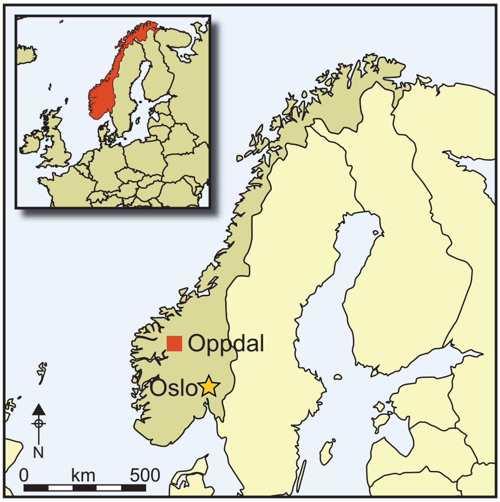
Melting snow patches reveal Neolithic archery

Martin Callanan*



High altitude snowfields provide repositories of well-preserved organic remains of considerable antiquity, as spectacular discoveries such as the Similaun Iceman illustrate. In Scandinavia, melting snow patches have been systematically surveyed by volunteer groups for almost a century, and a growing collection of archaeological artefacts has been recovered. Only recently, however, has AMS dating confirmed that some of the finds go back as far as the Neolithic. Here fragments of five Neolithic arrowshafts and a Neolithic longbow discovered in 2010–11 in the Oppdal area of Norway are described. They throw light on Neolithic bow and arrow technology and tangentially on the hunting techniques which may have attracted hunters to these snow patches in search of game. The progressive and accelerated melting of the snow patches in recent years draws attention to processes of climate change and the urgency of discovering and recovering these fragile perishable artefacts.

Keywords: Norway, Oppdal, Neolithic, snow patches, archery, climate change

Introduction

Snow patches are perennial accumulations of snow and ice, found in the mountains of Norway and other regions of the world at high altitude or latitude. Continually exposed to the varying effects of weather and climate, they are dynamic contexts, prone to constant change and development. On hot summer days, animals such as reindeer, sheep and birds often seek out high-lying snow patches to get some relief from both the heat and from parasitic insects. In the past, this behaviour attracted the attention of hunters who used snow patches as summer hunting grounds. Objects lost or discarded by these hunters are often very well preserved and are discovered when patches melt sufficiently. This chain of events forms the background for snow patch archaeology and the finds described here.

In this paper, a number of Neolithic (4000–1800 BC) artefacts recently discovered from snow patches in central Norway are reported. In 2010 and 2011 fragments of five Neolithic

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arrows and a Neolithic bow were discovered at two mountain sites. Despite a long tradition of artefact collection from snow patches in the region, these are the oldest snow patch artefacts that have yet been recovered in Scandinavia. The finds are significant for two reasons. First, they offer a rare glimpse into the archery technology of the Neolithic period in Scandinavia. Second, the repeated recovery of organic artefacts from melting snow patches serves as a warning to us of changes that are currently taking place in the alpine landscapes of central Scandinavia.

Background/setting

The snow patch region in question lies in the mountainous south-western corner of central Norway between 62° and 63° N. Here, the mountain complexes of Trollheimen and Dovre meet across a series of valleys converging on the town of Oppdal (Figure 1).

The geology of this area is complex, lying in a contact zone between Cambrosilurian and Precambrian bedrocks to the west and east respectively. The overlying landscape was heavily modified during the last ice age, especially in the west. Furthermore, the area has the character of a borderland with regard to climate. Maritime conditions in the west give way to mildly continental conditions in the east. Vegetation in the area follows elevation gradients from middle boreal vegetation in the valleys up to 700m asl. There follows a belt of sub-alpine birch forest up to *c.* 1100m asl. Archaeological snow patches are generally found at elevations above 1400m asl within middle and high alpine vegetation zones. Scattered communities of lichen and mosses between areas of bare bedrock and scree are found around the highest-lying snow patches (Moen 1987: 217). The fauna of the region includes herbivores such as reindeer and musk ox as well as carnivores such as wolverine, polar fox, gyrfalcon, rough-legged buzzard and golden eagle.

There is a long-standing tradition of artefact surveying among a group of local volunteer collectors in Oppdal. Regular surveying is carried out on foot and often involves long treks in demanding terrain, frequently in difficult weather conditions. Nonetheless, no fewer than 234 artefacts have been collected in the region from 27 different snow patches in the period 1914–2011 (Callanan 2012; Figure 2).

The material collected comprises arrowheads, shafts and bow fragments as well as other items associated with hunting activities (Farbregd 2009; Callanan 2012). Since 2006, snow patch discoveries have also been made in other parts of Norway, most notably in Oppland County in the inner mountains of southern Norway, where a series of complex sites, mostly from the Iron Age and medieval periods (*c.* 500 BC–AD 1500) have been identified and surveyed. Moreover, a few Bronze Age artefacts (1800–500 BC) have been recovered, most notably a shoe, a birch bark quiver and more recently a complete bow dated to *c.* 1300 BC (Finstad & Vedeler 2008; Mímisbrunnr n.d.).

Beyond Norway, archaeological snow patches have been identified in a number of high altitude/latitude environments around the globe. In many instances objects related to projectile/hunting technology have been found, as in the Yukon and Northwest Territories in Canada (Farnell *et al.* 2004; Andrews *et al.* 2012), and in Alaska (Dixon *et al.* 2005; VanderHoek *et al.* 2007) and the Rocky Mountains in the United States (Lee 2012). A more varied group of snow patch finds have been recovered from the Schnidejoch site in

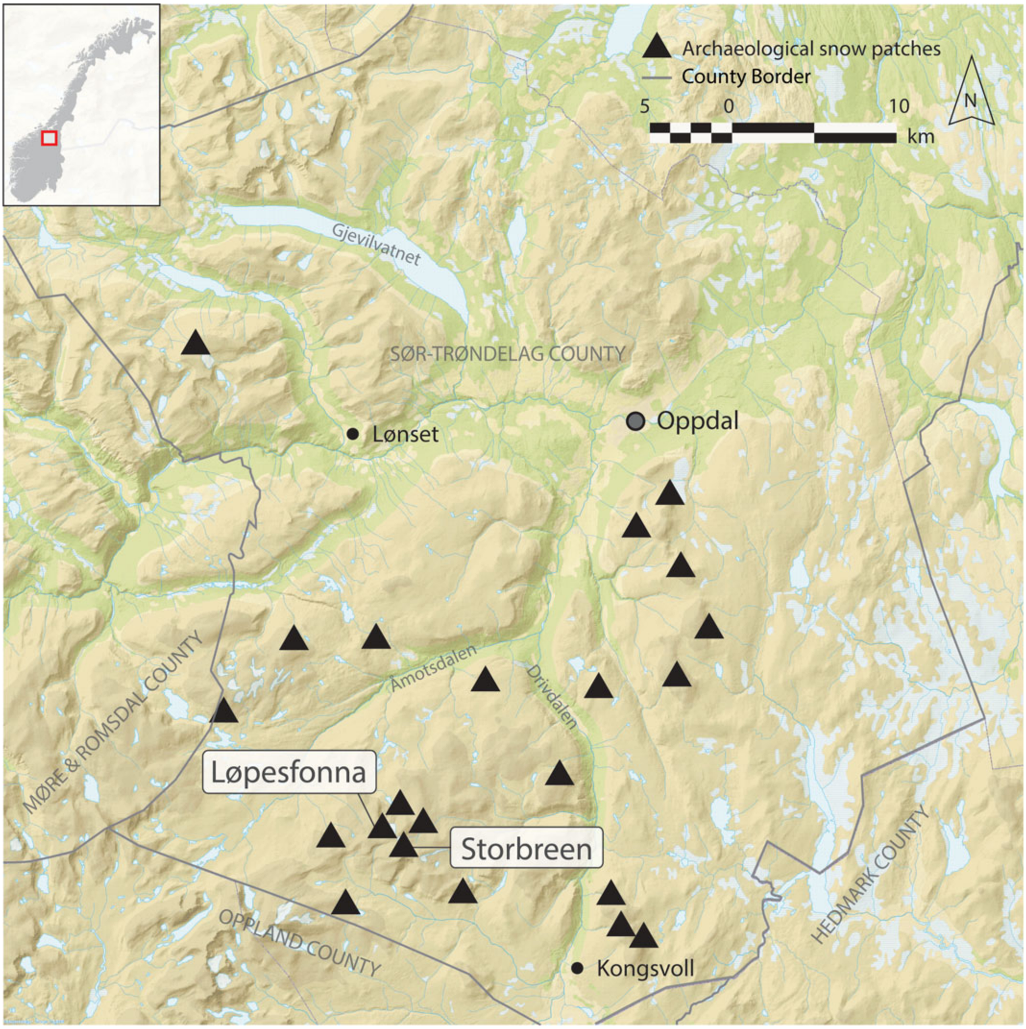

Figure 1. Archaeological snow patches identified in the Oppdal Mountains, central Norway. The sites mentioned in this article, Løpesfonna and Storbreen, are highlighted.

Switzerland (Suter *et al.* 2005). In each region, finds from snow patches offer researchers important chronological and technical information on human movements and on the utilisation of peripheral environments through prehistory. Snow patch archaeology also forms part of a global complex of finds and sites, associated with frozen contexts such as glaciers, permafrost and alpine sites where an increasing number of prehistoric and historic sites and materials are being exposed, often as a result of rising temperatures and changing climates.

Previous snow patch research in central Norway

Chronological patterns have been an important theme for research on the material recovered from the central Norwegian snow patches. Particular attention has been paid to determining

Figure 2. Examples of different contexts from which collectors discover objects around local snow patches. Few objects have been recovered directly from the ice itself (A). Artefacts are usually found on stony surfaces close to the edges of the snow patch (B & C). Photos: (A) Rune Pedersen; (B & C) Martin Callanan.

the antiquity of recovered artefacts. By monitoring the age of the oldest finds, researchers are able to formulate and update theories regarding the chronology of the use, formation and development of snow patches in the past (Farbregd 1972, 1983, 2009; Figure 3).

Until recently it was thought from the evidence available that the dearth of finds older than AD 200 was probably due to a large-scale melting of snow patches during the warm Roman Iron Age (0–AD 400) (Fægri 1938; Farbregd 1972: 95, 1983: 33, 2009: 167). In this scenario, a complete melt-out of snow patches would have exposed artefacts older than AD 200 to the elements, causing them to deteriorate and disappear. However, developments since 2001 make it necessary to revisit this issue. Since then, the assemblage of material from the region's snow patches has increased by 183 per cent as new finds have been recovered (Callanan 2012: 186–87). Further, in 2006, adhesive on a slate point discovered close to a snow patch was ^{14}C-dated to 2480–2340 cal BC and an atypical wooden arrow shaft was also dated to 1740–1600 cal BC (Åstveit 2007: 15–17). In short, we now have a much larger snow patch assemblage available for analysis and there are indications that local snow patches contain artefacts considerably older than the proposed AD 200 boundary. Previous questions hence arise anew. What is the age of the oldest material now appearing at local snow patches? Are the few old finds recovered hitherto simply the result of fortuitous preservation? Or have older finds continued to appear at the snow patches in recent times (Åstveit 2007: 20; Farbregd 2009: 167)? The aim of the research reported here was to

Figure 3. Snow patches melt and reduce in size during the summer. Once dirty surfaces with ice begin to appear, the possibility of finding ancient artefacts increases. A) Løpesfonna seen from the east, 20 August 2010. B) Storbreen seen from the east, 1 September 2008 (photos: Martin Callanan).

analyse systematically and date a selection of recent snow patch finds in order to gain a clearer view of the chronological developments currently taking place at local snow patches.

Method

Snow patches follow a natural annual cycle of growth during the winter months and decline during the summer. Recent investigations with ground penetrating radar (GPR) demonstrate the internal structure of snow patches consisting of a layer of recent snow superimposed on a core of ice (Callanan & Barton 2010). Geomorphic features registered around snow patches show that their size and extent fluctuated during the Holocene. But hunting probably took place on individual snow patches that were similar to those found in the landscape today, even during the coldest periods. Artefacts initially lost in the surface snow layer have probably, over time, become integrated within the ice core. They are subsequently released as the surface snow melts and the ice core reduces in size under warm and unstable weather conditions (Figure 4).

Artefacts are normally recovered from the edges of alpine snow patches towards the end of the summer, when the previous year's snow has melted sufficiently. Objects are often found lying on rocks and gravels surrounding the melting snow patch.

Following conservation, the artefacts were analysed with a particular focus on typological and morphological features. Farbregd has previously shown that certain arrow shaft elements are prone to change through time and are therefore typologically significant. These are the nock and hafting ends, as well as the length and width of the arrow shaft itself (Farbregd 2009: 161–63). Until 2006 the vast majority of the collection in Trondheim was dated

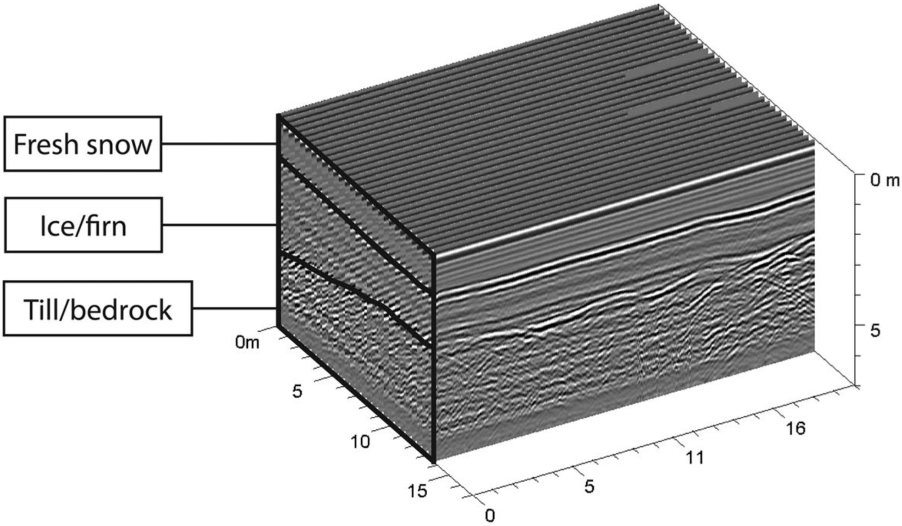

Figure 4. Ground penetrating radar profile generated in 2008 from the northern end of Storbreen, Oppdal, showing the internal structure of a snow patch. In this profile, recent snow has formed a layer over the core of ice, where ancient objects are probably situated. In years of advanced melting, the upper snow layer melts and the core becomes exposed. Under these conditions ancient objects can be found, often at the foot of the snow patch.

typologically to the Iron Age and medieval periods (*c.* 500 BC–AD 1500). For the present study, a selection of recent finds displaying nock ends, hafting ends or metric dimensions unlike examples previously analysed were submitted for radiometric dating. The following is a description of the Neolithic finds identified using this approach.

Results

Artefact A (T25675) (Tables 1 & 2; Figure 5) is an almost complete arrow shaft that is dated to between 3628 and 3371 cal BC. The shaft, identified as *Pinus,* is preserved as six contiguous fragments giving a total length of 420mm. The hafting split is V-shaped. With an internal width of 1–3mm, it was probably intended for a tanged point of bone, antler or lithic material. The nock end is missing, but the imprint of lashings is clearly visible between 25 and 35mm from the extant proximal end. (In the descriptions that follow, the nock end, closest to the archer when being fired, will be described as the 'proximal' end and the tip will be described as the 'distal' end.) A red-brown colouring can also be seen on the proximal end. This coloured area continues for some 150mm along either side of the shaft in two uniform 2–3mm-wide lines. The coloured material has not been identified but is probably decoration.

A volunteer collector recovered fragments of the shaft on two separate occasions from the southern end of Storbreen, Oppdal. During the first survey, four fragments were recovered at the foot of the snow patch. On a later visit, two more fragments were recovered on the surface of the snow patch itself, only 8m from the initial find. The six fragments were subsequently refitted during conservation. The manner in which the fragments were recovered, together

Table 1. Radiocarbon determinations of Neolithic artefacts presented in this paper.

Artefact ID	Museum no.	Snowpatch	Type	Lab no.	Radiocarbon age ^{14}C yr BP	1σ	2σ	Median cal.	^{13}C
A	T25675	Storbreen	arrowshaft	Beta-308922	4690±30	3519–3376 BC	3628–3371 BC	3447 BC	−23.5
B	T25674	Storbreen	arrowshaft	Beta-308921	4650±30	3499–3368 BC	3518–3362 BC	3456 BC	−25.4
C	T25676	Storbreen	arrowshaft	Beta-308923	4530±30	3356–3118 BC	3361–3102 BC	3206 BC	−23.8
D	T25170	Storbreen	arrowshaft	TRa-2770	3670±30	2132–1980 BC	2139–1956 BC	2056 BC	−30.2
E	T25287	Løpesfonna	arrowshaft	TRa-2771	3445±35	1871–1691 BC	1883–1682 BC	1759 BC	−27.5
F	T25677	Storbreen	bow frag.	Beta-308924	3490±30	1878–1770 BC	1894–1700 BC	1816 BC	−23.7

Figure 5. Artefact A (T25675): an almost complete arrowshaft of Pinus *discovered at Storbreen on 28 August & 13 September 2011, dated to between 3628 and 3371 cal BC. Pigment traces and lashing imprints are clearly visible on the proximal end of the shaft (photo: Åge Hojem/NTNU Museum of Natural History and Archaeology; layout: Martin Callanan).*

Table 2. Technical data on the five arrow shafts and bow limb presented in this paper. The diameter of each arrow is measured at 50mm intervals along the shaft, starting from the proximal end.

Museum ID	Wood type	No. of frags.	Description
T25675	*Pinus*	6	Distal + 5 medial. Contiguous.
0mm/break	6mm	**250mm**	7mm
50mm	6mm	**300mm**	6mm
100mm	7mm	**350mm**	6mm
150mm	7mm	**400mm**	5mm
200mm	7mm	**420mm/haft**	4mm

Museum ID	Wood type	No. of frags.	Description
T25674	*Salix*	3	Proximal, medial. and distal. Discontiguous.
0mm/break?	5mm	**350mm**	7mm
50mm	5mm	**372mm/break**	7mm
100mm	6mm	**0mm**	6mm
150mm	6mm	**50mm**	5mm
200mm	6mm	**100mm**	5mm
250mm	7mm	**137mm/haft**	3mm
300mm	6mm	**Point weight**	2.4g

Museum ID	Wood type	No. of frags.	Description
T25676	*Pinus*	1	Distal
0mm	7mm		
50mm	6mm		
70mm/haft	6mm	**Point weight**	13.8g

Museum ID	Wood type	No. of frags.	Description
T25170	*Betula*	1	Medial
0mm/break	3.5mm	**250mm**	5mm
50mm	5mm	**300mm**	5mm
100mm	6mm	**350mm**	4mm
150mm	5mm	**394mm**	4mm
200mm	6mm		

Museum ID	Wood type	No. of frags.	Description
T25677	*Ulmus*	6 + (4)	Bow limb and frags, leather strips
mm	**Location**	**Width**	**Breadth**
20mm	nock	9mm	15mm
50mm		14mm	15mm
100mm		15mm	14mm
150mm	frag. in place	14mm	16mm
200mm	frag. in place	16mm	17mm
250mm	frag. in place	16mm	17mm
290mm	frag. in place	18mm	19mm
300mm	damaged	-	-
310mm		16mm	22mm
350mm	frag. missing	11mm	29mm
385mm	break	-	-

Museum ID	Wood type	No. of frags.	Description
T25287	*Betula*	2	Whole shaft
0mm	5mm	**450mm**	8mm
50mm	5mm	**500mm**	8mm
100mm	6mm	**550mm**	8mm
150mm	7mm	**600mm**	8mm
200mm	7mm	**650mm**	7mm
250mm	8mm	**700mm**	7mm
300mm	8mm	**750mm**	6mm
350mm	8mm	**794mm/haft**	0mm
400mm	8mm		

with the clean, almost fresh nature of the breaks, appears to indicate that the shaft was released from the snow patch only recently.

Artefact B (T25674) (Tables 1 & 2; Figure 6) consists of a fragmented arrowshaft of *Salix,* with a small slate point, found together at the southern end of Storbreen, Oppdal. A sample from the shaft was dated to 3518–3362 cal BC. The shaft was recovered in three fragments, of which two are contiguous to a length of 372mm. The third fragment is 137mm long, but could not be definitively conjoined with the rest of the shaft, giving the shaft a minimum length of 509mm. The proximal end of the shaft is straight and ends in a wide, V-formed nock. Remains of a black adhesive associated with the spiral imprint of sinew lashings are clearly visible along the proximal end to a length of 105mm. Distinct markings are visible around 60mm from the proximal end, each consisting of three clear indentations, evenly distributed around the shaft at approximately 120° intervals. There are two sets of indentations close to one another. These are probably production marks, as they were covered by adhesive, sinew and vanes once the arrow was completed. Markings of this kind have not previously been observed on other shafts in the snow patch collection. However, similar markings are visible on other later finds, for example at the Nydam bog site in southern Denmark (Engelhardt 1865: pl. XIII).

At the distal end, the shaft narrows slightly to a rounded hafting split that measures 1–2mm internally. Here too, lashing imprints and faint remains of black adhesive can clearly be seen, concentrated in a 5mm wide area at the base of the split. In all respects, this shaft is a particularly well-fashioned and finished piece.

A small stone point was found together with the shaft. It is in a green-grey slate with red inclusions and has parallel to converging edges with a straight base and flat tang. The point is 65mm long and 9mm broad at the base of the blade.

Artefact C (T25676) (Tables 1 & 2; Figure 7) consists of a slate point together with a 70mm-long shaft fragment of *Pinus* from Storbreen, Oppdal. Also preserved is the adhesive used to join the point and shaft. The grey slate point is 105mm long and 19mm wide at the base and is slightly asymmetrical, possibly as a result of re-sharpening. The V-formed hafting split is around 22mm deep and between 1 and 7mm wide. From the features preserved, we can see that both the tang and shaft have been covered with adhesive before hafting. Moreover, the adhesive imprints show that the joint was subsequently strengthened by lashings that covered both shaft end and slate tang. A sample taken from the shaft was dated to between 3361 and 3102 cal BC. Although slate points are a common feature of the Neolithic of northern Scandinavia, this is a rare example of a hafted slate point.

Artefact D (T25170) (Tables 1 & 2; Figure 2c) consists of an incomplete shaft in two fragments, preserved to a total length of 420mm. Neither the haft nor the notch is preserved. The shaft was discovered on gravels below the center of Storbreen, Oppdal, and is dated to between 2139 and 1956 cal BC. The arrow is formed from a narrow sapling of *Betula*. This is only the second prehistoric arrow in the collection that was produced from a sapling, the other example being dated to the Bronze Age (Åstveit 2007: 15–17). This contrasts with the extensive use of shafts fashioned from staves split from solid tree trunks during the Iron Age and medieval period.

Artefact E (T25287) (Tables 1 & 2; Figures 2a & 8) from Løpesfonna, Oppdal, is one of the few artefacts recovered directly from within a snow patch. The arrow consists of a shaft of *Betula* preserved to a length of 794mm, with two small rings of sinew thread still attached. Lashing imprints are visible over *c.* 300mm adjacent to the split at one end. The split is 8mm deep × 4mm at its widest and has subsequently cracked along the arrow shaft. The other end is pointed and slightly askew. The shaft has been dated to between 1883 and 1682 BC and as such represents an arrow from a transitional phase between the local Neolithic and Bronze Age.

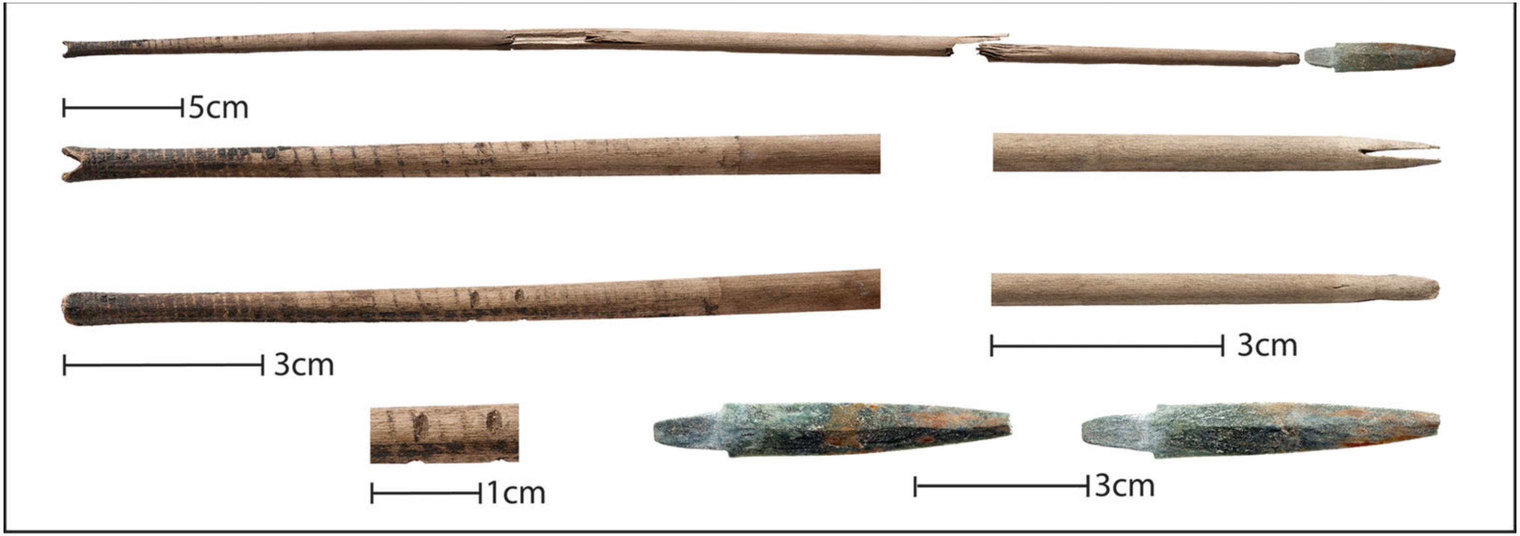

Figure 6. Artefact B (T25674): arrowshaft of Salix *with accompanying slate point found on 28 August 2011 at Storbreen, dated to between 3518 and 3362 cal BC (photo: Åge Hojem/NTNU Museum of Natural History and Archaeology; layout: Martin Callanan).*

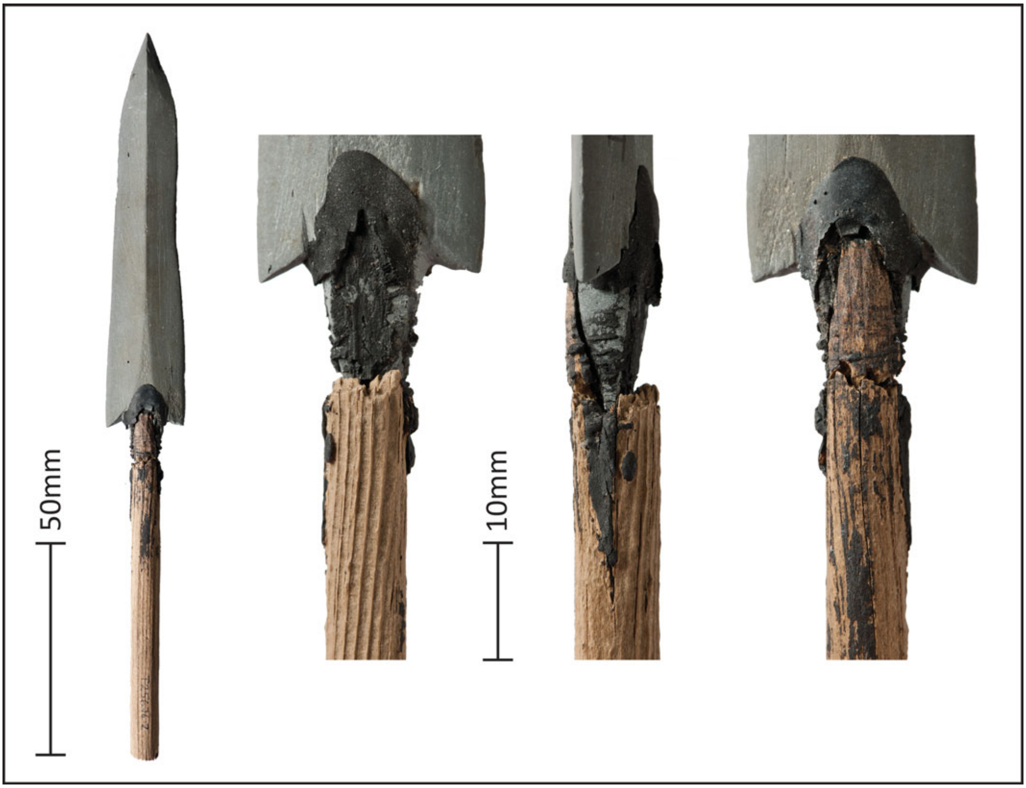

Figure 7. Artefact C (T25676): detail of a slate point hafted on a shaft fragment of Pinus *discovered on 29 August 2011 at Storbreen, dated to between 3361 and 3102 cal BC (photo: Åge Hojem/NTNU Museum of Natural History and Archaeology; layout: Martin Callanan).*

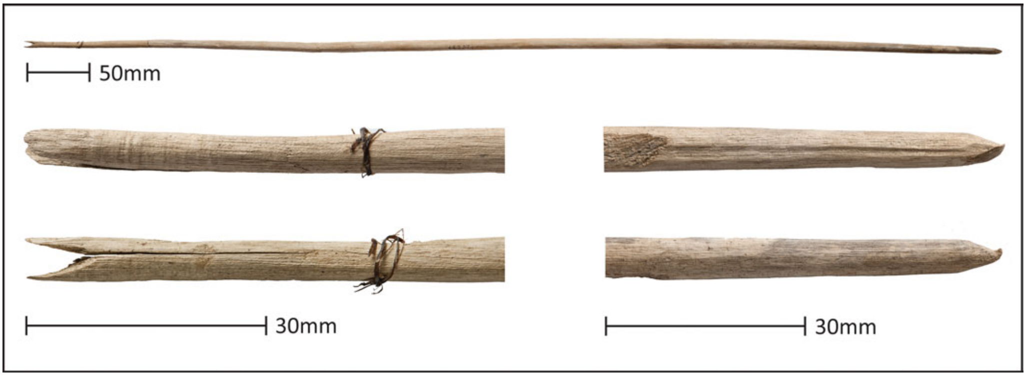

Figure 8. Artefact E (T25287): discovered at Løpesfonna on 21 August 2010, this complete shaft of Betula *is dated to between 1883 and 1682 cal BC (photo: Åge Hojem/NTNU Museum of Natural History and Archaeology; layout: Martin Callanan).*

This arrow is something of a conundrum as it is impossible to identify positively the function of the preserved split. This may be a self-pointed arrow (e.g. Waguespack *et al.* 2009), in which case the split would represent the proximal end. That seems unlikely, however, given the crude nature of the split, since nock ends are usually particularly well finished. Alternatively, we might interpret the split as the distal end. However, this would imply that the arrow, if used in its current form, had a pointed proximal end. Again this seems unlikely as it would have damaged the valuable bow-string. Perhaps some nock component such as a bone or antler blunt, used to hunt birds or furred animals, is missing from the distal end? The arrow might also be an anomaly. Perhaps, for example, a hunter was forced to improvise and use an unfinished arrow such as those found with the Neolithic Iceman at Similaun in the Tyrolean Alps or more recently at Schnidejoch, in the Bernese Alps (Egg 1992; Suter *et al.* 2005).

Artefact F (T25677) (Tables 1 & 2; Figure 9) is a bow fragment that was discovered lying exposed on stones and gravels by the upper edge of Storbreen, Oppdal. The find consists of a 385mm-long bow limb that begins with a well-formed plano-convex to oval nock, continuing to a *c.* 14–15mm rounded square section before widening out to a width of around 38mm at the break. Also recovered were four 2–4mm-wide hide lashings, found in direct association with the bow limb. Context photographs and imprints on the bow show that the lashings were attached to the limb between 255mm and 292mm from the nock end and may have formed a contiguous band. Given the short length and form of the extant limb, the lashings probably functioned as reinforcement. No other imprints have been located along the limb.

The bow is made from *Ulmus,* a raw material often chosen by northern bow makers in the past (Clark 1963: 51; Bergman 1993: 101; Junkmanns 2010). The site at Storbreen lies within the current northern border of European elm distribution, where the local upper limit is around 500m asl (Nedkvitne & Gjerdåker 1995: 18, 28). *Ulmus* appears in a mountain pollen diagram at Ølstadsetri (820m asl), some 25km to the south of the snow patch at Storbreen, at around 6000 BC, but the levels decline again as the post-glacial climatic optimum draws to a close around 5000 BC (Gunnarsdóttir & Høeg 2000: 39). The bow must therefore be of lowland origin.

Discussion: Neolithic archery

Slate points are signature artefacts of the Neolithic period in Scandinavia and are found throughout the region. The bow and arrows reported here span the whole period and were lost or discarded by groups or individuals on hunting expeditions. These early snow patch hunters probably originated from small, semi-sedentary, hunter-fisher communities based either in coastal areas to the west or further inland to the north or south (Alsaker 2005; Olsen 2009). Indicators of animal husbandry and cereal cultivation are clearly present in the region from around 2500 BC (Hjelle *et al.* 2006). However, the use of inland and mountain resources, a recurring feature of prehistory in western Norway, remained an important part of the economy throughout the Neolithic and subsequent periods.

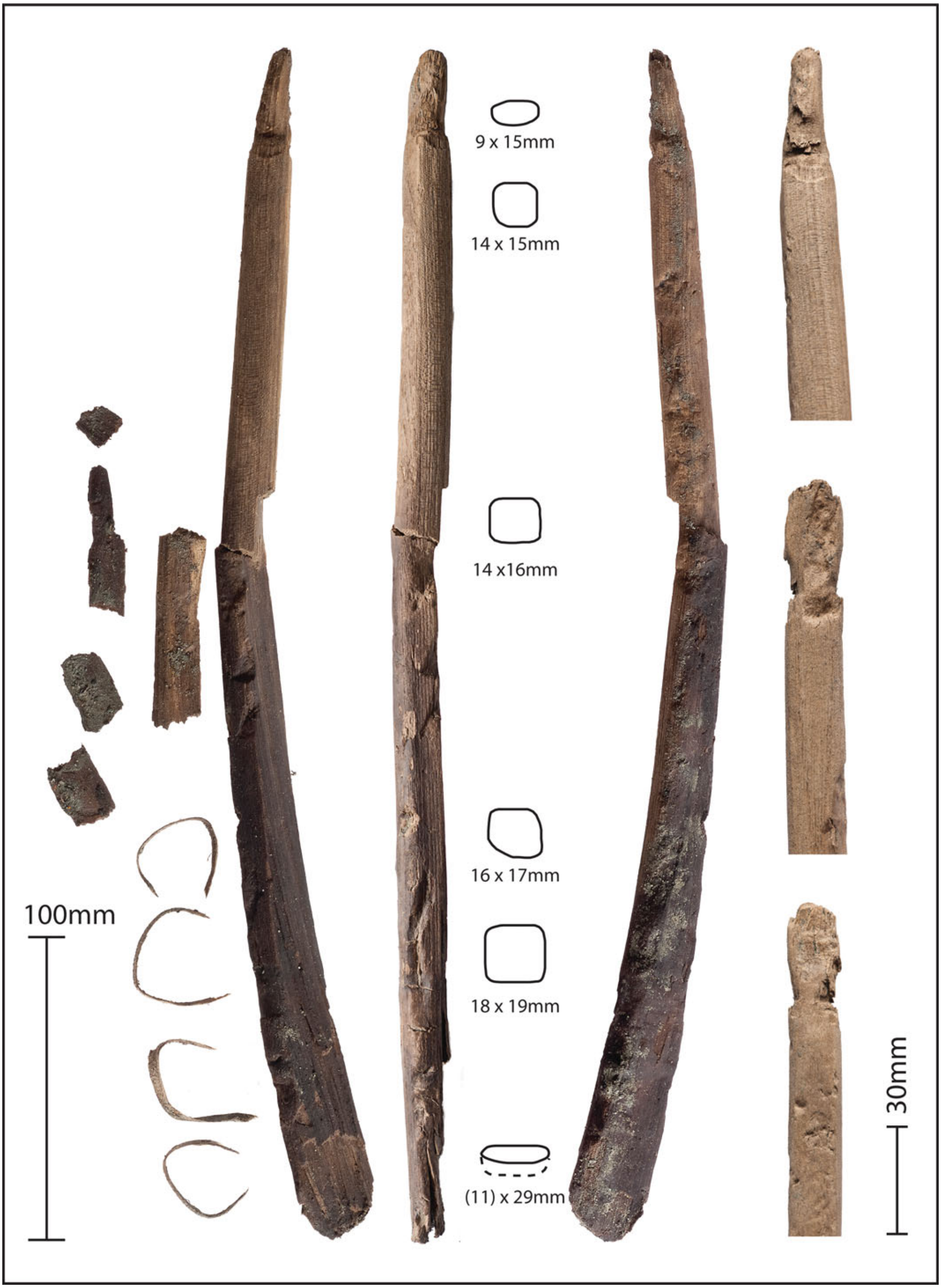

Figure 9. Artefact F (T25677): Neolithic bow limb from Storbreen (photo: Ole Bjørn Pedersen/NTNU Museum of Natural History and Archaeology; layout: Martin Callanan).

These finds from melting snow patches in central Norway offer, for the first time, insights into the organic component of Neolithic bow and arrow technology in central Scandinavia. In the following, these discoveries are discussed in relation to other European finds that are relevant from a morphological or typological perspective.

In Europe, between 140 and 150 Neolithic bow finds are known, a large proportion of them coming from lacustrine settlement sites in central Europe. In a recent analysis, Junkmanns (2010) organised these bows into two main groups based on their morphology. Bows in the propeller group (e.g. Rotten Bottom, southern Scotland, and Meare Heath, southern England) have broad, flat limbs with a narrowing at the grip. Bows in the staff group (e.g. Similaun, Ashcott Heath) are more regular along the length of the bow (Junkmanns 2010: 55–65). The Storbreen bow belongs to the staff group. Viewed diachronically, the preserved nock end closely resembles Bow 2 from Agerød V, southern Sweden, dated to *c.* 5500 cal BC (Larsson 1983). The oval/square section is reminiscent of Bow 1 from La Draga in northern Spain that is dated to between 5440 and 5045 cal BC (Junkmanns 2010: 61). These few scattered parallels indicate that the Storbreen bow was anchored within a broader European technical template. Locally, there are few bow finds to which the Storbreen bow can be compared. A complete, 1.31m-long bow, dated to *c.* 1300 cal BC, was recently discovered at Lendbreen, Oppland (Mímisbrunnr n.d.). The Lendbreen bow also belongs to the staff group, but has a triangular profile, similar to the older bow from Koldingen, northern Germany (Beckhoff 1977; Junkmanns 2010: 490–93). A few bow fragments have been found at local snow patches through the years, but these belong to later periods and a different, laminated bow tradition (Farbregd 2009: 162–65, fig. 10).

As regards the Neolithic arrows, the degree of variability demonstrated by the finds is striking. There is considerable variation in the choice of shaft wood as well as in the size and morphology of shafts and points. However the sample of Neolithic finds recovered from snow patches is very small when compared with the 1600-year time period they span. The variability might be the first emerging sign of older archery traditions in the region. On the other hand, it might be the result of a production mode based on individual manufacture and technological choices.

It is interesting to compare the length of the Neolithic arrow shafts with the few Mesolithic shafts found in Europe. As a group, Mesolithic shafts are rather long, varying between *c.* 650mm and 1200mm in length (e.g. Junkmanns 2010: 54). Arrows of this period were probably hafted with small, light points of flint or similar lithic materials.

The Neolithic shafts presented here appear shorter than their Mesolithic counterparts. The incomplete shaft A which was probably tipped with a stone point is at present 420mm long. From vane lengths measured on later Iron Age arrows, the missing proximal fragment was probably no longer than 100–200mm (see Farbregd 2009: 163). This brings the total length of shaft A to between 500 and 600mm. The same is also true of shaft B, to which a small 2.4g slate point was hafted. The shaft has a complicated medial fracture, but the whole shaft has been recovered and its total length comes to 510mm.

Shaft E is the only complete shaft recovered in this group and with a total length of 794mm is within the Mesolithic range quoted above. There are, however, considerable problems in interpreting this shaft. Furthermore, it is dated to the Neolithic–Bronze Age transition, a period when the use of slate projectiles had ceased, to be replaced by either bifacial stone or antler and bone points. In conclusion, this shaft is probably not typical of Neolithic shafts, especially those used in conjunction with slate projectiles.

One of the characteristic traits of slate point technology is the large variation in both morphology and size of the point. The four slate points found at snow patch sites in central Norway, for example, weigh 2.4g, 7g, 10.5g and 13.8g (Åstveit 2007; Table 2). Slate points are generally larger and heavier than the lithic points used earlier, such as microliths, tanged points and transverse points. As the total weight (point plus shaft) is one of the technical parameters important for a well-functioning arrow, the Neolithic bowyer probably had to take varying slate point weights into account when fashioning individual shafts (Kooi 1983: 28, 164–65). Seen in this light, one might suggest that the Neolithic shafts were shorter in order to compensate for the heavy weight of the slate points. Of course the weight of the bow would also be an important variable in the total equation, but for the time being we are limited to posing hypotheses based solely on the arrows. Should this hypothesis prove correct, however, the same technical dynamic may also be visible in other arrow configurations. We might expect, for instance, that lighter arrowheads of antler and bone were fitted to relatively long shafts in order to increase the total weight. As yet, however, the sample of Neolithic arrows is very small and these questions have to remain open. But if current trends at local snow patches continue, we can expect more clarity on this and related issues in the near future.

Melting snow patches

In recent years we have seen repeated instances of advanced melting at local sites. This has led to a number of record-breaking seasons with increasingly large numbers of finds being recovered on classic sites. Many finds have been also been discovered at new sites in new areas (Callanan 2012). Since snow patches are natural, dynamic formations, it is logical to view these developments in the light of ongoing weather and climate processes. The message from the foregoing is thus unequivocal: something is afoot in the mountains of central Norway. Ancient alpine ice is melting and yielding large numbers of organic artefacts. And the number and antiquity of some of these artefacts is unprecedented in the almost century-long history of snow patch surveying in the region.

These discoveries can also be viewed alongside the results of studies from other disciplines in the same region. Those studies map recent developments in the natural environment which, like the ablating snow patches, are presumed to be linked to unstable or extreme weather conditions and rising temperatures. Recent investigations at Snøhetta, close to Storbreen, have shown that alpine permafrost is retreating and becoming shallower (Isaksen *et al.* 2007). Other research maps early evidence for altitudinal creep in sub-alpine and alpine flora, as lower-lying plants begin to appear at increasingly high altitudes (Michelsen *et al.* 2011). Local fauna are also being affected, as can be seen by a recent outbreak of deadly pneumonia in the local musk ox herd during a particularly warm and humid summer (Ytrehus *et al.* 2008). Taken together, these studies paint a troubling picture of the episodic and systemic changes currently taking place in the sub-alpine and alpine environments of central Norway.

The relationship between current climate change and archaeology in its various intellectual, ethical and practical aspects is a theme that has been the focus of a number of recent contributions (e.g. Mitchell 2008; Brook 2009; Rowland 2010). Snow patch archaeology is situated at the frontline of this issue. As new objects continue to appear at melting snow patches, all efforts are focused on recovering as much as possible. Not only the finds but their contexts too are important as fragile sources of information that are disappearing before us. This is a demanding rescue mode that requires both being in the right place at the right time and asking the right questions before it is too late. The institutional challenge is to provide the reliable funding and flexible routines that permit effective field responses in the face of changing conditions.

For local collectors and snow patch archaeologists and managers, climate change has an immediacy of its own. On the one hand, there is the possibility of recovering unique ancient objects that will occupy and inform us for many years to come. At the same time, as the climate continues to heat up and the snows melt away, one wonders what long-term price there will be to pay for these precious glimpses of the frozen past.

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