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ARCHAEOLOGICAL SURVEY OF ALBERTA

OCCASIONAL PAPER NO. 36

Tertiary Hills Clinker in Alberta: A partially fused vesicular toolstone from the Mackenzie Basin of Northwest Territories, Canada

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ABSTRACT

This article is the first in the Alberta Lithic Reference Project series, the goal of which is to assist the identification of raw materials used for pre-contact stone tools in the province. Each article focuses on one raw material; the current article discusses a partially fused, glassy, vesicular rock that originates in Northwest Territories called Tertiary Hills Clinker (THC). THC appears in archaeological sites in northern and central Alberta. A suite of techniques indicates that it can be geochemically sourced much like obsidian. The accurate identification of THC can reveal significant relationships between occupants of Alberta and the Mackenzie Basin to the north.

KEYWORDS

clinker, coal, Alberta Lithic Reference Project, porcellanite, pXRF, fused, glass

1. The Alberta Lithic Reference Project

A lack of published references about pre-contact lithic materials (toolstones) in Alberta has led to inconsistent identifications. This article is one of a series of what will become chapters in a stand-alone Alberta toolstone guide. Each article focuses on a raw material used to make stone tools. A helpful, easy-to-use guide will amplify the utility of data generated by cultural resource management and academic projects; we hope this spurs new research agendas and helps answer questions about the province's past.

2. Introduction: Tertiary Hills Clinker

Tertiary Hills Clinker (THC) is appropriate to begin the toolstone series because it is poorly known, easy to misidentify, and until recently, has eluded accurate geological identification. It was first noted by MacNeish (1954:248) who called it Keele River Obsidian owing to its translucent, glassy nature, and appearance in assemblages from the Keele River basin that drains the Mackenzie Mountains of Northwest Territories. Millar (1968) called this material ignimbrite because he considered it instead to be either a lithified consolidation or a suspension of particles and gases deposited by pyroclastic flows (it contains distinct vesicles or gas bubbles). Cinq-Mars (1973) provided the first formal description of the raw material and revised its name to Tertiary Hills Welded Tuff. The basis for this name change was that the Geological Survey of Canada (Yorath and Cook 1981), with assistance from Shuhtagot'ine Dene First Nations, identified an outcrop in the Tertiary Hills, 30 kilometres west of the Mackenzie River (Figure

1). Cinq-Mars (1973) hypothesised that it formed when beds of tuff (consolidated volcanic ash) flowed and were "welded" into fine grained silica-rich rock. He conceded that the material could instead be "fused" when tuffs met rhyolitic lava domes, dykes, or granulated breccias at the base of rhyolitic flows.

Figure 1. THC outcrop and bedrock geology of North America. THC outcrops west of Mackenzie River, which flows north to the Arctic Ocean (bedrock geology data from USGS 2014).

Donahue (1976) used the name Keele River Welded Tuff but Ives and Hardie (1983) maintained Cinq-Mars' label when the material was first formally described in an Alberta context. Pokotylo and Hanks (1989) later proposed the name Tertiary Hills Tuffaceous Clinker for the reason that it appeared to have fused via combustion of neighbouring coal — clinkers form when naturally ignited coal seams bake and melt surrounding stone (Grapes 2011). Ignited coal seams are relatively common in the Mackenzie Basin and, according to oral history, Shuhtagot'ine Dene attribute them to burning fat that dripped down from a giant beaver killed by legendary culture hero Yamǫ́ria (Blondin 1990). Alexander Mackenzie recorded burning coal seams near the confluence of the Mackenzie and Great Bear Rivers as early as 1789 (Mackenzie 1801:95).

We propose the name Tertiary Hills Clinker on the grounds of our initial X-ray diffraction (XRD), thin section analysis, portable X-ray fluorescence (pXRF), and Instrumental Neutron Activation Analysis (INAA). These analyses all demonstrate that THC formed through in situ combustion of coal seams that partially fused surrounding shale or mudstone. That is, the material is a proper clinker with no evidence of origin from a volcanic eruption. Geographic distributions of clinkers, formation processes, and basic visual characteristics of THC are provided below. This background information is followed by our geochemical and mineralogical analyses of THC, which were conducted to properly define this material and demonstrate that it can be used in lithic provenance studies.

2.1. Geographic distribution of THC and clinker outcrops

The Tertiary Hills belong to the Flint Stone Range of the Mackenzie Mountains. They are drained by Tertiary Creek and East Little Bear River (Figure 2). The recorded THC outcrops are 620 kilometres from the Alberta border and 1320 kilometres from the furthest recorded southern occurrence of THC (near Barrhead northwest of Edmonton). By following major rivers, the Tertiary Hills are roughly 2100 kilometres from north central Alberta where THC artifacts have been recorded in the town of Athabasca, and northeast of Whitecourt. This estimate is based on movement via Tertiary Creek to the Mackenzie River to Great Slave Lake, Slave River, Lake Athabasca, and Athabasca River.

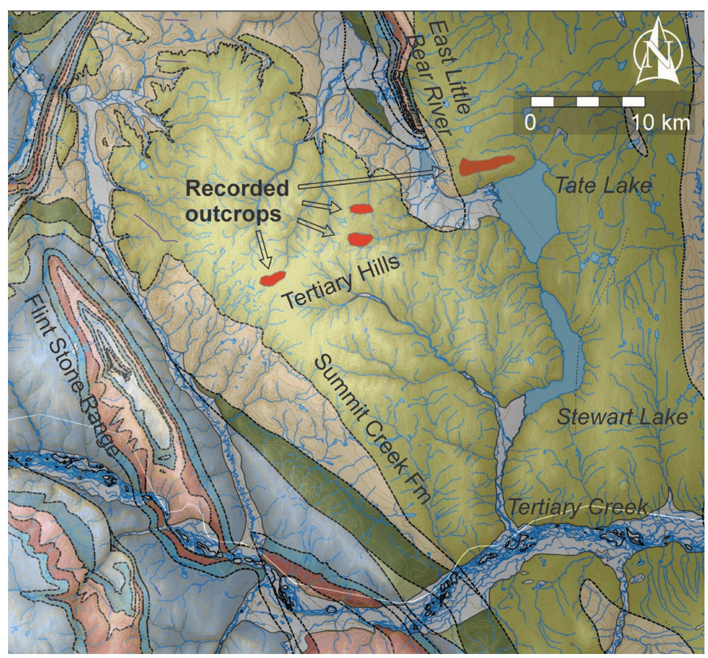

Figure 2. Four recorded outcrops of THC are in the Tertiary Hills (bedrock geology data from Fallas et al. 2013).

Other clinkers outcrop in a variety of settings associated with coal seams across North America (Grapes 2011). These clinkers are typically coarse grained and heterogeneous. The appearance of vitreous clinkers that are uniform enough to permit flintknapping are rare. Knappable clinkers in the sphere of the current paper include Cape Bathurst Clinker near the Mackenzie Delta in Northwest Territories (Le Blanc 1991) and a clinker material referred to as non-volcanic natural glass from Montana/Wyoming (Frison 1974). A knappable clinker was recently reported (Kurtis Blaikie, e-mail communication, April 21, 2016) from the Lesser Slave Lake region of central Alberta but has yet to be confirmed.

2.2. *Formation of clinker*

Clinkers form through combustion of coal seams or bituminous sediments that leads to the geochemical alteration ("pyrometamorphism") of neighbouring sedimentary rock (Grapes 2011:5). This pyrometamorphism of pre-existing rock is quite different from the formation of extrusive volcanic rocks produced by the rapid cooling of magma. Clinkers are baked and partially fused, as opposed to completely melted rocks called slag or paralavas (Grapes 2011). The degree of fusion in clinkers varies depending on the proximity to coal seams or bituminous sediments. THC nodules have burnt cortex (oxidized exteriors) and internal seams where the host material was subject to oxidation and combustion (Figure 3). The characteristic vesicles of THC are bubbles of trapped gas produced during the partial fusion of the sedimentary rocks.

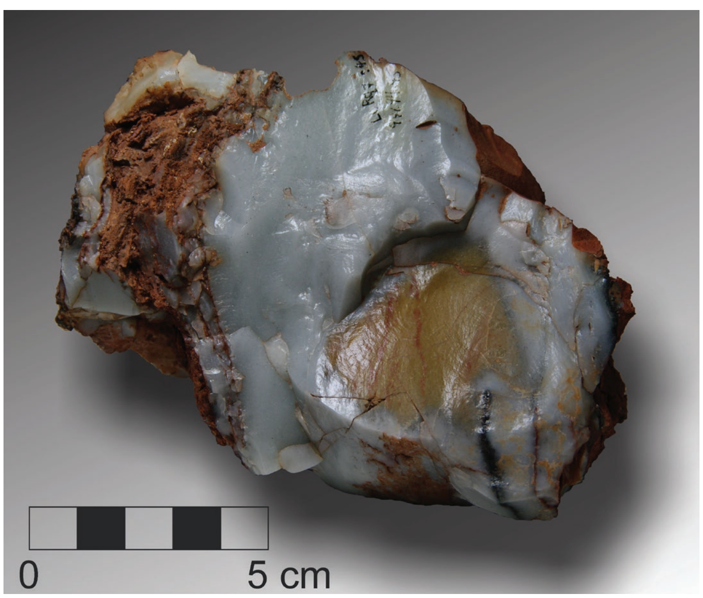

Figure 3. THC cobble displaying high quality clinker, oxidized cortex, and seams (LcRq-7:45, Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories). Photograph courtesy of Mike Donnelly.

THC outcrops are in the Summit Creek Formation, which is a Late Cretaceous to Paleocene unit that consists largely of sandstone interbedded with conglomerates, shales, ash beds, and coal (Fallas and MacLean 2013; Fallas et al. 2013). Fallas (e-mail communication, December 8, 2014) notes that the Summit Creek Formation contains tuff beds but these ashes were deposited in cool conditions and have not been sufficiently consolidated to become a tuffaceous rock. The sediments in which THC formed were mudstones or shales (Yorath and Cook 1981). These were subsequently fused by combustion of adjacent coal seams. The fusion of these argillaceous rocks created material with a propensity to fracture in a conchoidal fashion and hence, produced a very workable toolstone.

The formation process of clinker is archaeologically significant. Clinkers are generally found in dispersed and localized outcrops, which would predictably lead to small-scale quarries. Although relatively little archaeological work has been conducted at the outcrops, preliminary data suggest that the quarries (LcRf-7, LcRq-7, LdRq-3, LdRr-1, and LdRr-2) are small and exhibit low intensity exploitation. Because clinker formation requires oxygen for combustion, high quality sources are generally limited to areas where coal seams and adjacent fine-grained mudstones are exposed at the surface. The outcrops are within forests of the Taiga Cordillera ecoregion (Ecosystem Classification Group 2010:94), where surface exposures are generally minimal.

Volcanic rocks are internally consistent and readily usable but the use of clinkers would involve greater amounts of time and energy both to locate high quality outcrops and to reduce unusable cortex or internal seams so that high quality portions could be isolated. We expect small and scattered quarries to have high degrees of primary reduction activities in which large amounts of unusable cortex were removed (Figure 3).

2.3. *How to identify THC*

Tertiary Hills Clinker varies in colour from white to grey, and can also be light brown, red, and purple (Figures 4-6). Artifacts are typically made of the highest quality clinker, which is white or light grey (Figure 7). Laminar bands and minute red oxidized seams are common. THC varies from translucent to opaque, and characteristically contains vesicles. The vesicles impart a frosted glass texture with a vitreous to glimmering lustre (Ives and Hardie 1983). These vesicles are faintly visible to the naked eye (especially if they are filled with dirt on an otherwise clean artifact surface) but are easily detected under a magnification of 10x-30x (Figures 8 and 9). The presence of abundant circular vesicles, with diameters up to 2 millimetres, is a key observation to help identify THC. Current repositories of THC include the Prince of Wales Northern Heritage Centre, the Archaeological Survey of Alberta, the Royal Alberta Museum, and the Canadian Museum of History.

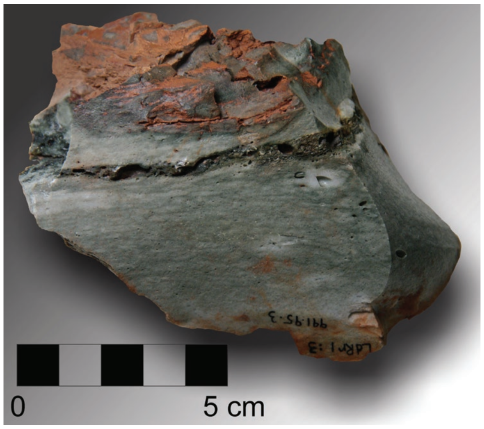

Figure 4. Grey variation of THC (LdRr-1:3, Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories). Photograph courtesy of M. Donnelly.

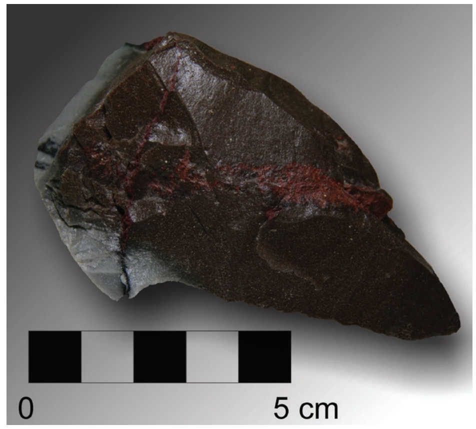

Figure 5. Purple THC (likely from LdRq-3), Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories). Photograph courtesy of M. Donnelly.

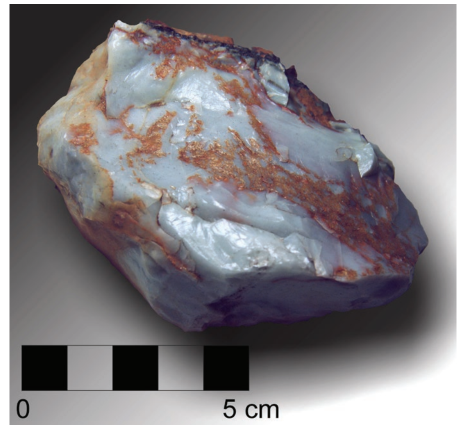

Figure 6. Most artifacts are of white-grey THC (LcRq-7:38, Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories). Photograph courtesy of M. Donnelly.

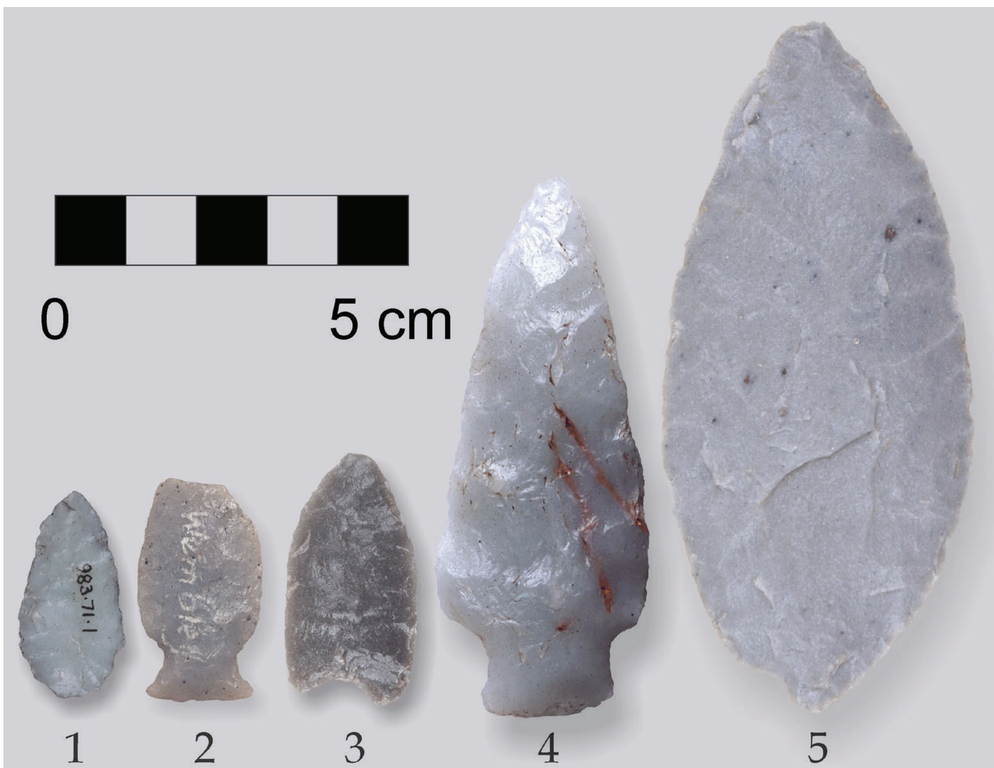

Figure 7. THC artifacts. 1: 983.71.1. (Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories), 2: No catalogue number (Grande Prairie Pioneer Museum, Grande Prairie, Alberta) from near Wembley, Alberta; 3: LgRk-2:988.67.3 (Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories), 4: no catalogue number (Athabasca Archives, Athabasca, Alberta) found in Athabasca; 5: LbRr-1:8 (Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories). Photographs of artifacts 1, 3, and 5 courtesy of Susan Irving.

THC can resemble fine-grained quartzite or quartz as well as lustrous cherts or chalcedonies: Figure 10 depicts high quality THC, while Figures 11 to 16 show potentially similar-looking materials with explanations of discriminating features. Ramah Chert (used in Newfoundland and Labrador) is superficially similar to THC and, while unlikely to appear in Alberta, is included because it was traded across the Arctic and may overlap with THC in the north. Chemically, it is relatively straightforward to differentiate THC from quartzite, quartz, chert, or chalcedony (discussed below). The diagnostic traits of THC are an abundance of vesicles and its non-crystalline nature. Vesicles also appear in tuffaceous rocks that may outcrop in Alberta or were imported for tool use. However, vesicles in tuffaceous rocks are often elongated due to flowing while those in clinkers are generally circular.

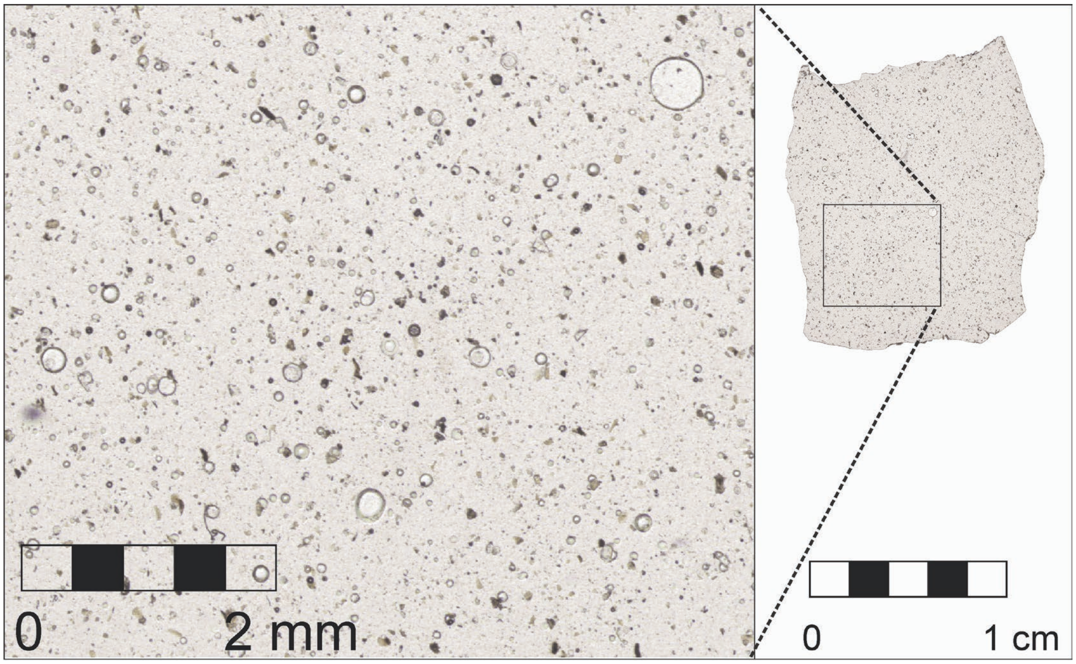

Figure 8. Characteristic vesicles of THC as seen in a polished thin-section (HhOu-113:34372, Royal Alberta Museum, Edmonton, Alberta).

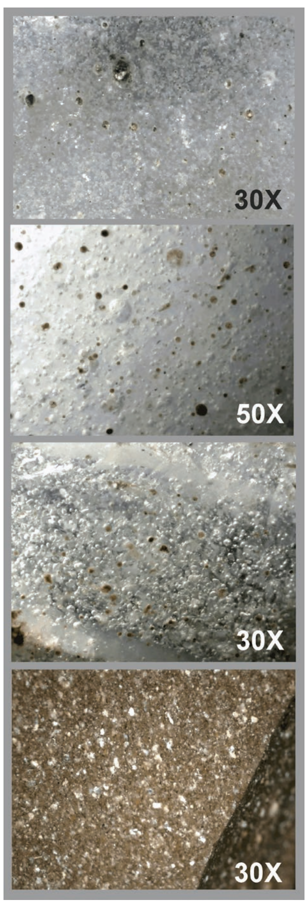

Figure 9. Compilation of microscope photographs illustrating THC vesicles and inclusions.

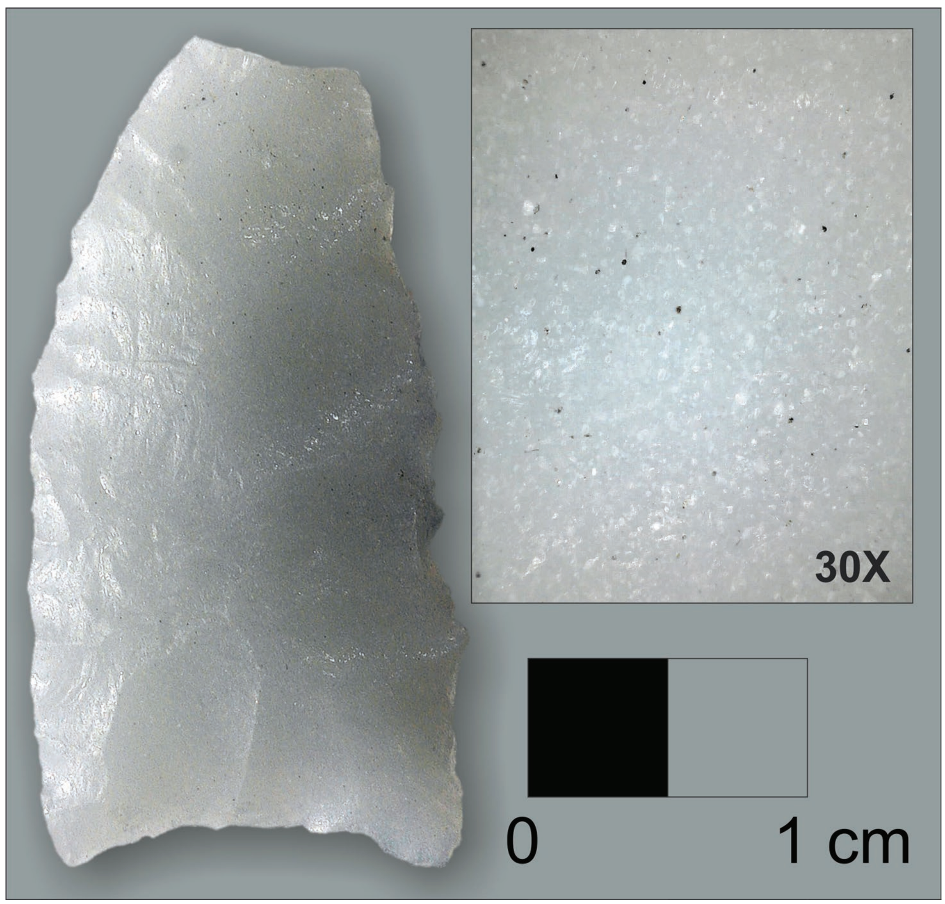

Figure 10. High quality THC is distinguishable from quartz or quartzite by its vesicles. Small black circles are dirt-filled surface vesicles (MaRe-11:1, Prince of Wales Northern Heritage Centre, Yellowknife, Northwest Territories).

Figure 11. Quartzite lacks vesicles and is angular (artifact number HcQt-1:26, Pederson collection from the Worsley area, northwest Alberta).

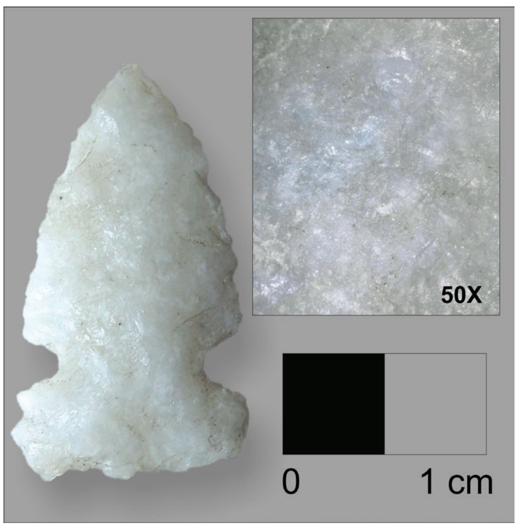

Figure 12. Quartz lacks the vesicles of clinker and, like quartzite, typically has angular grains (no catalogue number, Stettler Town and Country Museum, Stettler, Alberta).

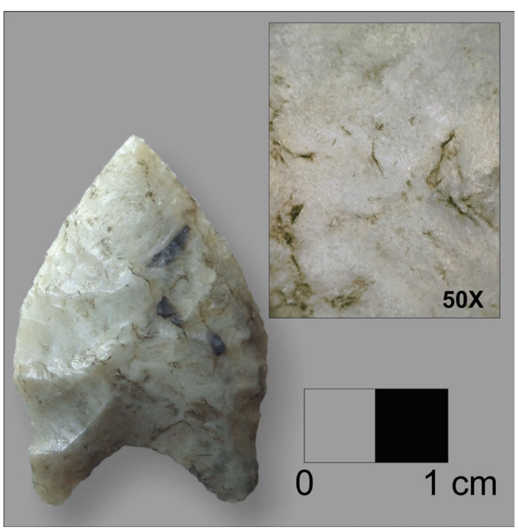

Figure 13. Cherts are generally opaque, lack vesicles, and are not as glossy as THC (no catalogue number, Stettler Town and Country Museum, Stettler, Alberta).

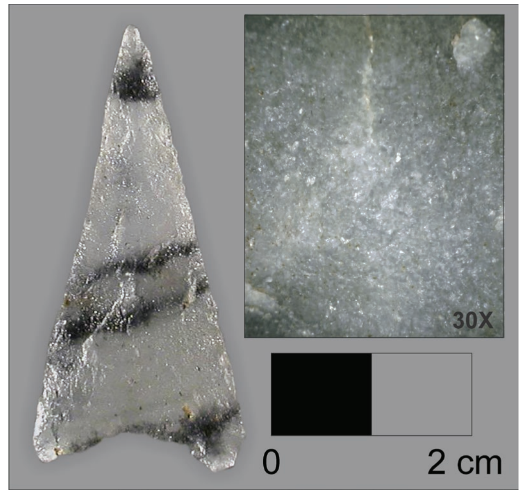

Figure 14. Ramah Chert (artifact from site IiCw-8, Provincial Archaeology Office, St. John's, Newfoundland and Labrador).

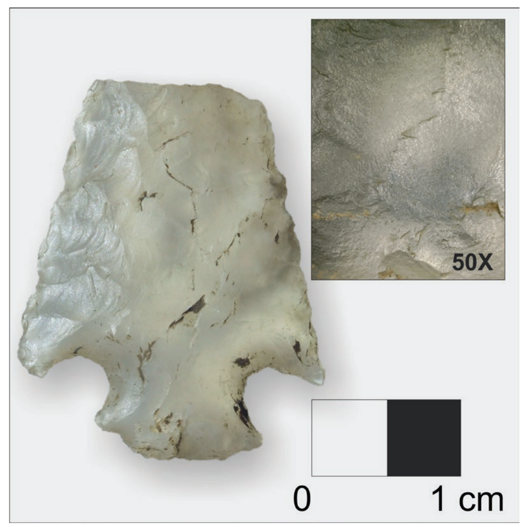

Figure 15. Chalcedony generally lacks any visible internal structure and is characteristically smooth and waxy (no catalogue number, Johnston private collection from Oyen area, Southeast Alberta).

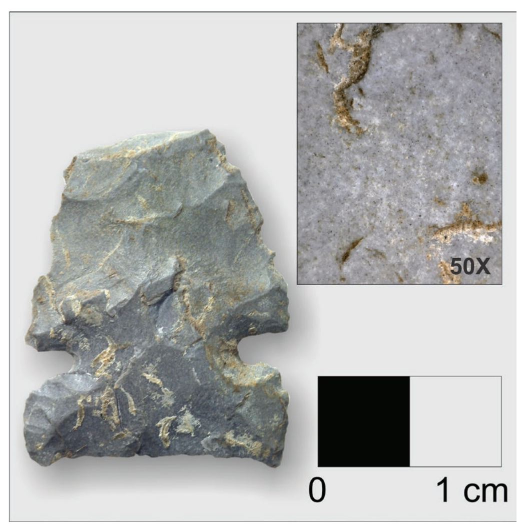

Figure 16. Porcellanite generally bears little resemblance to THC but has similar geological origins (DkPi-2:215594, Royal Alberta Museum, Edmonton, Alberta).

The most similar rock types to THC in Alberta and Montana's archaeological record (in terms of geological formation processes) are likely porcellanites (Figure 16) and fused glass. Fused glass, also called vesicular glass or non-volcanic natural glass (NVNG), appears to be a synonym for clinker although it is thought to form directly in vertical burning coal vents where maximum temperatures are reached as opposed to in beds overlying coal seams where THC forms (Fredlund 1976). Fused glass can be mistaken for obsidian because of its glassy, often black appearance (Fredlund 1976). Fused glass can, however, be differentiated by a high density of vesicles not found in obsidian. Most Montana fused glass is black or green although samples from Big Horn County in Southeast Montana, for example, are red, yellow, and grey (Fredlund 1976).

Porcellanite is related to fused glass or clinker although it is thought to form at greater distances from coal seams or vents, which generally results in a less vitreous though still uniform partially 'baked' rock that fractures conchoidally. The term porcellanite is also used for various siliceous rocks, including sedimentary and volcanic rocks (Fredlund 1976), but is here used as a near synonym with clinker. Porcellanite is formally defined by Grapes (2011) as a light coloured, very fine grained, completely recrystallized pyrometamorphosed clay, marl, shale, or bauxitic lithomarge.

Porcellanites outcrop in association with coal seams across eastern Montana, western North Dakota, and Wyoming where it can form major components of lithic assemblages (Fredlund 1976; Clark 1985; Ahler et al. 2002). The extent of non-volcanic glass is less well known but it occurs in Big Horn County (Fredlund 1976), Powder River County in Southeast Montana (Craig Lee, e-mail communication, March 5, 2016), and Texas (Frison 1974). Porcellanites and fused glasses are sometimes called "fused shale" elsewhere in western North America (Hughes and Peterson 2009) and the label has been applied in Alberta. Fused shale is a more general term that can encompass porcellanites and clinkers although many forms of fused shale are not porcellanite or clinker. We suspect that many "fused shales" described in an Alberta context are actually Montana porcellanites but local fused shales do occur, for example, a red-brown, dull variety outcrops near Wabamun in central Alberta. Based on geological definitions (Grapes 2011), it appears that clinker, fused shale, and porcellanites can all share similar formation processes (e.g., coal combustion) but generally differ due to various parent materials and degrees of fusion.

3. Methodology

Geochemical signatures of ten THC outcrop samples were compared with those of 43 THC artifacts from Northwest Territories, ten purported THC artifacts from the Yukon, nine purported THC artifacts from Alberta, ten outcrop samples of non-volcanic natural glass from Montana, eight samples of Montana porcellanite, seven samples of Cape Bathurst Clinker, and 23 samples of either chert, quartzite, quartz, chalcedony, and siltstone. Small samples of THC were also analysed by instrumental neutron activation analysis (INAA) and X-ray diffraction (XRD).

3.1. Portable X-ray fluorescence analysis

In this study, XRF elemental analyses were performed using a Bruker AXS Tracer III-SD handheld X-ray fluorescence spectrometer attached to a laptop computer running the Bruker software S1PXRF. The Bruker AXS Tracer III-SD is equipped with an Rh X-ray tube and a 10 millimetre² Silicon Drift Detector (SDD) with a resolution of 145 eV FWHM for 5.9 keV X-rays. The spot size of the X-ray excitation beam striking the sample was less than 10 millimetre in diameter. The pXRF was set up in a Bruker desktop stand and operated remotely by laptop. The pXRF unit was powered by an AC adapter and was run at an accelerating voltage and operating current of 40 kV and 30 μA, respectively. To optimize the determination of the elements of interest, a Bruker AXS excitation filter (comprised of 0.1523 millimetre Cu, 0.0254 millimetre Ti and 0.3047 millimetre Al) was utilized. Data collection was for a 300 second live-time count period. 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 the THC elemental determinations. Speakman et al. (2011) found that an obsidian calibration gave relatively accurate results for the analysis of ceramic data, which they considered reasonable given that obsidian and pottery are silica-rich. Given the expected elemental similarity between THC and obsidian, use of the obsidian calibration in this study seemed reasonable. 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.

3.2. Instrumental Neutron Activation Analysis

Preliminary examination of known THC material was carried out using instrumental neutron activation analysis (INAA) employing short-lived radionuclides. Samples weighing between 250 and 580 milligrams, were washed in deionized water, air dried, weighed, and individually placed in polyethylene irradiation vials. Samples were irradiated sequentially in the University of Alberta SLOWPOKE Nuclear Reactor for 240 seconds at a nominal thermal neutron flux of 1 x 10^{11}n cm^{-2} s^{-1}. Induced sample radioactivity was measured twice following the end of irradiation. Following a timed decay period (typically 15 minutes), each sample was counted for 240 seconds at a sample-to-detector distance of 13.5 centimetres; following a total decay period of ≥ 80 minutes, each sample was recounted for 600 seconds at a sample-to-detector distance of 6 centimetres. All counting was performed using a 40% relative efficiency ORTEC FX-Profile hyperpure Ge detector with carbon window. Utilizing the described analysis protocol, Al, Na, K, Mn, Ba, Dy, and U in the THC material were detected and quantified. Element quantification was performed by the semi-absolute comparator method of NAA (Bergerioux, et al. 1979) using standard reference materials of known composition (e.g., NIST 1633a, fly ash; USGS W1, diabase) analyzed under the same conditions as the THC samples.

3.3. X-ray diffraction

Three samples of Tetriary Hills Clinker (two Alberta artifacts and one natural outcrop piece) were analysed at the X-ray Diffraction Laboratory in the Department of Earth and Atmospheric Sciences at the University of Alberta. Samples were ground to a fine powder with a quartz pestle and mounted. X-ray diffraction patterns were acquired using Bragg-Brentano parafocussing reflection geometry with a Rigaku Ultima IV θ-θ diffractometer. This instrument has a Co X-ray source (*K*α 1.78899 Å) and Fe filter, and it 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.

4. Results

Based on XRD analysis, THC is heavily dominated by non-crystalline material with minute amounts of quartz and mullite. The latter is a needle-shaped aluminosilicate mineral characteristic of high-temperature geologic conditions. Relatively high rubidium concentrations in THC outcrop material from Northwest Territories substantiate an original shale or mudstone (argillaceous) composition of the THC precursor. Significantly, the geochemical fingerprint of THC lends itself to raw material sourcing studies via pXRF and INAA. The speed and ease of analysing a wide range of sample sizes by pXRF made it the preferred method for this study. As in obsidian-sourcing studies, trace element concentrations including rubidium (Rb), strontium (Sr), and zirconium (Zr) are useful for differentiating THC from similar-appearing materials and other clinkers (Figure 17). Some elements exhibit considerable intra-source variability, which likely reflects variable and dynamic processes of combustion pyrometamorphism of clinker (Table 1).

THC, porcellanite, Cape Bathurst Clinker, and non-volcanic natural glass all contain elevated values of zirconium, rubidium, strontium, yttrium, and other trace elements indicative of their shared coal-baked origins (although these elements are often elevated in volcanic rocks as well). Despite their proximity in some bivariate plots in Figures 17, porcellanite and Cape Bathurst Clinker are macroscopically distinct from THC (Figures 18 and 19). Cape Bathurst Clinker is typically dark grey or blue-grey while porcellanite is a typically an opaque grey or red-purple. Their inclusion in the geochemical analyses provides a means to assess the ability of pXRF to distinguish between clinkers. Surprisingly, Ti and V were not detected in the THC samples. Of the elements identified in this study only Mn was determined by both pXRF and INAA. For the few samples analyzed by both techniques the pXRF results agreed with the INAA determinations within ± 10% (1σ).

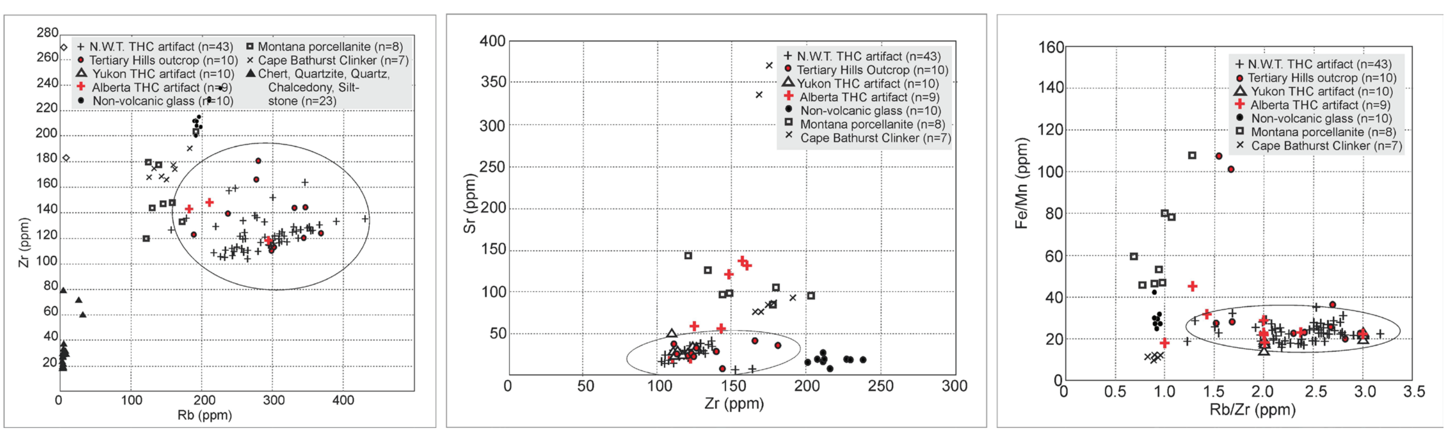

Figure 17. Bivariate plots of pXRF results (ellipse confidence interval of 95%). Concentrations are in parts per million (ppm).

Table 1. PXRF results from the analysis of natural outcrop specimens and artifacts of Tertiary Hills Clinker, and similar-looking materials. Concentration values are in parts per million. RAM=Royal Alberta Museum. PWNHC=Prince of Wales Northern Heritage Centre.

ID	Raw Material	Catalogue Number	Repository	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
TK-1	THC outcrop (grey)	LcRq-7:5	PWNHC	414	10700	97	21	18	302	26	23	113	11
TK-2	THC outcrop (grey)	LdRr-1:3	PWNHC	344	34600	341	24	18	277	41	30	166	19
TK-3	THC outcrop (white)	LcRq-7:42	PWNHC	356	13000	78	22	17	299	38	25	111	11
TK-4	THC outcrop (grey)	LdRr-2:1	PWNHC	422	9830	130	26	18	347	8	43	144	18
TK-5	THC outcrop (grey)	LcRq-7:9	PWNHC	477	10600	181	29	20	368	23	27	124	14
TK-6	THC outcrop (white)	LdRr-2:5	PWNHC	413	9380	111	22	18	332	8	44	144	20
TK-7	THC outcrop (grey)	LdRr-1:3	PWNHC	339	36500	384	28	16	279	35	34	181	17
TK-8	THC outcrop (white)	LcRq-7:42	PWNHC	482	9700	179	26	19	342	23	24	121	11
TK-9	THC outcrop (red)	H06 112:1	RAM	387	10900	137	23	16	235	29	24	140	13
TK-10	THC outcrop (purple)	H06 112:2	RAM	319	8830	83	22	13	187	25	24	123	12
TK-11	THC artifact	KlRs-13:309-15	PWNHC	451	8200	225	21	18	241	22	28	112	12
TK-12	THC artifact	KlPp-3:25	PWNHC	382	7490	69	20	17	233	16	25	111	12
TK-13	THC artifact	LgRk-2:988.67.28	PWNHC	387	7390	61	21	13	263	15	26	104	11
TK-14	THC artifact	LdRo-4:10	PWNHC	356	9190	55	20	16	299	23	23	118	11
TK-15	THC artifact	LgRk-2:988.67.51	PWNHC	337	7200	79	20	14	225	17	23	106	10
TK-16	THC artifact	LgRf-1:1	PWNHC	375	8090	98	23	17	298	7	46	152	20
TK-17	THC artifact	MaRe-5:1	PWNHC	375	8790	68	24	14	258	24	26	119	12
TK-18	THC artifact	KlRs-8:1	PWNHC	412	10100	142	29	20	344	7	54	163	24
TK-19	THC artifact	MaRe-11:1	PWNHC	327	8180	66	19	14	296	25	23	114	11
TK-20	THC artifact	LgRf-2:2	PWNHC	375	9100	114	27	18	301	28	25	122	13
TK-21	THC artifact	JhRd-9:4	PWNHC	422	9600	86	23	17	309	26	23	119	12
TK-22	THC artifact	LfRq-4:140a-d	PWNHC	393	9540	97	19	15	253	29	27	121	9
TK-23	THC artifact	LbRr-1:1	PWNHC	398	9940	183	28	17	314	26	28	125	13
TK-24	THC artifact	JhRd-3:2	PWNHC	324	8170	61	20	14	260	28	25	120	11
TK-25	THC artifact	KjPo-30:1	PWNHC	369	9750	75	26	20	348	29	26	129	11
TK-26	THC artifact	KlRs-20:54	PWNHC	374	9130	66	23	15	298	22	26	117	11
TK-27	THC artifact (red)	KlRs-2:700	PWNHC	428	11900	73	28	18	366	28	25	132	14
TK-28	THC artifact	LgRk-2:988.67.263	PWNHC	337	7520	100	19	16	242	17	25	107	11
TK-29	THC artifact	LbTa-2:35	PWNHC	357	11000	110	24	17	353	32	26	126	11
TK-30	THC artifact	LbTa-4:6	PWNHC	374	8350	89	22	15	294	22	26	115	12
TK-31	THC artifact	KlRs-5:227	PWNHC	362	6890	74	22	14	215	16	24	109	12
TK-32	THC artifact	LcRr-1:3	PWNHC	374	10160	67	21	17	315	28	25	122	12
TK-33	Quartzite artifact	LhRq-1:984.61.130	PWNHC	n.d.	910	29	13	n.d.	4	8	6	36	3
TK-34	THC artifact	LdRo-2:42	PWNHC	385	8430	70	21	16	313	26	24	118	12
TK-35	THC artifact	LcRq-5:28	PWNHC	335	10770	94	21	14	218	30	27	129	13
TK-36	THC artifact	LcRq-5:36	PWNHC	355	10070	94	21	15	319	29	24	118	10
TK-37	THC artifact	01-OGL-2013 ST40	PWNHC	332	8870	55	18	15	310	25	24	117	11
TK-38	THC artifact	KfTd-3:5	PWNHC	330	11600	64	22	15	278	20	24	110	11
TK-39	THC artifact	No cat. #	J. Fisher	206	9270	68	20	20	183	55	32	143	17
TK-40	THC artifact	GbPt-11:5	RAM	318	10050	66	20	20	211	120	23	148	14
TK-41	THC artifact	HhOu-113:34371-77	RAM	426	9800	96	25	16	287	21	27	121	14
TK-42	Cape Bathurst Clinker artifact	ObRw-1:368	PWNHC	882	8660	70	19	11	148	76	33	166	14
TK-43	Cape Bathurst Clinker artifact	ObRw-1:364	PWNHC	556	6500	59	22	11	141	75	34	169	13
TK-44	Montana Porcellanite outcrop	No cat. #	RAM	684	31360	69	26	10	138	84	31	177	15
TK-45	Montana Porcellanite outcrop	No cat. #	RAM	790	42200	121	41	14	191	96	34	203	19
TK-46	Montana Porcellanite outcrop	No cat. #	RAM	796	37200	86	26	12	129	97	29	144	13
TK-47	Montana Porcellanite outcrop	No cat. #	RAM	772	36500	81	24	11	144	98	27	147	14

Table 1. (*continued*)

ID	Raw Material	Catalogue Number	Repository	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
TK-48	Montana Porcellanite outcrop	No cat. #	RAM	866	52100	84	30	13	123	106	34	179	15
TK-49	Quartzite artifact	No cat. #	J. McIntosh	n.d.	960	3	6	n.d.	4	2	4	33	n.d.
TK-50	Quartzite artifact	No cat. #	Stettler Museum	n.d.	900	3	6	n.d.	4	4	3	29	n.d.
TK-51	Quartzite artifact	HcQt-1:26	K. Pederson	n.d.	970	4	5	n.d.	4	1	4	79	1
TK-52	Quartzite artifact	No cat. #	Steinrath	n.d.	1990	n.d.	6	n.d.	6	12	4	32	n.d.
TK-53	Quartz artifact	No cat. #	Stettler Museum	n.d.	920	5	13	n.d.	3	n.d.	2	19	1
TK-54	Cathead Chert outcrop	No cat. #	RAM	n.d.	750	n.d.	11	n.d.	4	5	2	19	1
TK-55	Swan River Chert outcrop	No cat. #	RAM	n.d.	900	6	13	n.d.	4	1	2	29	1
TK-56	Swan River Chert artifact	No cat. #	Stettler Museum	n.d.	860	5	6	n.d.	4	1	2	22	n.d.
TK-57	Chert artifact	HcQt-1:29	K. Pederson	n.d.	4630	19	13	n.d.	26	123	12	71	3
TK-58	Chert artifact	No cat. #	J. McIntosh	n.d.	1750	4	7	n.d.	9	53	4	29	n.d.
TK-59	Chert artifact	No cat. #	J. McIntosh	n.d.	840	6	7	n.d.	3	5	4	20	n.d.
TK-60	Ramah Chert outcrop	No cat. #	RAM	n.d.	1780	2	7	n.d.	3	n.d.	3	23	n.d.
TK-61	Ramah Chert outcrop	No cat. #	RAM	n.d.	2670	n.d.	6	n.d.	3	1	2	18	n.d.
TK-62	Ramah Chert outcrop	No cat. #	RAM	n.d.	3230	6	8	n.d.	3	4	2	19	n.d.
TK-63	Chert artifact	No cat. #	J. McIntosh	53	13600	22	11	1	32	33	9	59	9
TK-64	Chert artifact	No cat. #	Stettler Museum	n.d.	1120	9	9	n.d.	4	2	2	27	1
TK-65	Chalcedony artifact	2004.064.005	Brooks Museum	n.d.	1000	3	8	n.d.	4	2	2	20	n.d.
TK-66	Chalcedony outcrop	No cat. #	Todd Kristensen	n.d.	800	n.d.	10	n.d.	4	15	7	31	1
TK-67	Non-volcanic glass outcrop	No cat. #	RAM	239	10100	65	19	23	194	10	65	215	52
TK-68	Chalcedony outcrop	989.10.10	U of A	n.d.	900	1	9	n.d.	6	3	3	22	n.d.
TK-69	Quartz artifact (crystal)	KfTd-4:1	Todd Kristensen	n.d.	770	1	6	n.d.	3	n.d.	2	18	n.d.
TK-70	Missing Link outcrop	No cat. #	RAM	43	49200	71	17	n.d.	8	16	7	182	6
TK-71	Missing Link outcrop	No cat. #	RAM	190	79000	115	22	2	6	20	25	269	17

Figure 18. Porcellanite cobble from Montana (H87.56.69, Royal Alberta Museum, Edmonton, Alberta). Porcellanites that dominate Montana asseamblages range in colour from grey to red and purple. Lusters can vary from dull to glossy presumably due to different degrees of fusion during pyrometamorphism.

Figure 19. Cape Bathurst Clinker cobble from Northwest Territories (collected by Raymond Le Blanc near ObRw-1, no catalogue number, Royal Alberta Museum, Edmonton, Alberta). This cobble is described as a low quality clinker; more fused varieties of Cape Bathurst Clinker are generally more lustrous.

5. Archaeological significance

THC is one of a few materials in the archaeological record of Alberta with a known origin to the north. Consequently, it can be a valuable proxy indicator of cultural relationships with northern peoples. It was circulated beyond Northwest Territories to Yukon, northeast British Columbia, and Alberta (Figure 20). Because it is a poorly known raw material, the full extent of its distribution may be much larger.

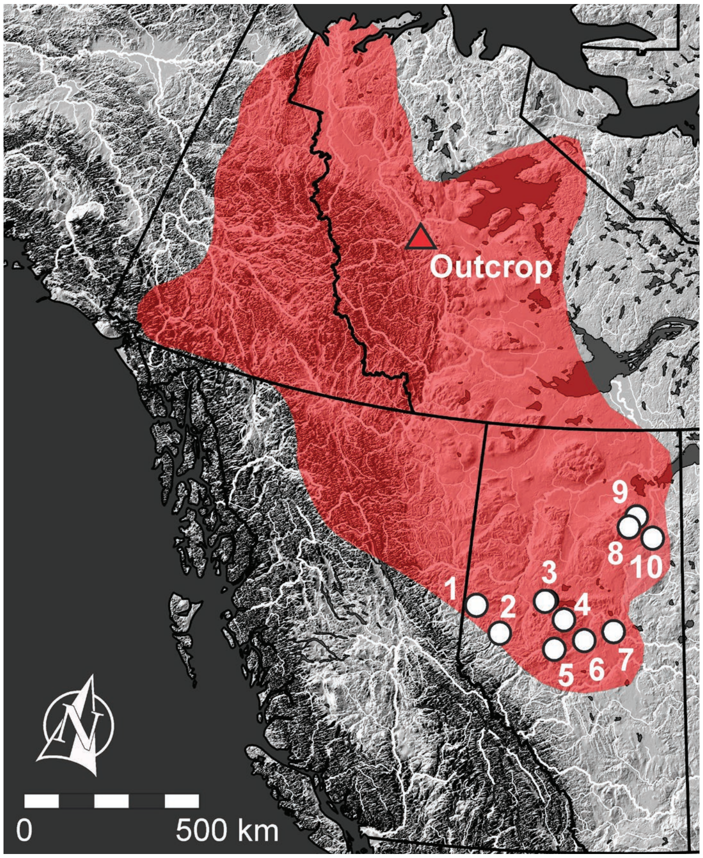

Figure 20. Distribution of THC and locations of archaeological sites in Alberta with recorded THC. 1=a private collection near Wembley, 2=GdQn-1 (Smuland Creek), 3=GjQa-3, 4= GhPv-1, 5=GbPt-11, 6=the Fisher collection near Barrhead, 7=Athabasca Archives specimen retrieved from north side of Athabasca townsite, 8=HjPd-1, 9=HkPa-4, 10= HhOu-113 (shaded relief data from USGS 2014).

THC does not appear to have been used more heavily during specific time periods in Northwest Territories but there are temporally informative appearances of THC in Alberta. Bereziuk (2001) noted a THC flake at the Smuland Creek site (GdQn-1) in northwest Alberta, which also produced a fluted point. The two artifacts are likely associated given the site's location on an isolated Glacial Lake Peace strandline. Ives (2006) reported a large lanceolate point of THC (Figure 21) from the Gardiner Lake Narrows site (HjPd-1) (see also Sims 1977; Ives and Hardie 1983). Originally described by Sims (1977) as Agate Basin, the point resembles forms from Spein Mountain, the Mesa Site, and Healy Lake in Alaska (Ackerman 2001; Holmes 2001; Kunz et al. 2003). It also strongly resembles a point with parallel collateral flaking from Northwest Territories ice patch site KfTe-1 (Andrews et al. 2012:16). Roskowski (2012) reported THC flakes (n=11) at HhOu-113 in northeast Alberta from a dated context of roughly 7000 years ago. These sites suggest affinities to or contact with northern peoples very early in Alberta's pre-contact past.

Figure 21. THC lanceolate spear tip or knife from the Gardiner Lake Narrows site (HjPd-1:924, Royal Alberta Museum, Edmonton, Alberta) recovered by Sims (1977). HjPd-1 yielded numerous tools and raw materials including Beaver River Sandstone and stemmed projectile points that Sims suggested were similar in morphology to examples from Northwest Territories.

Several THC artifacts are known from northern Alberta localities. Projectile points of THC have been identified in Alberta collections housed in Grande Prairie Pioneer Museum and the Athabasca Archives (see Figure 7). These resemble Shield Archaic points (roughly 3500-6000 yr BP) based on Gordon (1996:202). Flakes of THC have also been found at HkPa-4 (the Eaglenest Portage site in the Birch Hills of northeast Alberta), GhPv-1 (near Faust), and GjQa-3 along Lesser Slave Lake (Le Blanc 2004:24). A broken non-diagnostic projectile point was also found near Barrhead; this is currently in the Joe Fisher collection visited by Todd Kristensen in 2014. Lastly, an exhausted core and several flakes were identified by the authors at GbPt-11, northeast of Whitecourt.

THC has potential to add considerable information to archaeological reconstructions of some notable junctures in Alberta's past. First, if the Smuland Creek THC flake is truly associated with the fluted point, it suggests either wide-ranging early Paleoindian population movements through Alberta, or long distance intergroup contacts. Any similar examples of Paleoindian era THC far to the south will be of great interest. Secondly, THC can inform theories of the appearance of Shield Archaic groups from the east and Taltheilei groups who are purported to have colonized much of Northwest Territories and northern Alberta from the Peace Region 2500 years ago (Gordon 1996:115). Thirdly, well-documented instances of THC occurring in the interval of roughly 1000-1700 years ago in Alberta could be informative concerning displacement of Dene speakers by the destructive White River Ash falls and the hypothesized movements of the small founding population of proto-Apachean ancestors that may have departed Alberta for the American Southwest and southern Plains (Ives 2003, 2014; Jensen et al. 2014). Fourthly, microblades have been found at several Alberta sites (Sanger 1968; Le Blanc and Ives 1986; Younie et al. 2010; Wilson et al. 2011) but the age and morphological affiliations of these microblade instances remain imperfectly known. Secure identifications of THC at microblade sites could shed light on the origins and spread of these distinctive technological systems. These specific issues aside, the tremendous distances involved make any instances of THC in Alberta of significant archaeological interest.

6. Conclusion

Tertiary Hills Clinker (THC) is a partially fused toolstone from Northwest Territories that appears in northern and central Alberta. Preliminary results of pXRF and INAA analyses on THC suggest that it can be geochemically sourced like obsidian since it is of a limited geological origin with a distinct chemical signature. When combined with its relatively distinct macroscopic and microscopic qualities (circular vesicles, non-crystalline nature, a frosted glass texture, and glassy lustre), THC can be readily identified in Alberta assemblages. This toolstone can be a valuable proxy indicator of relationships between Alberta's pre-contact people and groups from Northwest Territories.

7. Acknowledgements

We would like to thank Dr. A. Weber for use of the pXRF equipment purchased with funds from the Canada Foundation for Innovation. XRD work was performed by Diane Caird. Archaeological research was supported by the Social Science and Humanities Research Council, the Landrex Distinguished Professorship, University of Alberta, the Polar Continental Shelf Project, Northern Scientific Training Program, and Circumpolar/Boreal Alberta Research. Permission to analyse Alberta artifacts was granted by Darryl Bereziuk of the Archaeological Survey of Alberta and permission to analyse Northwest Territories artifacts was granted by Joanne Bird of the Prince of Wales Northern Heritage Centre. Thank you to Ty Heffner and Ruth Gotthardt for granting permission and providing Yukon specimens for analysis. Thank you to Susan Irving and Mike Donnelly for artifact and outcrop cobble photographs.

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