer III-V no 510	Post
AOD-06308	JdVa-20	JdVa-20-2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06309	JdUr-10	JdUr-10-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06310	JdUs-6	JdUs-6-1	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06311	JeVc-31	JeVc-31-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-06312	JeVc-31	JeVc-31	Edziza	E	Bruker Tracer III-V no 510	
AOD-06313	JeVc-31	JeVc-31-x	Edziza	E	Bruker Tracer III-V no 510	
AOD-06314	JeUw-19	JeUw-19-2	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Post
AOD-06315	JeUw-19	JeUw-19-5	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06316	JeUs-6	JeUs-6	Edziza	E	Bruker Tracer III-V no 510	
AOD-06317	JeUs-11	JeUs-11-43.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06318	JeUs-11	JeUs-11-43.2	Edziza	E	Bruker Tracer III-V no 510	
AOD-06319	JeUs-11	JeUs-11-43.3	Edziza	E	Bruker Tracer III-V no 510	
AOD-06320	JeUs-11	JeUs-11-x	Edziza	E	Bruker Tracer III-V no 510	
AOD-06321	JeVc-31	JeVc-31-0.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06322	JeVc-31	JeVc-31-0.2	Edziza	E	Bruker Tracer III-V no 510	
AOD-06323	JeVk-3	JeVk-3-28.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06324	JeVk-3	JeVk-3-28.2	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06325	JeVk-3	JeVk-3-0.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06326	JeVk-3	JeVk-3-28.3	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06327	JeVd-15	JeVd-15-3	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-06328	JeUt-20	JeUt-20-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-06329	JeUt-24	JeUt-24-2	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-06330	JeUt-15	JeUt-15-8	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-06331	JfUt-11	JfUt-11-20	Group AL	AL	Bruker Tracer III-V no 510	
AOD-06332	JfUt-11	JfUt-11-21	Group AL	AL	Bruker Tracer III-V no 510	
AOD-06333	JfUt-11	JfUt-11-22	Group AL	AL	Bruker Tracer III-V no 510	
AOD-06334	JfUt-11	JfUt-11-14	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06335	JfUt-11	JfUt-11-16	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-06336	JfUt-11	JfUt-11-15	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06337	JfUt-11	JfUt-11-18	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06338	JfUt-11	JfUt-11-17	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06339	JfUt-11	JfUt-11-19.1	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-06340	JfUt-11	JfUt-11-19.2	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06341	JfUt-11	JfUt-11-19.3	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-06342	JfVg-18	JfVg-18-3	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06343	JfUt-11	JfUt-11-3	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06344	JfVg-20	JfVg-20-1	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-06345	JfUt-15	JfUt-15-0.1	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-06346	JfUt-15	JfUt-15-0.2	Edziza	E	Bruker Tracer III-V no 510	
AOD-06347	JfVg-28	JfVg-28-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06348	JfVg-20	JfVg-20-2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06349	JfVg-17	JfVg-17-6	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06350	JfVg-18	JfVg-18-4	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06351	JhVr-2	JhVr-2	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06352	JhVp-1	JhVp-1-33	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06353	JiVd-1	JiVd-1-9	Edziza	E	Bruker Tracer III-V no 510	
AOD-06354	JiVd-1	JiVd-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06355	JiVm-1	JiVm-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06356	JiVm-1	JiVm-1	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06357	JiVm-1	JiVm-1	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06358	JiVm-1	JiVm-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06359	KdVo-6	KdVo-6-1889	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06360	KdVo-6	KdVo-6-1986	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06361	KdVo-6	KdVo-6-	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06362	KdVo-6	KdVo-6-2169	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06363	KdVo-5	KdVo-5-24	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06364	JbUn-10	JbUn-10-10	Edziza	E	Bruker Tracer III-V no 510	
AOD-06365	JbUn-10	JbUn-10-11	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06366	JbUn-10	JbUn-10-12	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06367	JbUn-10	JbUn-10-13	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06368	JbUn-10	JbUn-10-14	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06369	JbUn-10	JbUn-10-15	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06370	no site no.	none	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-06377	JkUx-5	JkUx-5-1	Edziza (outlier)	E	Bruker Tracer III-V no 510	Pre
AOD-06378	JeUs?	MaryLake1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06379	none	MaeWest1	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06380	JkUx-5	JkUx-5	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06381	JkUx-5	JkUx-5-36.1	Edziza	E	Bruker Tracer III-V no 510	

AOD-06382	JkUx-5	JkUx-5-36.2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06383	JiTj-2	JiTj-2-9	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06384	KbTx-3	KbTx-3-23	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06385	JeUs-6	JeUs-6-0.01	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06386	JeUs-6	JeUs-6-59	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06387	JeUs-6	JeUs-6	Edziza	E	Bruker Tracer III-V no 510	
AOD-06388	JeUs-6	JeUs-6-84.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06389	JeUs-6	JeUs-6-84.2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06390	JeUs-6	JeUs-6-65	Edziza	E	Bruker Tracer III-V no 510	
AOD-06391	JeUs-6	JeUs-6-79	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06392	JeUs-6	JeUs-6-47	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06393	JeUs-6	JeUs-6-0.02	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06394	JeUs-6	JeUs-6	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-06395	JeUs-6	JeUs-6	Edziza	E	Bruker Tracer III-V no 510	
AOD-06396	JeUs?	none	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06397	JcUw-6	JcUw-6-9	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06398	JcUw-8P2	JcUw-8-3.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06399	JcUw-8	JcUw-8-3.2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06400	JbVf-6	JbVf-6-1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-06401	JcUw-6	JcUw-6-0.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06402	JcUw-6	JcUw-6-0.2	Edziza	E	Bruker Tracer III-V no 510	
AOD-06403	JcUw-6	JcUw-6-0.3	Edziza	E	Bruker Tracer III-V no 510	
AOD-06404	JcUw-6	JcUw-6-0.4	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06405	JbVf-6	JbVf-6-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-06406	JdVf-4	JdVf-4-27	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-06407	JdVf-6	JdVf-6-5	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06408	JdVf-2	JdVf-2-24.1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06409	JdVf-2	JdVf-2-24.2	Edziza	E	Bruker Tracer III-V no 510	
AOD-06410	JdVf-2	JdVf-2-28	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06411	JdVf-2	JdVf-2-18.1	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-06412	JdVf-2	JdVf-2-18.2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06413	JdVf-2	JdVf-2-18.3	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06414	JeVc-23	JeVc-23-8	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06415	JeVc-23	JeVc-23-11	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06416	JdVe-3	JdVe-3-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-06417	JdVe-5	JdVe-5-9	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06418	JeVc-24	JeVc-24-58	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06419	JeVc-23	JeVc-23-31	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06420	JeVc-23	JeVc-23-35	Edziza	E	Bruker Tracer III-V no 510	
AOD-06421	JeVc-23	JeVc-23-39	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06422	JeVc-23	JeVc-23-38	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06423	JeVc-23	JeVc-23-37	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06424	JeVc-24	JeVc-24-39	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06425	JeVc-23	JeVc-23-70	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06426	JeVd-13	JeVd-13-198	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-06427	JeVd-13	JeVd-13-10	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-06428	JeVd-13	JeVd-13-9	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06429	JeVd-13	JeVd-13-4.1	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-06430	JeVd-13	JeVd-13-4.2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06431	KaVn-2	KaVn-2-10	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06432	KeVe-4	KeVe-4-2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06433	KeVe-2	KeVe-2-326	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-06434	KeVd-3	KeVd-3-204	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06435	JeVc-20	JeVc-20-736	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06436	JeVc-20	JeVc-20-44	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06437	KdVa-8	KdVa-8-226	Group Y1	Y1	Bruker Tracer III-V no 510	Pre
AOD-06438	KdVa-8	KdVa-8-354	Group Y1	Y1	Bruker Tracer III-V no 510	Post
AOD-06439	JeVb-14	JeVb-14-8	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06440	JeVd-16	JeVd-14-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06441	JeVc-13	JeVc-13-6	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06442	KdVa-8	KdVa-8-573	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06443	JdUt-3	JdUt-3-155	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06444	JdUt-3	JdUt-3-124	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06445	JdUt-3	JdUt-3-98	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06446	JdUt-3	JdUt-3-688	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06447	JdUt-3	JdUt-3-432	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06448	JdUt-3	JdUt-3-409	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06449	JdUt-3	JdUt-3-162	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06450	JdUt-3	JdUt-3-164	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06451	JdUt-3	JdUt-3-549	Edziza	E	Bruker Tracer III-V no 510	
AOD-06452	JdUt-3	JdUt-3-550.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06453	JdUt-3	JdUt-3-550.2	Hoodoo Mountain	J1	Bruker Tracer III-V no 510	
AOD-06454	JdUt-3	JdUt-3-524	Group AL	AL	Bruker Tracer III-V no 510	
AOD-06455	JdUt-3	JdUt-3-522	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06456	JdUt-3	JdUt-3-482	Edziza	E	Bruker Tracer III-V no 510	

AOD-06457	JdUt-3	JdUt-3-749	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-06458	JdUt-4	JdUt-4-87	Edziza	E	Bruker Tracer III-V no 510	
AOD-06459	JdUt-4	JdUt-4-72	Edziza	E	Bruker Tracer III-V no 510	
AOD-06460	JdUt-4	JdUt-4-116	Edziza	E	Bruker Tracer III-V no 510	
AOD-06461	JdUt-4	JdUt-4-79	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06462	JdUt-4	JdUt-4-61	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06464	JdUt-4	JdUt-4-159	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06465	JfUv-7	JfUv-7-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06466	JcUr-3A	JcUr-3a-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-06467	JcUr-3	JcUr-3-1245	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06468	JcUr-3	JcUr-3-2793	Edziza	E1	Bruker Tracer III-V no 510	
AOD-06469	JeUt-18	JeUt-18-163	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06470	JeUt-18	JeUt-18-143	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-06471	JcUr-3	JcUr-3-3176	Edziza	E	Bruker Tracer III-V no 510	
AOD-06472	JcUr-3	JcUr-3-3100	Group AL	AL	Bruker Tracer III-V no 510	Pre
AOD-06473	JcUr-3	JcUr-3-3103	Group AL	AL	Bruker Tracer III-V no 510	Pre
AOD-06474	JcUr-3	JcUr-3-3121	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-06475	JcUr-3	JcUr-3-3087	Edziza	E	Bruker Tracer III-V no 510	
AOD-06476	JcUr-3	JcUr-3-3088	Edziza	E	Bruker Tracer III-V no 510	
AOD-06477	JcUr-3	JcUr-3-3125	Group AL	AL	Bruker Tracer III-V no 510	Pre
AOD-06478	JcUr-3	JcUr-3-1543	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-06479	JcUr-3	JcUr-3-1714	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06480	JcUr-3	JcUr-3-1717	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06481	JcUr-3	JcUr-3-1733	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06482	JcUr-3	JcUr-3-1679	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06483	JcUr-3	JcUr-3-1573	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06484	NcVi-8	NcVi-8-342	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-06485	LdVg-3	LdVg-3-8	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-06486	LaVk-9	LaVk-9-33	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-06487	KdVa-13	KdVa-13-2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06488	KeVc-10	KeVc-10-2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-06489	KeVb-13	KeVb-13-84	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06490	KeVb-13	KeVb-13-87	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-06491	KaVa-2	KaVa-2-110	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-06492	KaVa-3	KaVa-3-16	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-06493	KaVa-8	KaVa-8-32	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-06494	KbTx-3	KbTx-3-61	Edziza	E	Bruker Tracer III-V no 510	
AOD-07670	KbTx-4	KbTx-4-1	Batza Tena	B	Bruker Tracer III no 467	
AOD-07671	JiTj-2	JiTj-2-9	Edziza	E1	Bruker Tracer III no 467	Pre
AOD-07672	KbTx-3	KbTx-3-23	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-07673	JfUt-11	JfUt-11-18	Edziza	E	Bruker Tracer III no 467	
AOD-07674	JkUx-5	JkUx-5-46	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-07675	JbUl-A	JbUl-A-0	Group AH	AH	Bruker Tracer III no 467	
AOD-07676	JbUn-10	JbUn-10-12	Edziza	E1	Bruker Tracer III no 467	
AOD-07677	KaVn-2	KaVn-2-37-T10	Wiki Peak	A	Bruker Tracer III no 467	Pre
AOD-07678	LdVg-16	LdVg-16-3	Wiki Peak	A	Bruker Tracer III no 467	
AOD-07679	JbUn-10	JbUn-10-14	Edziza	E1	Bruker Tracer III no 467	
AOD-07680	JeVc-31	JeVc-31-4	Edziza	E	Bruker Tracer III no 467	
AOD-07681	KdVc-1	KdVc-1-29	Edziza	E	Bruker Tracer III no 467	
AOD-07682	KdVi-1	KdVi-1-0	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-07683	JbUn-10	JbUn-10-10	Edziza	E	Bruker Tracer III no 467	
AOD-07684	JbUn-10	JbUn-10-13a	Edziza	E1	Bruker Tracer III no 467	
AOD-07685	JbUn-10	JbUn-10-13b	Edziza	E1	Bruker Tracer III no 467	
AOD-07686	JcUr-3	JcUr-3-1581	Hoodoo Mountain	M	Bruker Tracer III no 467	Pre
AOD-07687	JdUt-3	JdUt-3-182	Edziza	E	Bruker Tracer III no 467	
AOD-07688	JbUq-17	JbUq-17-46	Edziza	E	Bruker Tracer III no 467	
AOD-07689	JeUs-6	JeUs-6-0	Edziza	E	Bruker Tracer III no 467	
AOD-07690	JbUq-17	JbUq-17-44	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-07691	JeUs-6	JeUs-6-7	Edziza	E1	Bruker Tracer III no 467	
AOD-07692	JdUr-5	JdUr-5-5003	Edziza	E1	Bruker Tracer III no 467	
AOD-07693	JgUu-1	JgUu-1-26	Hoodoo Mountain	M	Bruker Tracer III no 467	
AOD-07694	JbUn-10	JbUn-10-15	Edziza	E1	Bruker Tracer III no 467	
AOD-07695	JeUt-18	JeUt-18-106a	Unassigned	Unassigned	Bruker ARTAX 5816	
AOD-07696	JeUt-18	JeUt-18-106b	Unassigned	Unassigned	Bruker ARTAX 5816	
AOD-07697	JbUn-10	JbUn-10-11	Edziza	E1	Bruker Tracer III no 467	
AOD-08207	JeVn-1	27Y1A1-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08208	JeVn-1	27Y1A2-2	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08209	JeVn-1	27Y1A4-5	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08210	JeVn-1	27Y1A4-7	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08211	JeVn-1	27Y1A4-253	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08212	JeVn-1	27Y1A4-254	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08212_2	JeVn-1	27Y1A4-254	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08213	JeVn-1	27Y1A7-11	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08214	JeVn-1	27Y1A9-13	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08215	JeVn-1	27Y1A10-19	Hoodoo Mountain	M	Bruker Tracer III-V no 510	

AOD-08216	JeVn-1	27Y1A10-21	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08217	JeVn-1	27Y1A10-24	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08218	JeVn-1	27Y1A10-25	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08219	JeVn-1	27Y1A10-28	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08220	JeVn-1	27Y1A10-29	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08221	JeVn-1	27Y1A10-31	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08222	JeVn-1	27Y1A11-68	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08224	JeVn-34	29Y120A1-3477	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08225	JeVn-13	29Y43A1-289	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08226	JeVn-13	29Y43A1-291a	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08227	JeVn-13	29Y43A1-291b	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08228	JeVn-13	29Y43A1-291c	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08229	JeVn-14	29Y44A2-268	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08230	JeVn-14	29Y44A2-278a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08231	JeVn-14	29Y44A2-278b	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08232	JeVn-14	29Y44A2-278c	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08233	JeVn-14	29Y44A2-278d	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08234	JeVn-14	29Y44A2-278e	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08235	JeVn-14	29Y44A2-278f	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08236	JeVn-14	29Y44B1-279	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08237	JeVn-14	29Y44B1-334	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08238	JeVn-15	29Y45A1-269	Hoodoo Mountain	J1	Bruker Tracer III-V no 510	
AOD-08239	JeVn-15	29Y45A2-270	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08240	JeVn-34	29Y120A1-3479	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08240_2	JeVn-34	29Y120A1-3479	Hoodoo Mountain	J1	Bruker Tracer III-V no 510	
AOD-08248	JeVn-37	29Y124A1-3489	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08252	JhVu-8	27Y50A1-8	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08253	29Y999	29Y999C1-3530a	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08254	29Y999	29Y999C1-3530b	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08256	139Y0	139Y999A1-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08257	454T2	454T2A1-3027	Edziza	E	Bruker Tracer III-V no 510	
AOD-08258	560T1	560T1A3-3278	Edziza	E	Bruker Tracer III-V no 510	
AOD-08259	32T999	32T999A1-3353	Edziza	E	Bruker Tracer III-V no 510	
AOD-08260	32T199	32T199B1-3282	Edziza	E	Bruker Tracer III-V no 510	
AOD-08261	32T199	32T199B1-1602	Edziza	E1	Bruker Tracer III-V no 510	
AOD-08262	32T99	32T99B2-1589	Edziza	E	Bruker Tracer III-V no 510	
AOD-08263	32T99	32T99B2-1590	Edziza	E	Bruker Tracer III-V no 510	
AOD-08264	32T99	32T99B1-1582	Edziza	E	Bruker Tracer III-V no 510	
AOD-08265	32T20	32T20T7-1561	Edziza	E	Bruker Tracer III-V no 510	
AOD-08266	JlSt-7	118X43-15	Edziza	E	Bruker Tracer III-V no 510	
AOD-08267	JiSt-8	118X44A1-22a	Edziza	E	Bruker Tracer III-V no 510	
AOD-08268	JiSt-8	118X44A1-22b	Edziza	E	Bruker Tracer III-V no 510	
AOD-08269	38Y999	38Y999A2-6	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-08270	JbVj-1	35Y2A2-633	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Post
AOD-08271	JbVj-0001	35Y2A1-625	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-08272	17Y5	17Y5A1-8	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08273	JdVh-5	32Y100A1-3015	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08274	JdVh-5	32Y100A1-17-3021	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08275	JdVh-5	32Y100A1-16-3020b	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08276	JdVh-5	32Y100A1-16-3020a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08277	JdVh-5	32Y100A1-3011	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08278	JdVh-5	32Y100A1-3008	Edziza	E	Bruker Tracer III-V no 510	
AOD-08279	JgVu-6	42Y3A4-1-338	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08280	JgVu-5	41Y2A1-2958	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08281	JgVu-5	41Y2A1-2959	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08282	JgVu-4	40Y2A2-423	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08282_2	JgVu-4	40Y2A2-423	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08283	JgVu-3	39Y2M1-2-1571	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08284	JgVu-3	39Y4A1-2-308	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08285	JgVu-3	39Y4A17-1-329	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08286	JgVu-3	39Y5F1903-1-3796	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08287	JgVu-3	39Y2B12-886	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08288	JgVu-2	37Y5A1-1969	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-08289	JgVu-3	39Y4A1-204	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08290	JgVu-3	39Y4A9-272	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08291	JgVu-3	39Y4A15-1-283	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08292	JgVu-8	46YA1-1-2953	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08293	JgVu-6	42Y3A3-1-284	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08294	JgVu-1	23Y2C1-7	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08295	JgVu-1	23Y2C1-8	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08296	JgVu-1	23Y2C1-6	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08297	JgVu-1	23Y2B1-4	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08298	JgVu-1	23Y2C1-5	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08299	JgVu-2	37Y3A1-2467	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08300	JgVu-2	37Y3A1-2468	Group Y1	Y1	Bruker Tracer III-V no 510	

AOD-08301	JgVu-2	37Y3A1-2469	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08302	JgVu-2	37Y3A1-2470	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08303	JgVu-2	37Y3A1-3448	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08304	JeVn	Kluane_misc_001	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08308	JgVu-2	37Y4A1-2828	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08309	JgVu-2	37Y4A1-2827	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08310	JgVu-2	37Y4A2-416	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08311	JgVu-2	37Y4A14-1164	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08312	JgVu-2	37YY5A1-2651	Hoodoo Mountain	Mx	Bruker Tracer III-V no 510	
AOD-08313	JgVu-2	37YY5A1-2652	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08314	JgVu-2	37YY5A1-2653	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08315	JgVu-2	37YY5A1-2654	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08316	JgVu-2	37YY5A1-2655	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08317	JgVu-2	37YY5A1-2656	Hoodoo Mountain	Mx	Bruker Tracer III-V no 510	
AOD-08318	JgVu-2	37YY5A1-2657	Hoodoo Mountain	Mx	Bruker Tracer III-V no 510	
AOD-08320	JgVu-2	37Y5A6-3512	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08321	JgVu-2	37Y5A6-3513	Hoodoo Mountain	Mx	Bruker Tracer III-V no 510	
AOD-08322	JgVu-2	37Y5A6-3517	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08323	JgVu-2	37Y6A1-1768	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08324	JgVu-2	37Y6A1-1796	Hoodoo Mountain	Mx	Bruker Tracer III-V no 510	
AOD-08325	JgVu-2	37Y6A1-1805	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08326	JgVu-2	37Y6A1-1804	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08327	JgVu-2	37Y6A1-1806	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08328	JgVu-2	37Y6A1-1807	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08329	JgVu-2	37Y6A1-1809	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08332	JgVu-17	29Y17A1-310	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08333	JgVu-17	29Y17A1-331a	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08334	JgVu-17	29Y17A1-331d	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08335	JgVu-17	29Y17A1-438	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08336	JgVu-26	29Y26A1-265	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08336_2	JgVu-26	29Y26A1-265	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08337	JgVu-26	29Y26A1-264	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08338	JgVu-26	29Y26A1-266	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08339	JgVu-26	29Y26A1-1576	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08340	JdVh-5	32Y100A1-1589	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-08341	JdVh-5	32Y100A1-1590	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08342	JdVi-1	32Y103A1-3022	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08343	JgVu-5	41Y2A1-2951	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08344	JgVu-5	41Y2A1-2957	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08345	JgVu-5	41Y2A1-2995	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08346	JgVu-5	41Y2A1-2996	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-08347	JgVu-5	41Y2A1-2997	Group Y3	Y3	Bruker Tracer III-V no 510	
AOD-08348	JbVj-1	35Y2A2-635	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Post
AOD-08349	JbVj-1	35Y13E1-19	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Post
AOD-08350	JeVn-1	27Y1A4-1-4	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08351	JeVn-1	27Y1A21-1-705	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08352	JeVn-1	27Y1A10-1-30	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08353	JeVn-1	27Y1A16-475	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08354	JeVn-1	27Y1A16-498	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08355	JeVn	Kluane_misc_007	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-08356	JeVn	Kluane_misc_008	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08415	JhVl-4	JhVl-4:4	Edziza	E1	Bruker Tracer III-V no 510	
AOD-08416	JeUs-42	JeUs-42:705	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08417	JeUs-42	JeUs-42:1417	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-08448	Source Sample	Kluanemisc008	Hoodoo Mountain	M	MURR-INAA	
AOD-08449	JeVn	Kluanemisc001	Hoodoo Mountain	M	MURR-INAA	
AOD-08450	Source Sample	NA	Hoodoo Mountain	J	MURR-INAA	
AOD-08601	JhVf	JhVf	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-08676	KdVo-6	KdVo-6-2706	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08677	KdVo-6	KdVo-6-2133	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08678	KdVo-6	KdVo-6-1986	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08679	KdVo-6	KdVo-6-1807	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08680	KdVo-6	KdVo-6-1820	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08681	KdVo-6	KdVo-6-2031	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08682	KdVo-6	KdVo-6-2590	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08683	KdVo-6	KdVo-6-1689	Edziza	E	Bruker Tracer III-V no 510	
AOD-08684	KdVo-6	KdVo-6-1798	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08685	KdVo-6	KdVo-6-2397	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-08686	KdVo-6	KdVo-6-1887	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08687	KdVo-6	KdVo-6-2142	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08688	KdVo-6	KdVo-6-2394	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08689	KdVo-6	KdVo-6-2240	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08690	KdVo-6	KdVo-6-2607	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08691	KdVo-6	KdVo-6-2618	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08692	KdVo-6	KdVo-6-2714	Wiki Peak	A	Bruker Tracer III-V no 510	Pre

AOD-08693	KdVo-6	KdVo-6-2773	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08694	KdVo-6	KdVo-6-2719	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08695	KdVo-6	KdVo-6-2154	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08696	KdVo-6	KdVo-6-2950	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08697	KdVo-6	KdVo-6-2708	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-08698	KdVo-6	KdVo-6-2690	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08699	KdVo-6	KdVo-6-2705	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08700	KdVo-6	KdVo-6-2559	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08701	KdVo-6	KdVo-6-2702	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08702	KdVo-6	KdVo-6-2543	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08703	KdVo-6	KdVo-6-2547	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-08704	KdVo-6	KdVo-6-2605.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-08707	NcVi-3	NcVi-3:3723	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-08708	NcVi-3	NcVi-3:3749	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-08709	NcVi-3	NcVi-3:3755	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-08710	NcVi-3	NcVi-3:3788	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-08711	NcVi-3	NcVi-3:3841	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-08712	NcVi-3	NcVi-3:3964	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-08713	NcVi-3	NcVi-3:3969	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-08714	NcVi-3	NcVi-3:3975.1	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-08715	NcVi-3	NcVi-3:3975.2	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-08716	NcVi-3	NcVi-3:3986	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-08717	JjVi-7	JjVi-7-0306	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-09285	JfVi-4		Wiki Peak	A	MURR-INAA	
AOD-09286	YUKON		Wiki Peak	A	MURR-INAA	
AOD-09287	YUKON		Wiki Peak	A	MURR-INAA	
AOD-09288	YUKON		Edziza	E	MURR-INAA	
AOD-09289	YUKON		Edziza	E	MURR-INAA	
AOD-09290	KeVe-10		Unassigned	Unassigned	MURR-INAA	
AOD-09291	KaVd-3		Edziza	E	MURR-INAA	
AOD-09292	KaVa-3		Wiki Peak	A	MURR-INAA	
AOD-09293	YUKON		Edziza	E	MURR-INAA	
AOD-09358	MbVn-1	MbVn-1-427	Wiki Peak	A	QuanX-EC	
AOD-09516	JjVi-7	JjVi-7-0129	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09517	JjVi-7	JjVi-7-0459.1	Group Y3	Y3	Bruker Tracer III-V no 510	Pre
AOD-09530	JaUb-6	AY11-2-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-09531	JaUb-5	AY11-3-2	Edziza	E	Bruker Tracer III-V no 510	
AOD-09532	JaUb-1	AY11-7-1	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-09537	JaTo-3	AY11-18-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-09538	JfVi-2	AY11-22-2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09539	JeVb-20	AY11-28-16	Edziza	E	Bruker Tracer III-V no 510	
AOD-09540	JeVb-14	JeVb-14-f	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-09541	JfVg-12	JfVg-12-c	Edziza	E	Bruker Tracer III-V no 510	
AOD-09542	JfVg-12	JfVg-12-l	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-09543	JfVg-12	JfVg-12-i	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09544	JfVg-12	JfVg-12-j	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09545	JfVg-24	JfVg-24-a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09554	Kluane Park	Kluane20120410-01	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09555	29Y50B1	29Y50B1-4a	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-09556	29Y50B1	29Y50B1-4b	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-09557	154Y1A1	154Y1A1-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09558	29Y50B1	29Y50B1-3	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-09559	Kluane Park	Kluane20120410-02	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09560	Kluane Park	Kluane20120410-03	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09561	Kluane Park	Kluane20120410-04	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09576	JbUf-1	JbUf-1	Edziza	E	United Scientific Spectrace	Post
AOD-09577	JcUj-2a	JcUj-2a	Edziza	E	United Scientific Spectrace	Pre
AOD-09578	JcUj-2b	JcUj-2b	Edziza	E	United Scientific Spectrace	Pre
AOD-09579	JcUj-2c	JcUj-2c	Edziza	E	United Scientific Spectrace	Pre
AOD-09580	JcUj-2d	JcUj-2d	Group AH	AH	United Scientific Spectrace	Pre
AOD-09581	JcUj-2e	JcUj-2e	Edziza	E	United Scientific Spectrace	Pre
AOD-09582	JcUj-3	JcUj-3-3	Edziza	E	United Scientific Spectrace	
AOD-09583	JdUq-2	JdUq-2	Edziza	E	United Scientific Spectrace	
AOD-09584	JdUt-4	JdUt-4-15	Edziza	E	United Scientific Spectrace	
AOD-09585	JdUt-4	JdUt-4-26	Edziza	E	United Scientific Spectrace	
AOD-09586	JeUu-1	JeUu-1-10	Edziza	E	United Scientific Spectrace	
AOD-09587	JeUu-1	JeUu-1-37	Edziza	E	United Scientific Spectrace	
AOD-09588	JeUu-2	JeUu-2-10	Edziza	E	United Scientific Spectrace	
AOD-09589	JeUu-2	JeUu-2-11	Edziza	E	United Scientific Spectrace	
AOD-09590	JeUu-2	JeUu-2-13	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09591	JeUu-2	JeUu-2-14	Unassigned	Unassigned	United Scientific Spectrace	
AOD-09592	JeUu-2	JeUu-2-6	Edziza	E	United Scientific Spectrace	
AOD-09593	JeUu-3	JeUu-3-7	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09594	JeUu-7	JeUu-7-11	Wiki Peak	A	United Scientific Spectrace	
AOD-09595	JeUu-7	JeUu-7-12	Wiki Peak	A	United Scientific Spectrace	

AOD-09596	JeUu-7	JeUu-7-13	Wiki Peak	A	United Scientific Spectrace	
AOD-09597	JeUu-8	JeUu-8-5	Edziza	E	United Scientific Spectrace	
AOD-09598	JeUu-9	JeUu-9-1	Wiki Peak	A	United Scientific Spectrace	
AOD-09599	JeUv-1	JeUv-1-04	Edziza	E	United Scientific Spectrace	Pre
AOD-09600	JeUv-1	JeUv-1-11	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09601	JeUv-1	JeUv-1-12	Edziza	E	United Scientific Spectrace	Pre
AOD-09602	JeUv-1	JeUv-1-13a	Edziza	E	United Scientific Spectrace	Pre
AOD-09603	JeUv-1	JeUv-1-13b	Edziza	E	United Scientific Spectrace	Pre
AOD-09604	JeUv-1	JeUv-1-13c	Edziza	E	United Scientific Spectrace	Pre
AOD-09605	JeUv-20	JeUv-20-03	Edziza	E	United Scientific Spectrace	
AOD-09606	JeUv-21	JeUv-21-12	Edziza	E	United Scientific Spectrace	
AOD-09607	JeUv-22	JeUv-22-22	Edziza	E	United Scientific Spectrace	
AOD-09608	JeUv-22	JeUv-22-26	Edziza	E	United Scientific Spectrace	
AOD-09609	JeUv-22	JeUv-22-32	Edziza	E	United Scientific Spectrace	
AOD-09610	JeUv-22	JeUv-22-4	Edziza	E	United Scientific Spectrace	
AOD-09611	JeUv-23	JeUv-23-2	Edziza	E	United Scientific Spectrace	
AOD-09612	JeUv-23	JeUv-23-7	Edziza	E	United Scientific Spectrace	
AOD-09613	JeUv-23	JeUv-23-8	Edziza	E	United Scientific Spectrace	
AOD-09614	JeUv-25	JeUv-25-6	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09615	JeUv-25	JeUv-25-7	Edziza	E	United Scientific Spectrace	
AOD-09616	JeUv-9	JeUv-9-3	Edziza	E	United Scientific Spectrace	
AOD-09617	JeUw-6	JeUw-6-1	Edziza	E	United Scientific Spectrace	
AOD-09618	JeUw-6	JeUw-6-2	Edziza	E	United Scientific Spectrace	
AOD-09619	JeUw-8	JeUw-8-21	Edziza	E	United Scientific Spectrace	
AOD-09620	JeVc-18	JeVc-18-2	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09621	JeVd-4	JeVd-4-36	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09622	JeVd-4	JeVd-4-37	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09623	JeVd-4	JeVd-4-38	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09624	JeVd-4	JeVd-4-41	Wiki Peak	A	United Scientific Spectrace	
AOD-09625	JeVd-4	JeVd-4-44	Wiki Peak	A	United Scientific Spectrace	
AOD-09626	JeVd-4	JeVd-4-48	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09627	JeVd-4	JeVd-4-50	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09628	JeVd-4	JeVd-4-51	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09629	JeVd-4	JeVd-4-52	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09630	JeVd-4	JeVd-4-53	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09631	JeVd-4	JeVd-4-57	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09632	JeVd-4	JeVd-4-58	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09633	JeVd-4	JeVd-4-61	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09634	JeVf-1	JeVf-1-1	Wiki Peak	A	United Scientific Spectrace	
AOD-09635	JeVf-1	JeVf-1-10	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09636	JeVf-1	JeVf-1-17	Batza Tena	B	United Scientific Spectrace	Post
AOD-09637	JeVf-1	JeVf-1-2	Batza Tena	B	United Scientific Spectrace	Post
AOD-09638	JeVf-2	JeVf-2-1	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09639	JfUt-2	JfUt-2-1	Group AH	AH	United Scientific Spectrace	
AOD-09640	JfUu-2	JfUu-2	Edziza	E	United Scientific Spectrace	
AOD-09641	JfUx-7	JfUx-7-10	Edziza	E	United Scientific Spectrace	
AOD-09642	JfVg-1a	JfVg-1a	Edziza	E	United Scientific Spectrace	
AOD-09643	JfVg-1b	JfVg-1b	Edziza	E	United Scientific Spectrace	
AOD-09644	JfVg-1c	JfVg-1c	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09645	JfVg-3a	JfVg-3a	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09646	JfVg-3b	JfVg-3b	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09647	JgVo-1	JgVo-1	Edziza	E	United Scientific Spectrace	
AOD-09648	JgVp-1	JgVp-1	Wiki Peak	A	United Scientific Spectrace	
AOD-09649	JgVp-1a	JgVp-1a	Wiki Peak	A	United Scientific Spectrace	
AOD-09650	JgVp-2	JgVp-2-06	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09651	JhVp-1	JhVp-1-15	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09652	JhVp-1	JhVp-1-2	Wiki Peak	A	United Scientific Spectrace	
AOD-09653	JhVp-1	JhVp-1-24	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09654	JhVp-1	JhVp-1-28a	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09655	JhVp-1	JhVp-1-28b	Edziza	E	United Scientific Spectrace	
AOD-09656	JhVr-2	JhVr-2-13	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09657	JhVr-2	JhVr-2-16	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09658	JhVr-2	JhVr-2-19	Wiki Peak	A	United Scientific Spectrace	Pre
AOD-09659	JhVr-2	JhVr-2-20	Hoodoo Mountain	M	United Scientific Spectrace	Pre
AOD-09660	JiUw-6	JiUw-6-1	Wiki Peak	A	United Scientific Spectrace	
AOD-09661	JiUx-1	JiUx-1-1	Wiki Peak	A	United Scientific Spectrace	
AOD-09662	JiVa-4	JiVa-4-4	Group AH	AH	United Scientific Spectrace	
AOD-09663	KbVa-4	KbVa-4-9	Hoodoo Mountain	M	United Scientific Spectrace	
AOD-09664	KcVb-1a	KcVb-1a-7	Unassigned	Unassigned	United Scientific Spectrace	
AOD-09750	JeUs-42	JeUs-42-1472	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09751	JeUs-42	JeUs-42-1388	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09752	JeUs-42	JeUs-42-1389	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09753	JeUs-42	JeUs-42-1390	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09754	JeUs-42	JeUs-42-1391	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09755	JeUs-42	JeUs-42-1430	Wiki Peak	A	Bruker Tracer III-V no 510	Pre

AOD-09756	JeUs-42	JeUs-42-1425	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09757	JeUs-42	JeUs-42-1400	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09758	JeUs-42	JeUs-42-1378	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09759	JeUs-42	JeUs-42-1379	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09760	JeUs-42	JeUs-42-1377	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09761	JeUs-42	JeUs-42-573	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09762	JeUs-42	JeUs-42-539	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09763	KcVo-1	KcVo-1-9	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09764	KdVo-3	KdVo-3-39	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09765	KdVc-2	KdVc-2-35	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09766	LcVn-2	LcVn-2-2339	Group A’	A’	Bruker Tracer III-V no 510	Post
AOD-09767	LcVn-2	LcVn-2-2400	Group A’	A’	Bruker Tracer III-V no 510	Pre
AOD-09768	KkTw-1	KkTw-1-309	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09769	KkTw-1	KkTw-1-350-378	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09770	KkTw-1	KkTw-1-379-399	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09771	KdVa-8	KdVa-8-516	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-09772	KeVe-2	KeVe-2-851	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-09773	KeVe-2	KeVe-2-1191	Group A’	A’	Bruker Tracer III-V no 510	Post
AOD-09774	KeVe-2	KeVe-2-1479	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09775	JaUd-13	JaUd-13-5	Edziza	E	Bruker Tracer III-V no 510	
AOD-09776	JaUd-14	JaUd-14-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-09777	JaUd-3	JaUd-3-18	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09778	JaUd-11	JaUd-11-3	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09779	JaUd-10	JaUd-10-6	Group AH	AH	Bruker Tracer III-V no 510	Pre
AOD-09780	JaUd-10	JaUd-10-10	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09781	JaUd-10	JaUd-10-12	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-09782	JaUd-10	JaUd-10-11	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09783	JaUd-10	JaUd-10-40	Edziza	E	Bruker Tracer III-V no 510	
AOD-09784	JaUd-10	JaUd-10-53	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-09785	JeUs-28	JeUs-28-47	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-09786	JbUd-8	JbUd-8-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-09787	JaUe-7	JaUe-7-1	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09788	KeVi-6	KeVi-6-3	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-09789	KdVi-1	KdVi-1-17	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-09790	JfVg-24	JfVg-24-14	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-09791	JfVc-1	JfVc-1-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09792	LaVk-2	LaVk-2-1710a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09793	KhVc-1	KhVc-1-6	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09794	KhVc-1	KhVc-1-8	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09795	JdUr-4	JdUr-4-7a	Edziza	E	Bruker Tracer III-V no 510	
AOD-09796	JdUr-4	JdUr-4-7b	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09797	JcUw-4	JcUw-4-24	Edziza	E	Bruker Tracer III-V no 510	
AOD-09798	JcUw-4	JcUw-4-5	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-09799	JeUs-3	JeUs-3-9	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09800	JeUs-3	JeUs-3-8	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09801	JeUs-3	JeUs-3 pit 2a	Edziza	E	Bruker Tracer III-V no 510	
AOD-09802	JeUs-3	JeUs-3 pit 2b	Edziza	E	Bruker Tracer III-V no 510	
AOD-09803	JeUs-3	JeUs-3 pit 2c	Edziza	E	Bruker Tracer III-V no 510	
AOD-09804	JeUs-3	JeUs-3 pit 2d	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09805	JeUs-3	JeUs-3 pit 2e	Edziza	E	Bruker Tracer III-V no 510	
AOD-09806	JeUs-3	JeUs-3 low knoll a	Edziza	E	Bruker Tracer III-V no 510	
AOD-09807	JeUs-3	JeUs-3 low knollb	Edziza	E	Bruker Tracer III-V no 510	
AOD-09808	JeUs-3	JeUs-3 low knoll c	Edziza	E	Bruker Tracer III-V no 510	
AOD-09809	JjVu-4	JjVu-4-31a	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09810	JjVu-4	JjVu-4-31b	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09811	KbVo-2	KbVo-2-13	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-09812	KbVo-2	KbVo-2-12	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09813	KbVo-2	KbVo-2-3	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09814	KaVn-2	KaVn-2-28	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09815	KaVn-2	KaVn-2-59	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-09816	KaVn-2	KaVn-2-23	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09817	JeUn-20	JeUn-20-7	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-09818	JeUn-8	JeUn-8-1	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09820b	JeUs-42	JeUs-42-4	Group AH	AH	Bruker Tracer III-V no 510	Pre
AOD-09821	JeUs-43	JeUs-43-3	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-09822	JfUp-16	JfUp-16-5	Edziza	E	Bruker Tracer III-V no 510	
AOD-09823	JfUp-16	JfUp-16-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-09824	JfUp-7	JfUp-7-1a	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-09825	JfUp-7	JfUp-7-1b	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09826	JeUn-1	JeUn-1-175	Group Y1	Y1	Bruker Tracer III-V no 510	
AOD-09827	JeUn-1	JeUn-1-174	Group AH	AH	Bruker Tracer III-V no 510	
AOD-09828	JeUn-1	JeUn-1-176a	Edziza	E	Bruker Tracer III-V no 510	
AOD-09829	KfVk-5	KfVk-5-1	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-09830	JeUn-18	JeUn-18-1	Edziza	E1	Bruker Tracer III-V no 510	
AOD-09831	KhVl-2	KhVl-2-6	Wiki Peak	A	Bruker Tracer III-V no 510	Pre

AOD-09832	KfVj-2	KfVj-2-1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-09833	KfVk-1	KfVk-1-16	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09834	KgVn-1	KgVn-1-2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09835	KgVn-1	KgVn-1-3	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-09836	JeVk-7	JeVk-7-2a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-09837	JeVk-7	JeVk-7-2b	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10114	KdVo-6	KdVo-6-3207	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10116	KdVo-6	KdVo-6-3224	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10117	KdVo-6	kdVo-6-3228	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10118	KdVo-6	KdVo-6-3231	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10119	KdVo-6	KdVo-6-3235	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10120	KdVo-6	KdVo-6-3241	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10122	KdVo-6	KdVo-6-3252	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10123	KdVo-6	KdVo-6-3256	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10124	KdVo-6	KdVo-6-3355	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10125	KdVo-6	KdVo-6-3360	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10126	KdVo-6	KdVo-6-3367	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10127	KdVo-6	KdVo-6-3368	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10128	KdVo-6	KdVo-6-3378	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10129	KdVo-6	KdVo-6-3383	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10130	KdVo-6	KdVo-6-3431	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10131	KdVo-6	KdVo-6-3456	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10133	KdVo-6	KdVo-6-3482	Unassigned	Unassigned	Bruker Tracer III-V no 510	Pre
AOD-10134	KdVo-6	KdVo-6-3483	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10135	KdVo-6	kdVo-6-3586	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10136	KdVo-6	KdVo-6-3587	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10137	KdVo-6	KdVo-6-3588	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10138	KdVo-6	KdVo-6-3589	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10139	KdVo-6	KdVo-6-2894	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10140	KdVo-6	KdVo-6-2901	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10141	KdVo-6	KdVo-6-2910	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10142	KdVo-6	KdVo-6-3626	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-10143	KdVo-6	KdVo-6-3653	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10144	KdVo-6	KdVo-6-3654	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10145	KdVo-6	KdVo-6-3686	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10146	KdVo-6	KdVo-6-3693	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10147	KdVo-6	KdVo-6-3695	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10148	KdVo-6	KdVo-6-3709	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10149	KdVo-6	KdVo-6-3716	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10150	KdVo-6	KdVo-6-3718	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10151	KdVo-6	KdVo-6-3720	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-10152	KdVo-6	KdVo-6-3807	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10153	KdVo-6	KdVo-6-3809	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10154	KdVo-6	KdVo-6-3810	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10155	KdVo-6	KdVo-6-3813	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10156	KdVo-6	KdVo-6-3816	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10157	KdVo-6	KdVo-6-3822	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10158	KdVo-6	KdVo-6-3824	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10159	KdVo-6	KdVo-6-3829	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10160	KdVo-6	KdVo-6-3844	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10161	KdVo-6	KdVo-6-4088	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10162	KdVo-6	KdVo-6-4090	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10163	KdVo-6	KdVo-6-4021	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10164	KdVo-6	KdVo-6-4135	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10165	KdVo-6	KdVo-6-4136	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10166	KdVo-6	KdVo-6-4140	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10167	KdVo-6	KdVo-6-4144	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10168	KdVo-6	KdVo-6-4146	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10169	KdVo-6	KdVo-6-4148	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10170	KdVo-6	KdVo-6-4149	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10171	KdVo-6	KdVo-6-4150	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10172	KdVo-6	KdVo-6-4151	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10173	KdVo-6	KdVo-6-4201	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10174	KdVo-6	KdVo-6-4213	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10175	KdVo-6	KdVo-6-4214	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10176	KdVo-6	KdVo-6-4215	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10177	KdVo-6	KdVo-6-4216	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10178	KdVo-6	KdVo-6-4221	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10179	KdVo-6	KdVo-6-4224	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10180	KdVo-6	KdVo-6-4229	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10181	KdVo-6	KdVo-6-4154	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10183	KdVo-6	KdVo-6-4166	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10184	KdVo-6	KdVo-6-4167	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10185	KdVo-6	KdVo-6-4168	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10186	JhVn-2	JhVn-2:48	Edziza	E	Bruker Tracer III-V no 510	Pre

AOD-10187	JbUn-24	JbUn-24	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10188	JbVf-6	JbVf-6:13	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10189	JdUs-1	JdUs-1:5	Edziza	E	Bruker Tracer III-V no 510	
AOD-10190	KdVf-6	KdVf-6:10	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10191	KdVi-1	KdVi-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10192	KhVo-1	KhVo-1:2	Group AH	AH	Bruker Tracer III-V no 510	Pre
AOD-10193	KiVm-1	KiVm-1:7	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10194	KjVi-1	KjVi-1:3	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10195	KkVf-5	KkVf-5:2	Edziza	E	Bruker Tracer III-V no 510	
AOD-10196	LcVn-17	LcVn-17:1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-10197	KeVd-6	KeVd-6:35	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10198	JaUk-28	JaUk-28:10	Edziza	E	Bruker Tracer III-V no 510	
AOD-10199	JaUk-28	JaUk-28:18,19,20	Edziza	E	Bruker Tracer III-V no 510	
AOD-10200	JaUk-28	JaUk-28:7	Edziza	E	Bruker Tracer III-V no 510	
AOD-10201	KdVf-14	KdVf-14:2	Batza Tena	B	Bruker Tracer III-V no 510	
AOD-10202	KeVf-3	KeVf-3:39	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-10203	KdVi-2	KdVi-2:30	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-10204	KdVi-2	KdVi-2:26	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-10205	KdVi-2	KdVi-2:57	Group Y1	Y1	Bruker Tracer III-V no 510	Post
AOD-10206	KdVi-2	KdVi-2:31	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10209	KeVd-3	KeVd-3:8	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10210	KeVd-3	KeVd-3:9	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10211	KeVd-3	KeVd-3:16	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10212	KeVd-3	KeVd-3:7	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-10213	KeVd-3	KeVd-3:10	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10214	KeVd-3	KeVd-3:6	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-10215	KeVi-14	KeVi-14:3	Edziza	E	Bruker Tracer III-V no 510	
AOD-10216	KeVi-14	KeVi-14:2	Edziza	E	Bruker Tracer III-V no 510	
AOD-10217	KeVi-14	KeVi-14:1	Edziza	E	Bruker Tracer III-V no 510	
AOD-10218	KeVi-14	KeVi-14:4	Edziza	E	Bruker Tracer III-V no 510	
AOD-10219	KdVi-2	KdVi-2:18	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10220	KdVi-2	KdVi-2:18.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10221	JdUs-16	M13 CWL-SB11.1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-10222	JeUs-67	M13-NUCB-3.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-10223	JdUs-18	M13-S-UCB-5.1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-10224	JeUs-69	M13-NUCB-5.2	Edziza	E	Bruker Tracer III-V no 510	
AOD-10225	JeUs-66	M13-NUCB-TH2.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-10226	JdUs-2	JdUs-2.1	Edziza	E	Bruker Tracer III-V no 510	
AOD-10227	JdUs-7	M13 CWL SB2.1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10394	MaVc-3	MaVc-3:4	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10395	JeUs-44	JeUs-44:626	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10396	JeUs-44	JeUs-44:N36.5W69.5	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10397	JeUn-1	JeUn-1:6	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-10398	JeUn-11	JeUn-11:2	Edziza	E1	Bruker Tracer III-V no 510	Post
AOD-10399	JfVg-34	JfVg-34:6	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10400	Yukon	92.12.07	Group AH	AH	Bruker Tracer III-V no 510	
AOD-10401	JeUs-6	JeUs-6:88	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10402	JeUs-6	JeUs-6:89	Edziza	E	Bruker Tracer III-V no 510	
AOD-10403	JeUs-6	JeUs-6:90	Edziza	E	Bruker Tracer III-V no 510	
AOD-10404	JeUs-6	JeUs-6:91	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10405	JcUr-11	JcUr-11:11	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10406	JiVd-1	JiVd-1:26	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10407	JbVf-6	JbVf-6:2a	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-10683	JdUt-3	JdUt-3:797	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10684	JdUt-3	JdUt-3:784	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10685	JdUt-3	JdUt-3:888	Edziza	E	Bruker Tracer III-V no 510	
AOD-10686	JdUt-3	JdUt-3:890	Edziza	E4	Bruker Tracer III-V no 510	
AOD-10687	KfVj-4	KfVj-4:1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10688	KfVi-3	KfVi-3:93	Batza Tena	B	Bruker Tracer III-V no 510	Pre
AOD-10689	KfVi-3	KfVi-3:378	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10690	KfVi-3	KfVi-3:726	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10691	KdVi-1	KdVi-1:23	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10692	KdVi-1	KdVi-1:25	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10693	KdVi-1	KdVi-1:118	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10694	KdVi-1	KdVi-1:120	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10695	KdVi-6	KdVi-6:150	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10696	KdVi-6	KdVi-6:151	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10697	KdVi-6	KdVi-6:152	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10772	KdVo-6	KdVo-6-2135	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10773	KdVo-6	KdVo-6-2129	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10774	KdVo-6	KdVo-6-2130	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10775	KdVo-6	KdVo-6-2132	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10776	KdVo-6	KdVo-6-2141	Edziza	E1	Bruker Tracer III-V no 510	Post
AOD-10777	KdVo-6	KdVo-6-2143	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10778	KdVo-6	KdVo-6-2155	Wiki Peak	A	Bruker Tracer III-V no 510	Post

AOD-10779	KdVo-6	KdVo-6-2167	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10780	KdVo-6	KdVo-6-2170	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10781	KdVo-6	KdVo-6-2171	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10782	KdVo-6	KdVo-6-2211.01	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10783	KdVo-6	KdVo-6-2211.02	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10784	KdVo-6	KdVo-6-2211.03	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10785	KdVo-6	KdVo-6-2409	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10786	KdVo-6	KdVo-6-2455	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10787	KdVo-6	KdVo-6-2471	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10788	KdVo-6	KdVo-6-2501	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10789	KdVo-6	KdVo-6-2506	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10790	KdVo-6	KdVo-6-2513.01	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10791	KdVo-6	KdVo-6-2513.02	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10792	KdVo-6	KdVo-6-2513.03	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10793	KdVo-6	KdVo-6-2513.04	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10794	KdVo-6	KdVo-6-2514	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10795	KdVo-6	KdVo-6-2565	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10796	KdVo-6	KdVo-6-2569	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10797	KdVo-6	KdVo-6-2583	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10798	KdVo-6	KdVo-6-2597	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10799	KdVo-6	KdVo-6-2598	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10800	KdVo-6	KdVo-6-2599	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10801	KdVo-6	KdVo-6-2603	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10802	KdVo-6	KdVo-6-2604	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10803	KdVo-6	KdVo-6-2610.01	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10804	KdVo-6	KdVo-6-2610.02	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10805	KdVo-6	KdVo-6-2610.03	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10806	KdVo-6	KdVo-6-2610.04	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10807	KdVo-6	KdVo-6-2610.05	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10808	KdVo-6	KdVo-6-2610.06	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10809	KdVo-6	KdVo-6-2610.07	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10810	KdVo-6	KdVo-6-2610.08	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10811	KdVo-6	KdVo-6-2610.09	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10812	KdVo-6	KdVo-6-2610.10	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10813	KdVo-6	KdVo-6-2610.11	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10814	KdVo-6	KdVo-6-2610.12	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10815	KdVo-6	KdVo-6-2610.13	Unassigned	Unassigned	Bruker Tracer III-V no 510	Pre
AOD-10816	KdVo-6	KdVo-6-2610.14	Unassigned	Unassigned	Bruker Tracer III-V no 510	Pre
AOD-10817	KdVo-6	KdVo-6-2610.15	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10818	KdVo-6	KdVo-6-2610.16	Unassigned	Unassigned	Bruker Tracer III-V no 510	Pre
AOD-10819	KfVi-3	KfVi-3:1005	Hoodoo Mountain	J1	Bruker Tracer III-V no 510	Pre
AOD-10820	KfVi-3	KfVi-3:1046	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10821	KfVi-3	KfVi-3:1101	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10822	KfVi-3	KfVi-3:1105	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10823	KfVi-3	KfVi-3:1344	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-10824	JdUs-21	JdUs-21:2	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10825	KkTw-10	KkTw-10:2	Edziza	E	Bruker Tracer III-V no 510	
AOD-10826	JlWf-2	JlWf-2:7	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10827	JlVa-1	JlVa-1:2	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Post
AOD-10828	KeVg-3	KeVg-3:2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10829	KeVg-4	KeVg-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-10830	KdVf-10	KdVf-10:1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10831	Haines Road	Haines Road	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-10831-2	Haines Road	Haines Road	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-10832	JaUa-1	JaUa-1:1	Edziza	E	Bruker Tracer III-V no 510	
AOD-10833	JiTp-1	JiTp-1:24	Edziza	E	Bruker Tracer III-V no 510	
AOD-10834	JiTp-1	JiTp-1:43	Edziza	E	Bruker Tracer III-V no 510	
AOD-10835	KdTD-2	KdTd-2:7	Edziza	E	Bruker Tracer III-V no 510	
AOD-10836	KdTD-2	KdTd-2:15	Edziza	E1	Bruker Tracer III-V no 510	
AOD-10837	KdTd-3	KdTd-3:3	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-10838	KdTd-3	KdTd-3:4	Edziza	E1	Bruker Tracer III-V no 510	
AOD-10839	KdTd-3	KdTd-3:6	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10840	KdTd-3	KdTd-3:8	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-10841	KdVo-6	KdVo-6-2611.1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10842	KdVo-6	KdVo-6-2611.2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10843	KdVo-6	KdVo-6-2616	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10844	KdVo-6	KdVo-6-2630	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10845	KdVo-6	KdVo-6-2662.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10846	KdVo-6	KdVo-6-2662.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10847	KdVo-6	KdVo-6-2673	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10848	KdVo-6	KdVo-6-2695	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10849	KdVo-6	KdVo-6-2722	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10850	KdVo-6	KdVo-6-2763	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10851	KdVo-6	KdVo-6-2764.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10852	KdVo-6	KdVo-6-2764.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre

AOD-10853	KdVo-6	KdVo-6-2765.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10854	KdVo-6	KdVo-6-2765.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10855	KdVo-6	KdVo-6-2798	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10856	KdVo-6	KdVo-6-2808	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10857	KdVo-6	KdVo-6-2832	Edziza	E1	Bruker Tracer III-V no 510	Pre
AOD-10858	KdVo-6	KdVo-6-2844	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10859	KdVo-6	KdVo-6-2883	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10860	KdVo-6	KdVo-6-2945	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10861	KdVo-6	KdVo-6-2968	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10862	KdVo-6	KdVo-6-2996	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10863	KdVo-6	KdVo-6-0158	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-10864	KdVo-6	KdVo-6-276.1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10865	KdVo-6	KdVo-6-276.2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10866	KdVo-6	KdVo-6-0327.1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10867	KdVo-6	KdVo-6-0327.2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10868	KdVo-6	KdVo-6-0320	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10869	KdVo-6	KdVo-6-0273.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10870	KdVo-6	KdVo-6-0273.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10871	KdVo-6	KdVo-6-0269	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10872	KdVo-6	KdVo-6-0431	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10873	KdVo-6	KdVo-6-0304	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10874	KdVo-6	KdVo-6-0318	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10875	KdVo-6	KdVo-6-0150	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10876	KdVo-6	KdVo-6-2654	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10877	KdVo-6	KdVo-6-0309	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10878	KdVo-6	KdVo-6-3923	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10879	KdVo-6	KdVo-6-3925	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10880	KdVo-6	KdVo-6-3920	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10881	KdVo-6	KdVo-6-3910	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10882	KdVo-6	KdVo-6-3898	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10883	KdVo-6	KdVo-6-3003	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10884	KdVo-6	KdVo-6-3896	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10885	KdVo-6	KdVo-6-3077	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10886	KdVo-6	KdVo-6-3080	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10887	KdVo-6	KdVo-6-3081	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10888	KdVo-6	KdVo-6-3486	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10889	KdVo-6	KdVo-6-3886	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10890	KdVo-6	KdVo-6-3887	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10891	KdVo-6	KdVo-6-3888	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10892	KdVo-6	KdVo-6-3892	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10893	KdVo-6	KdVo-6-3895	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10894	KdVo-6	KdVo-6-3882	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10895	KdVo-6	KdVo-6-3877	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10896	KdVo-6	KdVo-6-3928	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10897	KdVo-6	KdVo-6-3930	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10898	KdVo-6	KdVo-6-3931	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10899	KdVo-6	KdVo-6-3935	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10900	KdVo-6	KdVo-6-3937	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10901	KdVo-6	KdVo-6-3939	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10902	KdVo-6	KdVo-6-3852	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10903	KdVo-6	KdVo-6-3612	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10904	KdVo-6	KdVo-6-3609	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10905	KdVo-6	KdVo-6-3604	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10906	KdVo-6	KdVo-6-3608	Unassigned	Unassigned	Bruker Tracer III-V no 510	Pre
AOD-10907	KdVo-6	KdVo-6-3597	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10908	KdVo-6	KdVo-6-0451	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10909	KdVo-6	KdVo-6-0502	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10910	KdVo-6	KdVo-6-0520	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10911	KdVo-6	KdVo-6-0606	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10912	KdVo-6	KdVo-6-0818.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10913	KdVo-6	KdVo-6-0818.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10914	KdVo-6	KdVo-6-0818.3	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10915	KdVo-6	KdVo-6-1319	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10916	KdVo-6	KdVo-6-1323.1	Group Y3	Y3	Bruker Tracer III-V no 510	Post
AOD-10917	KdVo-6	KdVo-6-1323.2	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10918	KdVo-6	KdVo-6-1323.3	Group Y3	Y3	Bruker Tracer III-V no 510	Post
AOD-10919	KdVo-6	KdVo-6-1325.1	Group Y3	Y3	Bruker Tracer III-V no 510	Post
AOD-10920	KdVo-6	KdVo-6-1325.2	Group Y3	Y3	Bruker Tracer III-V no 510	Post
AOD-10921	KdVo-6	KdVo-6-1325.3	Group Y3	Y3	Bruker Tracer III-V no 510	Post
AOD-10922	KdVo-6	KdVo-6-1325.4	Group Y3	Y3	Bruker Tracer III-V no 510	Post
AOD-10923	KdVo-6	KdVo-6-1347	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10924	KdVo-6	KdVo-6-1347.01	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-10924b	KdVo-6	KdVo-6-1347.01	Unassigned	Unassigned	Bruker Tracer III-V no 510	
AOD-10925	KdVo-6	KdVo-6-1347.02	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10926	KdVo-6	KdVo-6-1347.03	Group Y3	Y3	Bruker Tracer III-V no 510	Pre

AOD-10927	KdVo-6	KdVo-6-1347.04	Group Y3	Y3	Bruker Tracer III-V no 510	Pre
AOD-10928	KdVo-6	KdVo-6-1354.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10929	KdVo-6	KdVo-6-1354.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10930	KdVo-6	KdVo-6-1354.3	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10931	KdVo-6	KdVo-6-1354c	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10932	KdVo-6	KdVo-6-1433.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10933	KdVo-6	KdVo-6-1433.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10934	KdVo-6	KdVo-6-1416	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10935	KdVo-6	KdVo-6-1406	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10936	KdVo-6	KdVo-6-1469	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10937	KdVo-6	KdVo-6-1441	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10938	KdVo-6	KdVo-6-1492	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10939	KdVo-6	KdVo-6-0904	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10940	KdVo-6	KdVo-6-1699	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10941	KdVo-6	KdVo-6-1583	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10942	KdVo-6	KdVo-6-1795	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10943	KdVo-6	KdVo-6-1787	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10944	KdVo-6	KdVo-6-1902	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10945	KdVo-6	KdVo-6-1908	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10946	KdVo-6	KdVo-6-1910	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10947	KdVo-6	KdVo-6-1912.1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-10948	KdVo-6	KdVo-6-1912.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10949	KdVo-6	KdVo-6-1912.3	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10950	KdVo-6	KdVo-6-1891	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10951	KdVo-6	KdVo-6-1885	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10952	KdVo-6	KdVo-6-1880.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10953	KdVo-6	KdVo-6-1880.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10954	KdVo-6	KdVo-6-1785	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10955	KdVo-6	KdVo-6-1829	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10956	KdVo-6	KdVo-6-1789	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10957	KdVo-6	KdVo-6-1631	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-10958	KdVo-6	KdVo-6-1628	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10959	KdVo-6	KdVo-6-1621.1	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10960	KdVo-6	KdVo-6-1621.2	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10961	KdVo-6	KdVo-6-1622	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-10962	KdVo-6	KdVo-6-1531.1	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10963	KdVo-6	KdVo-6-1531.2	Wiki Peak	A	Bruker Tracer III-V no 510	Post
AOD-10964	KdVo-6	KdVo-6-1525	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10965	KdVo-6	KdVo-6-1524	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10966	KdVo-6	KdVo-6-1523	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10967	KdVo-6	KdVo-6-1522	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10968	KdVo-6	KdVo-6-1521	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-10969	KdVo-6	KdVo-6-1501	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-12032	JcUj-21	YK27:129	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12033	JcUj-21	YK27:147	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12034	JcUj-21	YK27:150	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12035	JcUh-9	YK22:4	Edziza	E	Bruker Tracer III-V no 510	
AOD-12036	JeUu-25	YK7:1	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-12037	JcUj-21	YK27:148	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12038	JcUm-2	JcUm-2:176	Edziza	E	Bruker Tracer III-V no 510	
AOD-12039	JeUu-26	YK9:1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12040	JbUe-5	YK37:2	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12041	JcUm-2	JcUm-2:153	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12042	JeUu-3	JeUu-3:59	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-12043	JcUm-2	JcUm-2:58	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12044	JjVu-5	JjVu-5:1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-12045	JeVd-6	JeVd-6:a	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12046	JeVb-14	JeVb-14:e	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12053	JeUn-1	JeUn-1-14	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12054	JeUn-1	JeUn-1-157	Edziza	E3	Bruker Tracer III-V no 510	Post
AOD-12055	JeUn-1	JeUn-1-157	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-12056	JeUn-1	JeUu-1-181	Group AH	AH	Bruker Tracer III-V no 510	Pre
AOD-12057	JeUn-1	JeUn-1-317	Edziza	E	Bruker Tracer III-V no 510	
AOD-12058	JeUn-1	JeUn-1-324	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-12059	JeUn-1	JeUn-1-368	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12060	JeUn-1	JeUn-1-372	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12061	JeUn-1	JeUn-1-373	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12062	JeUn-1	JeUn-1-374	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-12063	JeUn-1	JeUn-1-376	Edziza	E	Bruker Tracer III-V no 510	
AOD-12064	JeUn-1	JeUn-1-378	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-12065	JeUn-1	JeUn-1-389	Edziza	E	Bruker Tracer III-V no 510	Pre
AOD-12066	JeUn-1	JeUn-1-531	Group AH	AH	Bruker Tracer III-V no 510	Pre
AOD-12067	JeUn-1	JeUn-1-535	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-12068	JeUn-10	JeUn-10-6	Edziza	E	Bruker Tracer III-V no 510	
AOD-12069	JeUn-10	JeUn-10-35a	Edziza	E	Bruker Tracer III-V no 510	

AOD-12070	JeUn-17	JeUn-17-1	Edziza	E	Bruker Tracer III-V no 510	
AOD-12071	JeUs-42	JeUs-42-1628	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-12072	JeUs-42	JeUs-42-1810	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-12073	JeUs-44	JeUs-44-7	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Pre
AOD-12074	JeUo-11	JeUo-11-7	Hoodoo Mountain	M	Bruker Tracer III-V no 510	Post
AOD-12075	JeUo-12	JeUo-12-14	Wiki Peak	A	Bruker Tracer III-V no 510	Pre
AOD-12076	JfUp-13	JfUp-13-2	Edziza	E	Bruker Tracer III-V no 510	
AOD-12077	JfUp-14	JfUp-14-1	Edziza	E	Bruker Tracer III-V no 510	Post
AOD-12078	JeVk-7	JeVk-7-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12079	JeVk-7	JeVk-7-3	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12080	JeVh-2	JeVh-2-1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	
AOD-12081	JeVh-1	JeVh-1-1	Hoodoo Mountain	M	Bruker Tracer III-V no 510	
AOD-12082	KhVm-6	KhVm-6-4	Wiki Peak	A	Bruker Tracer III-V no 510	
AOD-12083	LbTp-2	LbTp-2-4	Edziza	E	Bruker Tracer III-V no 510	
AOD-12084	JeVh-2	JeVh-2-1	Hoodoo Mountain	J	Bruker Tracer III-V no 510	Pre
AOD-12085	JeVk-7	JeVk-7-3	Hoodoo Mountain	M	Bruker Tracer III-V no 510	

APPENDIX B – Tertiary Hills Clinker provenance results

Category	Project ID	Catalogue/Field Number	Element									
			Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
Flat Top Mountain Clinker Outcrop	FTMC 1	Cut 1	343	10573	84	15	19	186	68	34	195	14
	FTMC 2	Cut 2	337	10469	85	17	20	194	76	35	194	14
	FTMC 3	Cut 3	346	10576	86	15	20	192	80	36	192	15
	FTMC 4	Cut 4	354	11034	86	15	19	189	72	34	190	14
	FTMC 5	Cut 5	290	11008	84	15	20	190	74	33	193	15
	FTMC 6	Cut 6	330	10625	85	17	18	200	79	37	199	14
	FTMC 7	Cut 7	373	9827	68	14	17	190	88	34	191	14
	FTMC 8	Black Striped	318	11373	105	16	20	191	80	35	203	14
	FTMC 9	Pale Grey 2	314	11855	84	17	20	141	84	35	196	15
	FTMC 10	Pale Grey 3	332	8944	42	14	19	197	52	34	170	13
	FTMC 11	Pale Grey 4	315	10227	87	16	22	192	85	33	191	14
	FTMC 12	Glassy White	366	11239	50	17	19	190	90	37	203	15
Non-Volcanic Natural Glass Outcrop	NVNG 1	TK-67	239	10099	65	19	23	194	10	65	215	52
	NVNG 2	Red Black Type 2-S	490	13185	102	37	33	189	20	66	212	57
	NVNG 3	Red Black Type 2-L	444	12365	98	39	34	190	17	69	212	57
	NVNG 4	Red Black Type 1-S	453	13312	106	43	37	209	20	72	227	59
	NVNG 5	Red Black Type 1-L	575	14375	120	37	37	209	20	72	229	57
	NVNG 6	Red 2	480	15141	120	46	41	225	19	79	237	65
	NVNG 7	Red 1	442	11953	97	35	32	190	17	66	200	56
	NVNG 8	Opaque Black	439	12901	92	37	30	189	28	67	211	55
	NVNG 9	Gray	433	12536	65	35	31	191	17	66	208	54
	NVNG 10	Glassy Black	482	13002	93	38	34	196	20	66	207	56
Tertiary Hills Outcrop	THC 1	LcRq-7:5	414	10655	97	21	18	302	26	23	113	11
	THC 2	LdRr-1:3	344	34637	341	24	18	277	41	30	166	19
	THC 3	LcRq-7:42	356	13026	78	22	17	299	38	25	111	11
	THC 4	LdRr-2:1	422	9831	130	26	18	347	8	43	144	18
	THC 5	LcRq-7:9	477	10634	181	29	20	368	23	27	124	14
	THC 6	LdRr-2:5	413	9380	111	22	18	332	8	44	144	20
	THC 7	LdRr-1:3	339	36477	384	28	16	279	35	34	181	17
	THC 8	LcRq-7:42	482	9699	179	26	19	342	23	24	121	11
	THC 9	H06 112:1	387	10940	137	23	16	235	29	24	140	13
	THC 10	H06 112:2	319	8831	83	22	13	187	25	24	123	12
	THC 11	H06 112:1	394	9251	94	15	18	195	27	25	125	12
	THC 12	H06 112:1a	377	9033	88	13	15	199	27	25	123	11
	THC 13	H06 112:1b	340	9192	95	16	17	199	26	23	125	11
	THC 14	H06 112:1c	377	9443	91	17	16	196	27	26	130	11
	THC 15	H06 112:2 grey	351	9398	74	16	18	313	28	25	121	10
	THC 16	H06 112:2 toffee	408	9029	76	19	20	326	32	27	130	12
	THC 17	H06 112:2 toffee 2	355	8744	76	16	18	327	31	27	127	11
	THC 18	H06 112 grey black	398	9262	66	15	16	232	22	26	108	10
	THC 19	H06 112 brown	396	8994	101	19	17	208	28	27	131	11
	THC 20	H06 112 grey	332	8046	78	15	18	291	23	24	112	10
	THC 21	DP 1	400	7842	53	22	15	270	19	24	110	11
	THC 22	DP 2	349	9264	63	22	19	329	24	26	112	11
	THC 23	DP 3	392	8931	95	21	19	341	25	23	112	12
	THC 24	DP 4	366	10837	74	25	18	364	24	26	118	11
	THC 25	DP 5	375	9772	82	21	17	330	26	26	112	12
	THC 26	DP 6	419	9134	87	20	19	384	24	25	114	12

	THC 27	DP 7	297	9458	73	23	17	348	23	24	114	12
	THC 28	DP 8	366	7400	35	20	16	260	17	25	109	12
	THC 29	DP 9	389	9677	70	22	17	348	23	24	112	11
	THC 30	DP 10	377	8569	67	20	18	342	22	23	110	10
	THC 31	DP 11	360	11391	99	21	14	178	29	25	134	13
	THC 32	DP 12	376	9669	82	22	18	202	26	27	130	13
	THC 33	DP 13	353	9155	79	23	17	207	26	25	127	13
	THC 34	DP 15	388	9514	83	26	16	216	25	28	135	14
	THC 35	DP 16	474	10876	101	32	19	239	31	27	142	14
Montana Porcellanite Outcrop	MP 1	Porc 1	684	31357	69	26	10	138	84	31	177	15
	MP 2	Porc 2	790	42194	121	41	14	191	96	34	203	19
	MP 3	Porc SE 4	796	37237	86	26	12	129	97	29	144	13
	MP 4	Porc SE 6	772	36548	81	24	11	144	98	27	147	14
	MP 5	Porc SE 6	866	52056	84	30	13	123	106	34	179	15
	MP 6	Ox Grey red	308	33210	105	34	26	171	128	32	133	25
	MP 7	Ox Grey	313	24362	173	37	26	157	120	34	148	25
	MP 8	Green Grey	331	26340	183	38	18	120	143	28	120	20
	MP 9	PR 1	1037	50466	142	27	14	150	113	35	168	16
	MP 10	PR 2	729	27739	139	24	16	147	138	36	179	17
Cape Bathurst Artifact / Outcrop	CBC 1	ObRw-1:368	882	8659	70	19	11	148	76	33	166	14
	CBC 2	ObRw-1:364	556	6499	59	22	11	141	75	34	169	13
	CBC 3	Cobble 2	454	97096	1089	50	24	131	371	51	175	24
	CBC 4	Cobble 1	424	76707	957	44	21	123	338	32	168	23
	CBC 5	ObRw-1:476	1195	13805	120	49	29	181	95	43	191	25
	CBC 6	ObRw-1:354	1085	11573	107	45	23	160	85	39	174	22
	CBC 7	ObRw-1:339	894	10224	84	42	24	158	87	39	177	21
Other Artifact (Quartzite, Quartz, Chalcedony, Chert)	OT 1	Quartzite 1	n.d.	960	3	6	n.d.	4	2	4	33	n.d.
	OT 2	Quartzite 2	n.d.	896	3	6	n.d.	4	4	3	29	n.d.
	OT 3	HcQt-1:26 Quartzite 3	n.d.	973	4	5	n.d.	4	1	4	79	1
	OT 4	Quartzite 4	n.d.	1994	n.d.	6	n.d.	6	12	4	32	n.d.
	OT 5	LhRq-1:984.61.130 Quartzite	n.d.	913	29	13	n.d.	4	8	6	36	3
	OT 6	Quartz 1	n.d.	915	5	13	n.d.	3	n.d.	2	19	1
	OT 7	KfTd-4:1 Quartz	n.d.	771	1	6	n.d.	3	n.d.	2	18	n.d.
	OT 8	Cathead Chert	n.d.	751	n.d.	11	n.d.	4	5	2	19	1
	OT 9	Swan River Chert 1	n.d.	904	6	13	n.d.	4	1	2	29	1
	OT 10	Swan River Chert 2	n.d.	856	5	6	n.d.	4	1	2	22	n.d.
	OT 11	HcQt-1:29 Chert	n.d.	4627	19	13	n.d.	26	123	12	71	3
	OT 12	Chert 1	n.d.	1748	4	7	n.d.	9	53	4	29	n.d.
	OT 13	Chert 2	n.d.	839	6	7	n.d.	3	5	4	20	n.d.
	OT 14	Chert 3	53	13621	22	11	1	32	33	9	59	9
	OT 15	Chert 4	n.d.	1119	9	9	n.d.	4	2	2	27	1
	OT 16	2004.064.005 Chalcedony	n.d.	1005	3	8	n.d.	4	2	2	20	n.d.
	OT 17	Chalcedony	n.d.	796	n.d.	10	n.d.	4	15	7	31	1
	OT 18	989.10.10 Chalcedony	n.d.	900	1	9	n.d.	6	3	3	22	n.d.
	OT 19	Missing Link Chert	43	49240	71	17	n.d.	8	16	7	182	6
	OT 20	Missing Link Chert	190	78986	115	22	2	6	20	25	269	17
Northwest Territories Artifact Tertiary Hills Clinker	NWT Art 1	KlRs-13:309-10, 312-15	451	8203	225	21	18	241	22	28	112	12
	NWT Art 2	KlPp-3:25	382	7485	69	20	17	233	16	25	111	12
	NWT Art 3	LgRk-2:988.67.28	387	7387	61	21	13	263	15	26	104	11
	NWT Art 4	LdRo-4:10	356	9194	55	20	16	299	23	23	118	11
	NWT Art 5	LgRk-2:988.67.51	337	7200	79	20	14	225	17	23	106	10
	NWT Art 6	LgRf-1:1	375	8092	98	23	17	298	7	46	152	20
	NWT Art 7	MaRe-5:1	375	8788	68	24	14	258	24	26	119	12
	NWT Art 8	KlRs-8:1	412	10085	142	29	20	344	7	54	163	24
	NWT Art 9	MaRe-11:1	327	8181	66	19	14	296	25	23	114	11
	NWT Art 10	LgRf-2:2	375	9104	114	27	18	301	28	25	122	13
	NWT Art 11	JhRd-9:4	422	9600	86	23	17	309	26	23	119	12
	NWT Art 12	LfRq-4:140a-d	393	9540	97	19	15	253	29	27	121	9
	NWT Art 13	LbRr-1:1	398	9943	183	28	17	314	26	28	125	13

	NWT Art 14	JhRd-3:2	324	8165	61	20	14	260	28	25	120	11
	NWT Art 15	KjPo-30:1	369	9754	75	26	20	348	29	26	129	11
	NWT Art 16	KlRs-20:54	374	9128	66	23	15	298	22	26	117	11
	NWT Art 17	KlRs-2:700	428	11926	73	28	18	366	28	25	132	14
	NWT Art 18	LgRk-2:988.67.263	337	7523	100	19	16	242	17	25	107	11
	NWT Art 19	LbTa-2:35	357	10996	110	24	17	353	32	26	126	11
	NWT Art 20	LbTa-4:6	374	8350	89	22	15	294	22	26	115	12
	NWT Art 21	KlRs-5:227	362	6886	74	22	14	215	16	24	109	12
	NWT Art 22	LcRr-1:3	374	10158	67	21	17	315	28	25	122	12
	NWT Art 23	LdRo-2:42	385	8430	70	21	16	313	26	24	118	12
	NWT Art 24	LcRq-5:28	335	10766	94	21	14	218	30	27	129	13
	NWT Art 25	LcRq-5:36	355	10069	94	21	15	319	29	24	118	10
	NWT Art 26	KgTd-1:ST40	332	8873	55	18	15	310	25	24	117	11
	NWT Art 27	KfTd-3:5	330	11603	64	22	15	278	20	24	110	11
	NWT Art 28	LgRk-2:1	667	11085	128	43	27	282	27	32	117	18
	NWT Art 29	LdRo-2:51	458	12904	117	37	23	176	41	40	136	21
	NWT Art 30	LdRo-2:20	616	11425	96	44	28	308	33	32	124	19
	NWT Art 31	LcRq-5:9	547	15111	146	43	28	273	35	32	138	21
	NWT Art 32	LcRq-5:51	556	14577	150	43	27	328	36	32	129	18
	NWT Art 33	LcRq-5:38	594	16956	154	45	29	276	34	33	136	22
	NWT Art 34	LcRq-5:25	561	13851	139	43	26	256	32	33	134	21
	NWT Art 35	LcRq-5:12	534	14557	135	35	26	300	34	29	120	17
	NWT Art 36	LbTa-2:32	588	13645	178	43	27	350	37	31	129	19
	NWT Art 37	LbTa-2:30	647	14750	187	46	31	364	39	30	130	19
	NWT Art 38	LbTa-2:29	633	14116	120	46	28	332	36	30	126	19
	NWT Art 39	LbTa-2:28	597	13651	152	45	29	338	36	31	127	19
	NWT Art 40	KgTc-1:56	603	11827	90	45	29	287	36	33	133	20
	NWT Art 41	KgTc-1:37	588	10931	142	38	24	243	28	30	110	18
	NWT Art 42	IkQt-2:933P	628	13107	247	32	26	428	9	51	177	22
	NWT Art 43	IkQp-19:1169P	575	12131	184	27	21	317	24	26	136	12
	NWT Art 44	LbTa-4:7	467	10000	104	31	21	340	24	27	133	13
	NWT Art 45	KfTd-9:5	357	9861	75	30	16	198	36	39	135	16
Yukon Artifact Tertiary Hills Clinker	YT Art 1	NcVi-3:3551	588	9843	145	35	24	231	24	31	105	17
	YT Art 2	LdVg-30:8	601	9303	93	35	26	248	23	30	114	17
	YT Art 3	KeVb-18:1	571	9969	72	38	24	255	27	29	112	18
	YT Art 4	KdVa-8:62	497	8448	107	34	24	258	51	30	110	18
	YT Art 5	KdTe-1:8	623	13627	147	44	26	430	35	30	135	16
	YT Art 6	KdTe-1:13	657	11869	119	48	31	327	31	32	125	20
	YT Art 7	KdTe-1:11	635	13789	123	51	32	355	33	33	126	21
	YT Art 8	KdTe-1:10	697	14759	138	52	34	388	37	33	134	22
	YT Art 9	KaVa-3:57	924	20164	231	47	28	335	30	29	121	17
	YT Art 10	KaVa-3:32	648	14346	197	42	28	300	29	31	116	19
Alberta Artifact Tertiary Hills Clinker	AB Art 1	J. Fisher 1	206	9266	68	20	20	183	55	32	143	17
	AB Art 2	GbPt-11:5	318	10048	66	20	20	211	120	23	148	14
	AB Art 3	HhOu-113:34371-34377	426	9803	96	25	16	287	21	27	121	14
	AB Art 4	2004.7A-GMP-3-1	594	11320	457	38	25	287	35	31	121	17
	AB Art 5	HgPd-1:924	630	11490	116	36	23	155	31	30	127	18
	AB Art 6	GPM-2-1	556	14851	140	46	32	259	60	38	125	28
	AB Art 7	GfPt-3:24	631	14169	112	36	35	246	132	28	159	21
	AB Art 8	GfPt-3:20	486	12281	78	37	29	237	138	27	157	22
	AB Art 9	ABARCH-1	547	12399	106	36	26	299	27	28	115	18
	AB Art 10	GdQn-1:9	488	11087	84	20	20	197	103	18	122	12