Proteomics and Coast Salish blankets: a tale of shaggy dogs?

Caroline Solazzo[1,2], Susan Heald[3], Mary W. Ballard[2], David A. Ashford[4], Paula T. DePriest[2], Robert J. Koestler[2] & Matthew J. Collins[1]

Identifying animals to species from relict proteins is a powerful new archaeological tool. Here the authors apply the method to answer questions relating to the Salish of west coast North America. Did they weave their blankets out of dog hair? The proteomic analysis shows that they did, interweaving it with goat, and that the woolly dog was increasingly superseded by sheep in the later nineteenth century.

Keywords: North America, nineteenth century, Coast Salish, textiles, sheep, goat, woolly dog

Introduction

Protein mass spectrometry, already successfully applied to materials such as archaeological seeds and paint binders (Cappellini *et al*. 2009; Chambery *et al*. 2009; Fremout *et al*. 2010), is a useful new tool for the study of textiles, and indeed cultural artefacts composed of proteins (for example silk, wool, ivory, leather, bone, parchment), in which the original source of production is difficult to identify. It has advantages over conventional microscopic

[1] *Departments of Biology, Archaeology and Chemistry, BioArCh, University of York, P.O. Box 373, York YO10 5YW, UK (correspondence email: solazzo.c@gmail.com)*
[2] *Museum Conservation Institute, Smithsonian Institution, 4210 Silver Hill Road, Suitland, MD 20746, USA*
[3] *National Museum of the American Indian, Cultural Resources Center (CRC), 4220 Silver Hill Road, Suitland, MD 20746, USA*
[4] *Proteomics and Analytical Biochemistry Laboratory, Technology Facility, Department of Biology and Centre of Excellence in Mass Spectrometry, University of York, P.O. Box 373, York YO10 5YW, UK*

Received: 3 November 2010; Accepted: 21 January 2011; Revised: 1 February 2011

ANTIQUITY 85 (2011): 1418–1432 http://antiquity.ac.uk/ant/085/ant0851418.htm

methods (Wortmann *et al.* 2003), when only small sample sizes (mg) are available and in cases in which mechanical or chemical damage may have altered the morphology of the fibres. Finding specific peptides is the key for a rapid and unambiguous identification (Buckley *et al.* 2009, 2010).

Here we show how the analysis of some significant Coast Salish textiles from the Smithsonian's NMNH and NMAI collections, representing different styles and periods, has confirmed an important aspect of the Coast Salish oral tradition by corroborating the regular use of dog hair in traditional weaving. Despite the minute quantities of fibres used, the analytical sensitivity of the instrumentation was able to reveal not only the use of dog hair but also the unexpected importance of sheep wool in the Salish weaving tradition.

The people

The Coast Salish peoples, indigenous to the Pacific Northwest coastal areas of northern Washington and southern British Columbia (Figure 1) have an ancient weaving tradition notable for large, finely woven blankets (Hill-Tout 1907; Ashwell 1978) made of animal fibres (Figures 2–4), sometimes supplemented by vegetal fibres (hemp, stinging nettles) and bird down (Wells 1969). The blankets were important items in pre-contact times: their gift and distribution were present in all aspects of social life (Barnett 1938; Wells 1969; Ashwell 1978; Suttles 1987). Not just functional items, they served for ceremonial purpose at marriages, funerals, naming ceremonies and body wrapping (Mohs 1992). The primary source of traded wool used by the Coast Salish came from the dense white to yellow fleece of the mountain goat (*Oreamnos americanus*). Absent from the homeland of the Coast Salish (Nagorsen & Keddie 2000), the fibre was traded with interior communities who collected it from the goats living in the Rocky and Cascade Mountains (Willoughby 1910; Amoss 1993).

Coast Salish oral history also has many allusions to a special dog locally bred until the mid nineteenth century for its woolly hair or fleece for use in the textile industry (Jones 2005). But the importance of dog fibre in Salish weaving has been questioned: a re-examination of over 100 textiles from Salish collections in 21 museums in North America and Europe, published in 1980 in Gustafson's book *Salish weaving* (Gustafson 1980), failed to identify any dog hair fibres. However support for the dog hair hypothesis was produced through the analysis of a child burial blanket found near Yale (Fraser River, British Columbia), estimated to belong to the late eighteenth/early nineteenth century. Stable carbon isotope analysis concluded that the fibres were from an animal fed on a marine diet (Schulting 1994). Fish (especially salmon) and sea mammals (seals and porpoises) were the main source of food of the Coast Salish (Barnett 1938; Amoss 1993), and their dogs would have access to the same diet, quite unlike that of mountain goats. Salish weaving is also undergoing a resurgence; with this revival it is crucial to have the history of the use of dog hair confirmed. Because of their colour and structure (Gibbs 1877; Olsen 1936; Kane 1971), woolly dog hair can easily be confused with that of the mountain goat (Willoughby 1910; Orchard 1926; Kissell 1929).

Figure 1. The Coast Salish inhabit the area delimited by the Strait of Georgia in the north and the Strait of Juan de Fuca and Puget Sound in the south, the Fraser River in the east and part of Vancouver Island in the west (Barnett 1938; Smith 1941). These communities form part of the Salishan language group, together with the Nuxalk in the north and the Interior Salish in the east.

The woolly dog in historical accounts

The existence of a woolly dog is supported by historic accounts of eighteenth-century European explorers such as Cook and Galiano (Ledyard 1783; Howay 1918). The most famous quote comes from Vancouver (1792) who describes a Pomeranian-type of dog, whose fleece "could be lifted up by a corner without causing any separation" and was composed "of a mixture of a coarse kind of wool, with very fine, long hair, capable of being spun into yarn" (Roberts 2005). As long hair is a recessive trait, preventing the dog from interbreeding with the short-haired village dog was essential to ensure a continual supply of dog wool (Crockford 2000), and the dogs were reported to be corralled on small islands off the coast, attended daily (Scouler 1905; Kissell 1929; Ashwell 1978). The only remaining specimen

Figure 2. Ceremonial blanket 138571. National Museum of the American Indian (NMAI), Smithsonian Institution; photograph by Walter Larrimore.

of the woolly dog can be found in the Smithsonian collections, along with a specimen of the common dog, both collected in 1858–1859 and prepared at the Chiloweyuck Depot (Chilliwack, British Columbia, see Figure 1). Based upon the similarity in size and build of the two dogs, Barsh *et al.* (2002) argue that they were of the same breed, but that the woolly dog was noteworthy for its fleece (a dense coat of exceptionally fine underwool and long guard hair). Paul Kane's painting of a woman weaving a blanket on a loom with a white dog in the foreground (1848–1856, Royal Ontario Museum) served to associate the woolly dog with Salish weaving, and the blankets quite often became known as 'dog-hair blankets' (Howay 1918). Kane (1971) also produced some sketches which more accurately show the features of the woolly dog. These sketches, augmented with osteological measurements from archaeological remains suggest the dog was a small Spitz-like breed (Crockford 1997, 2000; Crockford & Pye 1997).

The dog disappeared less than 100 years after the first contact with Europeans, and the traditional Salish art of weaving progressively declined into the twentieth century. Both events may be linked to the establishment of a Hudson Bay's Company post at Fort Langley (British Columbia) on the Lower Fraser River in 1827, which used the company's cheaper point blankets for exchange in the fur trade (Barraclough 1969). Dogs have a long history of interaction with humans, from companionship to guarding and hunting; but raising dogs for fibre production was a unique cultural adaptation in the Pacific Northwest. It is perhaps the unusual strategy that has led some to doubt of the use of dog wool.

Figure 3. Colonial blanket 144864. National Museum of the American Indian (NMAI) Smithsonian Institution; photograph by Ernest Amoros.

The samples examined

The Salish blankets have been classified in two families, plain and organised blankets, and the second group subdivided in three categories, classic (1778–1850), colonial (1850–1900) and hybrid (1850 and beyond) (Gustafson 1980). We followed this categorisation to classify the nine blankets selected for analysis (Table 1): two ceremonial plain blankets, three classic, two hybrid, and two colonial blankets. A fur robe and a belt were also included.

The earliest blanket NMNH 177710 (1190 × 940mm) may date to the early nineteenth century. It was part of Catlin's collection, who had himself acquired the Lewis collection of Northwest Coast artefacts from the Lewis and Clark expedition (1803–1806). Although the painter was acquainted with Clark, the origin of the blanket is still speculative, with regard to the lack of documentation on the origin of the collections themselves. It entered the

Figure 4. Classical blanket catalogue no. E2124, Department of Anthropology, National Museum of Natural History (NMNH), Smithsonian Institution; photograph by Donald E. Hurlbert.

Table 1. The Salish blankets examined.

Description	Acc. no.	Date	Provenance	Composition
Classic blanket	NMNH 177710	1803	Lewis & Clark expedition	Dog/goat
Classic blanket (Figure 4)	NMNH 2124	1838	Wilkes expedition	Dog/goat
Hybrid blanket	NMNH 1894	1838	Wilkes expedition	Dog/goat/sheep
Colonial blanket	NMNH 1891	1838	Wilkes expedition	Dog/goat
Sash belt	NMNH 2120	1838	Wilkes expedition	Dog/goat
Fur robe	NMNH 1895	1838?	Wilkes expedition	Dog
Colonial blanket (Figure 3)	NMAI 144864	*c*. 1860	Yale, B.C.	Goat/sheep
Hybrid blanket	NMNH 221408	Before 1862		Dog/goat
Plain blanket	NMNH 311257	Before 1919		Goat
Plain blanket (Figure 2)	NMAI 138571	Before 1925	Fraser River, B.C.	Goat
Classic blanket	NMAI 155607	Before 1927	Saanich Salish, SW of Vancouver Island, B.C.	Goat/vegetable fibre

Smithsonian records in 1881. This classic-type blanket suffered from fire damage (Krieger 1928) and at least half of it is missing. Five objects are attributed to the 1838–1842 Wilkes US exploring expedition: NMNH2120 (tumpline strap), NMNH2124 (classic blanket), NMNH1891 (colonial blanket), NMNH1894 (hybrid blanket), and NMNH1895 (fur robe). The attribution of NMNH1895 to the Wilkes collection has, however, been questioned. The collection was exhibited in the Great Hall of the Patent Office before been transferred to the Smithsonian Institution in 1858. NMNH1895 (760 × 1040mm) is made of strips of fur held together with a cedar bark cordage structure. NMNH2120 (72.5 × 1380mm) is a sash belt, composed of a main tightly woven structure, a fringe of identical materials and a braid incorporated in the fringe. NMNH2124 (1575 × 1270mm, fringe length 180mm; Figure 4) is a large, colourful classic blanket, made of typical horizontal geometric patterns with one side faded from exposure to the light. NMNH1894 (1040–1240 × 1015mm) is a hybrid blanket, the main body of which is made of animal fibres woven with down and feathers. NMNH1891 (1540 × 1540mm) is another example of a colonial blanket. Its provenance has been questioned; according to the Gustafson classification, the colonial style had not been developed at the period the blanket was collected. Finally we sampled another plain blanket, NMNH311257, of which provenance (possibly Cowichan) and date are not clear (it first appears in the Smithsonian records in 1919). The last blanket, NMNH221408 (1140 × 1040–1170mm), is a hybrid blanket, woven of down with animal fibres, possibly collected by Gibbs in the mid nineteenth century.

Blankets 138571, 155607 and 144864 were acquired by the NMAI and are all from British Columbia. Blanket NMAI138571 (Figure 2) is a plain ceremonial blanket, with red fabric strips across its width. It was collected near the Fraser River and first recorded in 1925. NMAI155607 is an organised classic-type blanket fragment. It was made by the Saanich Salish (central Coast Salish, south-west of Vancouver Island) and first recorded in 1927. The warp is made of vegetal fibres and the weft of animal fibres. The organised colonial-type blanket NMAI144864 (1120 × 1170mm; Figure 3) was first acquired at Yale (Fraser River) *c*. 1860. It was obtained (possibly commissioned) by Joseph McKay, a Hudson's Bay Company employee, from the Tsakuam band of the Cowichan Indians (Orchard 1926); it entered the Museum of the American Indian records in 1925.

Proteomics identification of animal fibre

Animal fibres are made of highly resistant and specific structural proteins, mainly α-keratins or Intermediate Filament Proteins (IFPs) classified in type I and type II families. Although proteins from each family are highly conserved (Plowman *et al.* 2002), these structural proteins are specific to the animal genus (Hollemeyer *et al.* 2007). They differ between sheep/goat and dog to as much as 14% but only to 2% between sheep and goat. Public databases give the complete set of hair keratins for *Canis familiaris*, but limited information is available for *Ovis aries* and *Capra hircus* with a number of seven (four type I and three type II) and one sequences known respectively. Clerens *et al.* (2010) gives an extended record of eight type I IFPs and seven type II IFPs for *Ovis aries*. The mountain goat (*Oreamnos americanus*) is the only species from the genus Oreamnos (subfamily Caprinae). Consensus

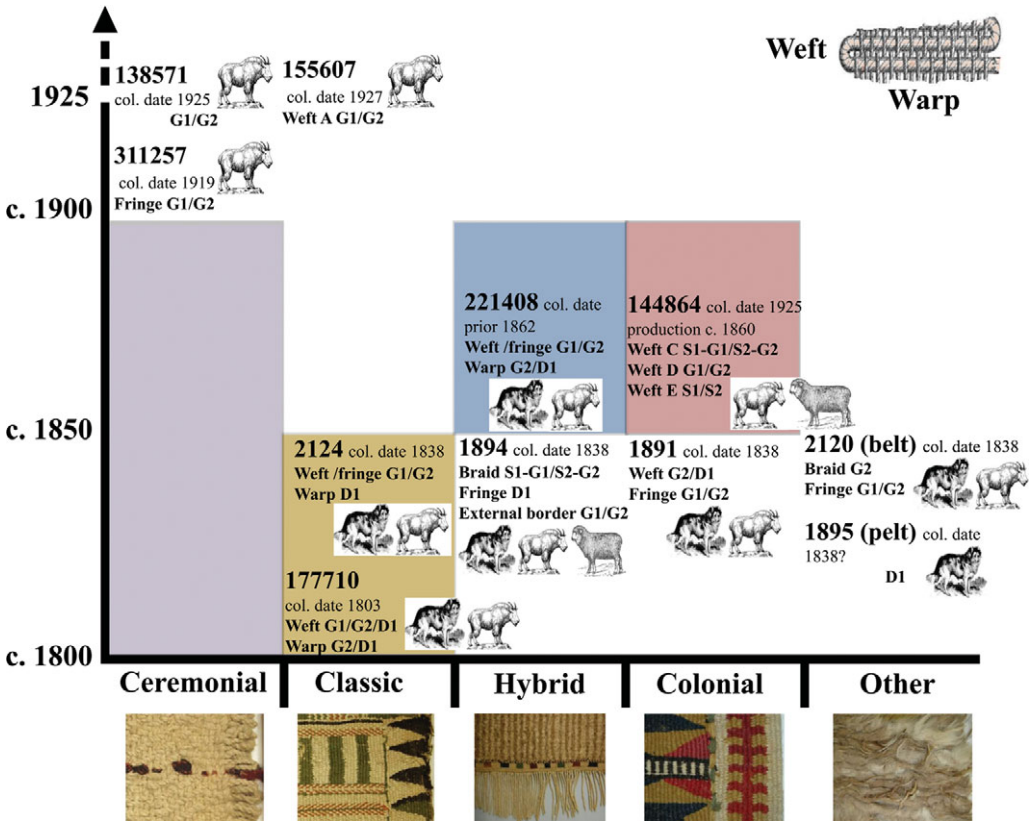

Figure 5. Summary plot of the identification of each textile with their production and collection dates (or acquisition dates) estimated from available records. Each style described by Gustafson (1980) with her time periods for production is illustrated by details of some of the Salish blankets sampled for analysis: the plain ceremonial blanket NMNH *311257, the classic Lewis and Clark blanket* NMNH *177710, the hybrid blanket* NMNH *1894 and the colonial blanket* NMNH *1891. An additional section is reserved for the other textiles illustrated by the fur robe* NMNH *1895. Whenever identified, the markers for distinguishing between mountain goat, sheep and dog are specified: YSCQLNQVQSLISNVESQLAEIR, m/z 2679 (S1/G1), common to sheep and goat, YSCQLNQVQSLIVSVESQLAEIR and YSCQLSQVQSLIVNVESQLAEIR, m/z 2664 (S2), unique to sheep, YSCQLNQVQSLIVNVESQLAEIR, m/z 2691 (G2), unique to goat, and YSSQLGQLQCMITNVESQLAEIR, m/z 2668 (D1), unique to dog.*

IFP mountain goat sequences were therefore created by comparison with available *Ovis aries* and *Capra hircus* sequences.

We analysed the protein composition of 11 Salish textiles (ten woven pieces and a fur robe) representing 25 samples (including fringe, warp and weft yarns) from the Smithsonian Institution collections of the National Museum of the American Indian (NMAI, three textiles) and the National Museum of Natural History (NMNH, eight textiles) (Figure 5). Small quantities of hair (3–9mg) were taken from accessible parts of the textile such as damaged areas or loose threads to minimise any impact of the sampling on the visual character of the textiles. Careful examination of the different structures of the textiles allowed sampling of visually different yarns (colour, brittleness, thickness) and whenever possible weft, warp and fringe were sampled. Finally samples were chosen from undyed threads to avoid possible interaction (chemical modifications, protein extractability) due to

the dyes. The hairs were dissolved to extract the proteins, which were then cut into their component peptides by an enzyme. The peptides are identified by their mass and sequence, measured by mass spectrometry (Hollemeyer *et al.* 2002, 2007, 2008).

Results

Specific peptides were identified for *Ovis aries* (sheep)/*Capra hircus* (goat) (Table 2) or *Canis familiaris* (dog) (Table 3). *Ovis aries/Capra Hircus* peptides were found in 19 textile samples in addition to the reference samples of mountain goat and merino sheep. Of 21 specific peptides, 13 were present in the mountain goat and 15 in the merino sheep. *Canis familiaris* peptides were found in ten textile samples in addition to the reference sample of the Salish dog. Of 17 specific peptides, 11 were present in the Salish dog. In addition, mountain goat wool was differentiated from sheep wool on the basis of a single peptide m/z 2691 (Figure 6) manually sequenced in goat (YSCQLNQVQSLIVNVESQLAEIR), and equivalent to an m/z 2664 peptide in merino sheep wool, in which $N_6 \rightarrow S_6$. All non-dog fibres had the m/z 2691 mountain goat peptide except for the one sample that had the m/z 2664 sheep peptide, while in two cases both sheep and goat peptides were present.

The majority of the samples thus matched ovicaprid sequences, which were found in all ten woven textiles for a total of 86% of the 22 samples (fur robe excluded). Dog sequences were found in seven textiles from NMNH's collection, six woven pieces and the fur robe. With a minimum of five specific peptides, dog hair keratins were identified in ten samples: as a pure yarn in two samples ($_{NMNH}$1894 fringe and $_{NMNH}$2124 warp) and as a blend in five samples ($_{NMNH}$1891 weft, $_{NMNH}$2120 braid, $_{NMNH}$177710 warp and weft and $_{NMNH}$221408 warp). The remaining three samples are from $_{NMNH}$1895 and were taken from three locations, each of a different colour. This robe appears to be designed with alternating rows of brown and yellow to white fur; both coarse guard hair and fine under hair are present. The differing hair lengths and colours suggest that more than one dog was used in the robe's construction.

Dog hair was mainly found in the earlier blankets (Figure 5). The $_{NMNH}$177710 'Lewis and Clark' blanket is a mixture of both goat and dog (in both warp and weft). Dog hair was also found in all textiles produced prior to 1862 but is absent from blankets woven in the late nineteenth century to early twentieth century. Pure yarn of dog hair was found in only one warp and one fringe, while pure mountain goat yarn was used in six wefts and five fringes. These results suggest that in the NMNH textiles dog hair was mainly used to supplement the goat hair, possibly as a bulking material. Noticeably, dog is absent from the plain twill-woven ceremonial-type blankets ($_{NMAI}$138571 and $_{NMNH}$311257) where both warp and weft are equally visible as a balanced weave, indicating a strong preference for mountain goat hair, in both aesthetic and technical aspects.

The results also reveal the use of sheep wool, present in the samples $_{NMAI}$144864-E, $_{NMAI}$144864-C and $_{NMNH}$1894 braid. In the later period of traditional Salish weaving, sheep had been introduced to the area and trading posts would have stocked commercial wool yarn. Sheep wool was expected in the late colonial blanket $_{NMAI}$144864, as commercially manufactured yarns were observed during the sampling of the blanket (sample $_{NMAI}$144864-E was from a three-ply commercially-produced yarn, as opposed to the hand-spun two-ply yarn, sample $_{NMAI}$144864-C). More surprising is the sheep/mountain goat blend found in

Table 2. Goat/sheep peptides identified in mountain goat (MG), merino wool (MW) and the Coast Salish textiles: $_{NMAI}$138571 (loose fibres), $_{NMAI}$155607-A and –B, $_{NMAI}$144864-C, -D, and –E, $_{NMNH}$1894 external border (EB) (chevron-patterned twining) and braid (B), $_{NMNH}$1891 fringe (F) and weft (We), 2120 braid (B) and fringe (F), $_{NMNH}$311257 fringe (F), 2124 fringe (F) and weft (We), $_{NMNH}$177710 warp (Wa) and weft (We), and $_{NMNH}$2211408 fringe (F), warp (Wa) and weft (We). The table displays the specific sheep/goat sequences, their Mr (relative molecular weight) and the proteins in which they were identified: from a to d type I hair keratins and from e to h type II hair keratins. Accession numbers for the cited proteins are: [a]gi|41350553 for K31 *Capra hircus*; [b]gi|164652864 for K31 *Ovis aries*; [c]gi|125091 for K33a *Ovis aries*; [d]Type I EST *Ovis aries*; [e]gi|1308 for K81 *Ovis aries*; [f]gi|125116 for K83 *Ovis aries*; [g]gi|125117 for K85 *Ovis aries*; [h]gi|313244 for IFP type II. Samples were identified by: [1]MALDI-TOF/TOF; [2]ESI-MS/MS.

Mr	Identified sequences	Protein	MG[1]	MW[1]	138571	155607		144864			1894		1891		2120		311257	2124		177710		221408		
					[1]	A[1,2]	B[1]	C[1,2]	D[2]	E[1,2]	EB[2]	B[1,2]	F[2]	We[2]	B[2]	F[2]	F[2]	F[2]	We[2]	Wa[2]	We[2]	F[2]	Wa[2]	We[2]
1012.59	LVIQIDNAK	d			x			x	x	x	x	x	x	x			x		x		x			x
1108.52	DVEEWYIR	a, b, c	x	x	x	x	x	x	x	x	x	x				x	x		x		x			x
1123.55	LESEINTYR	d	x	x	x	x		x	x	x		x	x	x			x	x	x					x
1272.67	QLVESDINSLR	d	x	x	x			x									x		x		x	x		
1292.64	AQYEALVETNR	a, b, c	x	x				x																x
1448.74	AQYEALVETNRR	a, b, c	x		x	x	x	x		x	x							x			x			x
1516.71	SYNFCLPNLSFR	a, d	x	x	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x	x	x
1833.97	TVNALEVELQAQHNLR	a, b, c	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2103.08	SDLEAQVESLKEELICLK	a, b										x	x	x		x	x	x			x	x		x
889.47	VGGSILGCK	h		x	x						x		x					x			x	x		x
978.51	ISPGYSVTR	g	x	x	x		x																	
1157.55	GFSTVGSGFGSR	f	x	x	x		x																	
1373.69	DLNMDNIVAEIK	e		x	x	x					x	x	x	x		x	x	x	x		x	x		x
1508.86	VLQAHISDTSVIVK	e				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
1512.70	GGVACGGLTYSSTAGR	g	x	x	x																			
1807.92	LSSELNSLQEVLEGYK	e		x		x			x	x		x	x	x		x	x	x	x	x	x	x		x
2013.00	LEAAVTQAEQQGEAALADAK	e, h				x		x				x	x	x		x	x	x			x	x		x
2112.05	LEAAVTQAEQQGEVALNDAR	f	x	x				x		x			x			x	x	x						x
2134.08	KSDLEANVEALVEESNFLK	g				x				x		x	x			x	x					x		x
2155.02	QCCESNLEPLFSGYIETLR	e	x	x	x							x					x							x
2190.12	KSDLEANVEALIQETDFLR	e	x	x	x	x				x		x	x			x	x				x	x		

Method

Table 3. Dog peptides identified in the Salish dog and the Coast Salish textiles: $_{NMNH}$1894 fringe (F), $_{NMNH}$1891 weft (We), $_{NMNH}$2120 braid (B), $_{NMNH}$1895 long beige Lbe, short yellow Sy and long brown Lbr, $_{NMNH}$2124 warp (Wa), $_{NMNH}$177710 warp (Wa) and weft (We), and $_{NMNH}$2211408 warp (Wa). The table displays the specific dog sequences, their Mr (relative molecular weight) and the proteins in which they were identified: from a to f type I hair keratins and from i to k type II hair keratins. Accession numbers for the cited proteins are: [a]gi|73965889 for K31; [b](gi|73965900 and gi|73965891) for K33a; [c]gi|73965893 for K33b; [d]gi|73965827 for K35; [e]gi|73965853 for K37; [f]gi|73965851 for K38; [g]gi|73965945 for K40; [h](gi|73996366, gi|73996368, gi|73996364 and gi|73996577) for K81; [i]gi|73996557 for K83; [j](gi|73996502 and gi|73996510) for K85; [k]gi|73996559 for K86. Samples were identified by: [1]MALDI-TOF/TOF; [2]ESI-MS/MS.

Mr	Dog sequences	Dog protein	Salish dog[1]	1894[2]	1891[2]	2120[2]	1895[2]			2124[2]	177710[2]		2211408[2]
				F	We	B	Lbe	Sy	Lbr	Wa	Wa	We	Wa
1008.52	YQTELSLR	b	x							x			
1122.53	VTMQFLNDR	e, f		x						x		x	
1160.61	GILDELTLCK	g							x		x		
1194.62	TKYETEVGLR	b	x	x			x		x	x			
1212.63	LDVEPTVDLGR	e, f	x	x	x	x	x	x	x	x	x	x	x
1378.69	QNHEQEVNILR	b	x						x	x			
1594.83	LNVEVDAAPAVDLNR	a	x	x									
1792.95	TVNALEVELQAQHTLK	e, f		x	x			x		x	x	x	x
1847.98	TVNALEIELQAQHNLR	b, c	x	x	x	x	x	x	x	x	x	x	x
1867.85	DVEEWFTTQTEELNK	a, b, c		x	x		x	x	x	x	x	x	
2030.08	SDLEAQVESLKEELLSLK	b, c		x	x	x	x	x	x	x	x	x	
2058.08	SDLEAQVESLREELLSLK	b		x	x		x	x	x	x	x	x	x
1065.51	AQYDDIVSR	k	x	x					x	x			
1084.61	LAELEAALQK	h, i, j, k	x	x	x	x	x	x	x	x	x	x	x
1151.58	KYEEEVSLR	h, k	x	x	x		x		x	x	x		
1518.97	VLHAHISDTSVIVK	h, i, j, k	x	x								x	
2071.02	LEAAVTQAEQQGEAALTDAR	h, i, k	x	x	x	x	x	x	x	x	x	x	x

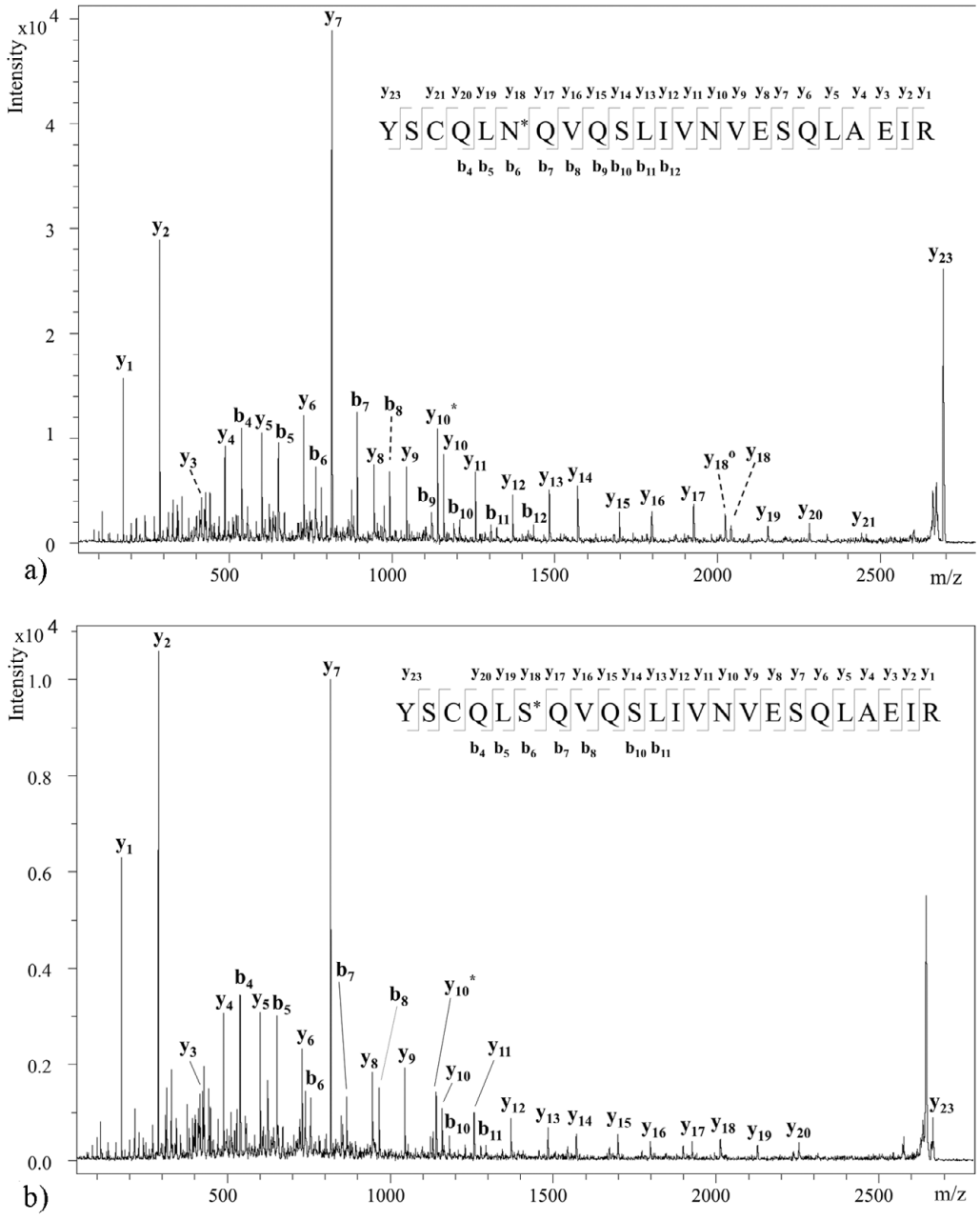

Figure 6. MS/MS spectra obtained by nanoLC-MALDI-TOF/TOF analysis of (a) m/z 2691.186 peptide YSCQLNQVQSLIVNVESQLAEIR from sample NMAI138571 identified by de novo sequencing, and (b) m/z 2664.501 peptide YSCQLSQVQSLIVNVESQLAEIR from merino wool identified by de novo sequencing.

the other weft sample, as well as in the hybrid blanket NMNH 1894 (in the braid, a structure appearing between the main body of the blanket and the chevron-patterned twining, see detail on Figure 5), which is supposedly one of the earlier textiles in the NMNH collection. The results presented here would indicate that commercial sheep wool was incorporated in the nineteenth century.

Discussion and conclusion

The short supply of raw materials conferred on the blankets a high economic value and a measure for wealth. Access to the goat herds and the hunting grounds, dependent on the Interior groups, was often a source of conflict (Mohs 1992). Dog wool would have allowed more blankets to be made and Amoss (1993) suggests that it was developed by the wealthier people to increase their domination in the potlatch systems. If we believe the early ethnological reports, the woolly dogs were to be found in great number. Yet the dog disappeared quickly after the arrival of Europeans, probably as a result of its economic devaluation, a consequence of the trade with affordable European point blankets.

Based on these results, the description of textiles in museum collections as 'dog hair blankets' should be reconsidered; in no case did we find a textile made solely of this fibre. It may have been the case that pure dog hair blankets were once more common, but considered of lower value and consumed in use and lost. According to oral traditions, the use of dog hair also extends to other communities in the region. A systematic proteomic analysis of Pacific Northwest Coast textiles in museums would clarify the role of the woolly dog in the traditional weaving of the Coast Salish and neighbouring communities.

Acknowledgements

This work was supported by a Smithsonian Museum Conservation Institute grant, project MCI # 5927.2 and by a Marie Curie International Outgoing Fellowship (PIOF-GA-2009-236425) from the University of York, UK and AgResearch, NZ. The Centre of Excellence in Mass Spectrometry at York is supported by Science City York and Yorkshire Forward, using funds from the Northern Way Initiative. Drs Peter Ashton, Enrico Cappellini, Stefan Clerens and Prof. Jane Thomas-Oates are all thanked for their support, and we would single out Marilyn Jones, Director of the Suquamish Museum, for providing the impetus in 2003 to determine if there was indeed dog hair in the textiles in Smithsonian's collections and for providing support through the following years.

References

Amoss, P.T. 1993. Hair of the dog: unravelling pre-contact Coast Salish social stratification, in A. Mattiana & T. Montler (ed.) *American Indian linguistics and ethnography in honor of Laurence C. Thompson*: 3–35. Missoula (MT): University of Montana.

Ashwell, R. 1978. *Coast Salish, their art, culture and legends*. Saanichton (BC) & Seattle (WA): Hancock House.

Barnett, H.G. 1938. The Coast Salish of Canada. *American Anthropologist* 40(1): 118–41.

Barraclough, W. 1969. Dogs that were indigenous to the Pacific Northwest. *British Columbia Historical News*: 6–13.

Barsh, R.L., J.M. Jones & W. Suttles. 2002. History, ethnography, and archaeology of the Coast Salish woolly-dog, in L.M. Snyder & E.A. Moore (ed.) *Dogs and people in social, working, economic and symbolic interaction* (Proceedings of the 9th Conference of the International Council of Archaeozoology): 1–11. Oxford: Oxbow.

Buckley, M., M. Collins, J. Thomas-Oates & J.C. Wilson. 2009. Species identification by analysis of bone collagen using matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry. *Rapid Communications in Mass Spectrometry* 23: 3843–54.

Buckley, M., S. Whitcher Kansa, S. Howard, S. Campbell, J. Thomas-Oates & M. Collins. 2010. Distinguishing between archaeological sheep and goat bones using a single collagen peptide. *Journal of Archaeological Science* 37: 13–20.

Cappellini, E., M.T.P. Gilbert, F. Geuna, G. Fiorentino, A. Hall, J. Thomas-Oates, P.D. Ashton, D.A. Ashford, P. Arthur, P.F. Campos, J. Kool, E. Willerslev & M.J. Collins. 2009. A multidisciplinary study of archaeological grape seeds. *Naturwissenschaften* 97(2): 205–217.

Chambery, A., A. Di Maro, C. Sanges, V. Severino, M. Tarantino, A. Lamberti, A. Parente & P. Arcari. 2009. Improved procedure for protein binder analysis in mural painting by LC-ESI/Q-q-TOF mass spectrometry: detection of different milk species by casein proteotypic peptides. *Analytical Bioanalytical Chemistry* 395: 2281–91.

Clerens, S., C.D. Cornellison, S. Deb-Choudbury, A. Thomas, J.E. Plowman & J.M. Dyer 2010. Developing the wool proteome. *Journal of Proteomics* 73(9): 1722–31.

Crockford, S.J. 1997. *Osteometry of Makah and Coast Salish dogs*. Burnaby (BC): Archaeology Press, Simon Fraser University.

– 2000. A commentary on dog evolution: regional variation, breed development and hybridization with wolves, in S.J. Crockford (ed.) *Dogs through time: an archaeological perspective* (British Archaeological Reports international series 889): 295–312. Oxford: Archaeopress.

Crockford, S.J. & C.J. Pye. 1997. Forensic reconstruction of prehistoric dogs from the North West Coast. *Canadian Journal of Archaeology* 21: 149–53.

Fremout, W., M. Dhaenens, S. Saverwyns, J. Sanyova, P. Vandenabeele, D. Deforce & L. Moens. 2010. Tryptic peptide analysis of protein binders in works of art by liquid chromatography-tandem mass spectrometry. *Analytica Chimica Acta* 658: 156–62.

Gibbs, G. 1877. *Tribes of Western Washington and Northwestern Oregon* (Contributions to North American ethnology 1). Washington (DC): Government Printing Office.

Gustafson, P. 1980. *Salish weaving*. Vancouver (BC): Douglas & McIntyre.

Hill-Tout, C. 1907. *The native races of the British Empire: British North America. 1, The far west, the home of the Salish and Déné*. London: Archibald Constable and Company Ltd.

Hollemeyer, K., W. Altmeyer & E. Heinzle. 2002. Identification and quantification of feathers, down, and hair of avian and mammalian origin using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry. *Analytical Chemistry* 74(23): 5960–68.

Hollemeyer, K., W. Altmeyer & E. Heinzle. 2007. Identification of furs of domestic dog, racoon dog, rabbit and domestic cat by hair analysis using MALDI-ToF mass spectrometry. *Spectroscopy Europe* 19(2): 8–15.

Hollemeyer, K., W. Altmeyer, E. Heinzle & C. Pitra. 2008. Species identification of Oetzi's clothing with matrix-assisted laser desorption/ionization time-of-flight mass spectrometry based on peptide pattern similarities of hair digests. *Rapid Communications in Mass Spectrometry* 22: 2751–67.

Howay, F.W. 1918. The dog's hair blankets of the Coast Salish. *The Washington Historical Quarterly* 9(2): 83–92.

Jones, M. 2005. Coast Salish: the beauty of everyday things, in P. Macnair, J. Stewart, R. Joseph & M.J. Lenz (ed.) *Listening to our ancestors: the art of native life along the north Pacific Coast*: 14–27. Washington (DC): National Museum of the American Indian, Smithsonian Institution in association with National Geographic.

Kane, P. 1971. *Paul Kane's frontier: including Wanderings of an artist among the Indians of North America*. Austin (TX): University of Texas Press.

Kissell, M.L. 1929. Organized Salish blanket pattern. *American Anthropologist* 31(1): 85–8.

Krieger, H.W. 1928. *American Indian costumes in the United States National Museum*. Washington (DC): Government Printing Office.

Ledyard, J. 1783. *A journal of Captain Cook's last voyage to the Pacific Ocean, and in quest of a north-west passage, between Asia & America*. Hartford: Printed and sold by Nathaniel Patten.

Mohs, G. 1992. Mountain goats and wooly dogs: the weaving industry of the Stó:lo Indians. Unpublished manuscript. Chilliwack: Stó:lo Nation Archives.

Nagorsen, D.W. & G. Keddie. 2000. Late Pleistocene mountain goats (*Oreamnos americanus*) from Vancouver Island: biogeographic implications. *Journal of Mammalogy* 81(3): 666–75.

Olsen, R.L. 1936. *The Quinault Indians*. Seattle (WA): University of Washington.

Orchard, W.C. 1926. *A rare Salish blanket* (Leaflets of the Museum of the American Indian, Heye Foundation 5). New York: Museum of the American Indian, Heye Foundation.

PLOWMAN, J.E., W.G. BRYSON, L.M. FLANAGAN & T.W. JORDAN. 2002. Problems associated with the identification of proteins in homologous families: the wool keratin family as a case study. *Analytical Biochemistry* 300(2): 221–9.

ROBERTS, J.E. 2005. *A discovery journal: George Vancouver's first survey season — 1792*. Bloomington (IN): Trafford Publishing.

SCHULTING, R. 1994. The hair of the dog: the identification of a Coast Salish dog-hair blanket from Yale, British Columbia. *The Canadian Journal of Archaeology* 18: 57–76.

SCOULER, J. 1905. Dr John Scouler's Journal of a voyage to N.W. America. [1824-'25-'26.] II. Leaving the Galapagos Islands for the North Pacific Coast. *The Quarterly of the Oregon Historical Society* 6(2): 159–205.

SMITH, M.W. 1941. The Coast Salish of Puget Sound. *American Anthropologist* 43(2): 197–211.

SUTTLES, W. 1987. *Coast Salish essays*. Vancouver (BC): Talonbooks.

WELLS, O.N. 1969. *Salish weaving. Primitive and modern.* Sardis (BC): The author.

WILLOUGHBY, C.C. 1910. A new type of ceremonial blanket from the Northwest Coast. *American Anthropologist* 12(1): 1–10.

WORTMANN, F.J., K.H. PHAN & P. AUGUSTIN. 2003. Quantitative fiber mixture analysis by scanning electron microscopy. Part V: analyzing pure fiber samples and samples with small admixtures according to test method IWTO-58. *Textile Research Journal* 73(8): 727–32.