The worked quartz vein at Cnoc Dubh, Uig parish, Isle of Lewis, Western Isles

Presentation and discussion of a small prehistoric quarry

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1 Summary

In 2002, an examination was carried out of a small quartz vein at the knoll of Cnoc Dubh, a few hundred metres from the southern shores of Loch Ceann Hulabhig on the Isle of Lewis (NGR NB 2318 2998). The vein proved to have been worked in prehistoric time, defining it as a quarry, and it was measured, photographed and characterized. In the present paper, the Cnoc Dubh quartz quarry is presented in detail, to allow comparison with other lithic quarries, and it is attempted to define attributes diagnostic of prehistoric exploitation, and to schematically describe the 'mining operations' by which the quartz was procured. As part of this process, quartz quarrying is compared to the procurement of other lithic and stone raw materials, mainly drawing on research from Scandinavia, Australia and the USA, and the location of quartz quarries in relation to prehistoric settlements is discussed. The average distance between quartz sources and Neolithic – Bronze Age sites on Lewis is then used to discuss ownership of, and access to, prehistoric quartz sources, as well as the possible exchange of quartz.

2 Introduction

The quartz vein at Cnoc Dubh was first discovered by amateur archaeologist Mr James Crawford in connection with his reconstruction of a corbelled shieling north-east of the site. As Mr Crawford believed the vein to have been worked in prehistory, he reported it to Western Isles archaeologist Dr Mary MacLeod. She inspected the location with Mr Crawford and, as she agreed that the vein might have been exploited, she invited the author to assess the site in his capacity as a lithics specialist.

In January 2002 the author undertook a cursory examination of the vein and its surroundings and, as he was able to confirm that it had indeed been worked, a more thorough investigation was planned. A detailed assessment was carried out in September 2002 and, as part of this exercise, the vein was examined, measured, photographed and characterized. This work was accomplished with the generous funding of the Katherine Mackichan's Bursary Trust. The analysis of the Cnoc Dubh quartz vein forms part of the project *Quartz Technology in Scottish Prehistory* (Saville & Ballin 2000), the main aim of which is to explain quartz assemblage variability in Scotland. This project has previously received funding from Historic Scotland, the National Museums of Scotland and the Russell Trust.

It is a well-known fact that production of core rough-outs, blanks and tool preforms, or in some cases final tools, took place in the vicinity of prehistoric mines (cf. Ericson & Purdy 1984). As a consequence, Schneiderman-Fox & Pappalardo 1996 put forward a detailed model for the investigation of prehistoric quarry sites, emphasizing the following four activity areas:

- the quarry itself where material is extracted
- the tailing pile, just below the quarry face, containing blocks of quarried material
- the ore dressing, milling, or transition area, located below and within 50 m of the quarry face, where large blocks are broken down for transport, and
- the lithic reduction site above the quarry face or on a level terrace adjacent to the quarry face, where reduced blocks are further reduced into preforms or final tools

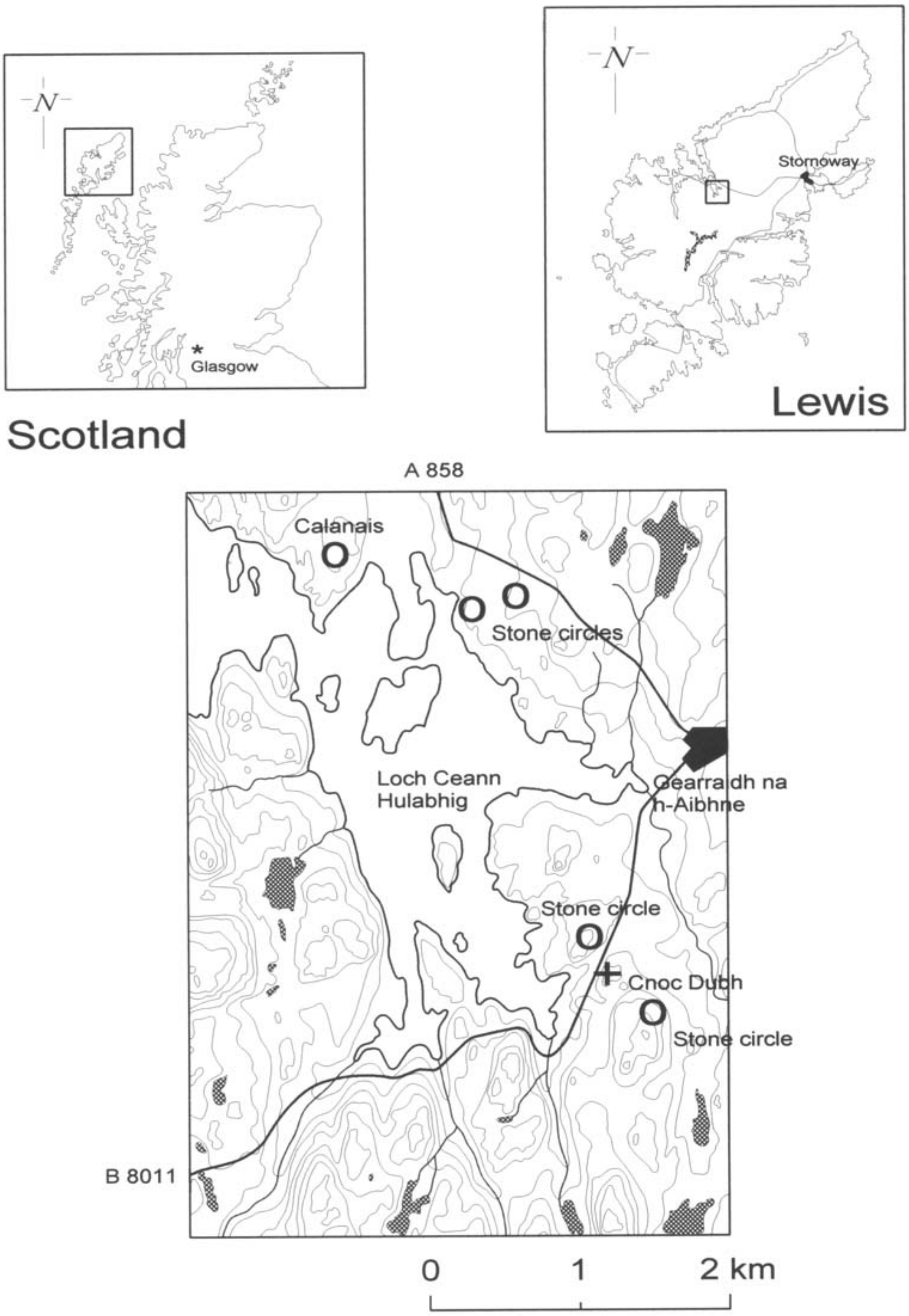
Examination of printed and Web-based papers demonstrates that archaeologists tend to focus on the latter three points, with the characterization of the actual quarry being much less detailed than the description of the associated activity areas (eg, most of the papers in Ericson & Purdy 1984) – if the quarry itself is not completely ignored. In Abbott *et al.* 2001 the authors suggest a number of specific research domains with regards to quartz and other silicate sources; one of these research domains is specified in the following way:

> 'The location and intensive investigation of more quartz and silicate quarries: Additional quarries need to be examined in order to compare procurement strategies, mining techniques, tools used to extract the raw materials, artifact assemblages, the quality of material being mined, estimates on labor investments, and transportation costs. In addition, feasibility studies should be undertaken to determine if it is possible to identify individual sources by trace elements or chemical composition. Data obtained from quarry sites serve as a baseline in which later production activities on other sites in the settlement system are measured. Without this basic level of information, lithic production models for specific populations will be suspect.'

Consequently, the aims of the present paper are to:

- characterize the actual Cnoc Dubh worked quartz vein in detail, and as part of this process, define attributes diagnostic of prehistoric exploitation
- obtain information on the physical exploitation of the vein, that is, the 'mining operations' by which quartz was procured
- compare the Cnoc Dubh quartz quarry with other lithic quarry sites and define how the extraction of quartz may relate to the extraction of other lithic raw materials, and
- discuss the ownership of, and access to, the Scottish quartz sources.

Examination and discussion of the Cnoc Dubh quarry's associated activity areas (as in Schneiderman-Fox & Pappalardo 1996's model, noted earlier) do not form part of this paper. When the sheep pen in front of the vein was constructed, no excavation was carried out. A slab of concrete was simply laid on top of rocks that had been dragged over to level off the ground (James Crawford *pers comm*). The tailing pile, just below the quarry face, may therefore still be intact, though presently inaccessible. During 2003/04 James Crawford carried out excavations around the Cnoc Dubh beehive structure, mainly to increase his understanding of the building's foundations. As part of this work, a small assemblage of lithic artefacts was recovered, supplemented by prehistoric and more recent pottery. The lithic assemblage includes: one crude single-platform core and one side-scraper in flint, 10 platform and bipolar flakes in quartz, one irregular quartz core, three end- and side-scrapers in quartz, one piercer in quartz, one scraper-piercer in



Illus 1 Location map. The Cnoc Dubh quartz quarry is marked by a cross, and the Calanais ritual complex, as well as the area's numerous stone circles, are marked by circles.

quartz, and one hammerstone/anvil in stone. This assemblage may relate to the quartz quarry, and possibly represents part of the associated activity areas where the quarried quartz was further reduced, or an actual settlement. The lithic debitage, cores and tools are quite plain, and the assemblage most likely represents a later prehistoric industry (post Early Bronze Age). Beverley Ballin Smith kindly examined the pottery which appears to be mainly middle and later Iron Age (some of it probably dating to the first millennium AD), supplemented by small amounts of more recent material.

3 Location

Cnoc Dubh, meaning *'the black knoll'* in Gaelic, is a small hillock situated approximately 1½ km south-west of the village Gearraidh na h-Aibhne, Uig parish, and a few hundred metres from the southern shores of Loch Ceann Hulabhig (NGR NB 2318 2998) (Illus 1). There is some discussion as to whether it is most correct to spell the names of the sea loch Ceann Hulabhig, and the stone circle by the same name, with an initial 'H', as Hulabhig, or with an initial 'Th', as Thulabhig (Mary MacLeod *pers comm*). To avoid confusing matters, the author has chosen to spell the two names with an H, as this is the form used on most Ordnance Survey maps.

The knoll is roughly D-shaped, with an approximately rectilinear rockface running parallel with, and facing, the road between Gearraidh na h-Aibhne and Tuimsgearraidh (the B 8011) to the northwest (Illus 2), whereas the curved, and gently sloping, lee of the knoll faces the boggy interior of the island. The quartz vein covers part of the said rockface, with full view of the sea-loch and, at a few kilometres' distance, the Calanais ritual complex (Illus 3). The site is situated almost exactly on a SE-NW line connecting the stone circles Ceann Hulabhig, or Calanais IV (in front of the knoll), and Airidh nam Bidearan (behind the knoll). If this line is extended further to the northwest, and across Loch Ceann Hulabhig, it almost meets the Calanais ritual complex and the stone circle Calanais I.

As briefly touched on in the Introduction, the site is situated in a rich ritual landscape, surrounded as it is by stone circles, standing stones and cairns (Illus 1). The focal point of this landscape is the ritual complex of Calanais approximately 3.5 km to the north-north-west. Most known prehistoric settlements are situated further away from the vein, the most prominent being Berie Sands (Lacaille 1937), Dalmore (Sharples in prep.) and Barvas (Cowie in prep.), cf. Table 1. Most probably, one or more prehistoric settlements are to be found in the area around Calanais, as suggested by Patrick Ashmore's work at Calanais (Ashmore in prep.) and the Calanais Field Project (Flitcroft *et al*. 2000).

The immediate surroundings of the Cnoc Dubh quarry include a number of features, such as, stone structures and signs of agricultural activity. The most prominent stone construction is a beehive structure (corbelled shieling) on the north-eastern slope of the knoll; it is in the process of being re-constructed by Mr Crawford. North of the knoll, and *c*. 6–7 m from the corbelled shieling, is a small oval structure of unknown date and function (prehistoric dwelling / modern sheep shelter?).

Agricultural remains include extensive dyke

Illus 2 View of the Cnoc Dubh rock face and vein, from the north-west.

Illus 3 View towards the stone circle Ceann Hulabhig and, across the sea loch, the Calanais ritual complex; from the terrace above the Cnoc Dubh quartz vein.

systems in the area around Cnoc Dubh, mainly in the hinterland to the south-east. Systems of rigs are to be found not only in front of the site, between the vein and the road (B 8011), and across the road, but also on the terrace above it, and behind it (Illus 3). Parts of the knoll (the gneiss), primarily south and south-west of the vein, has been quarried for building material, probably for the structures north of the site. This activity may explain an iron object lodged in a crack in the gneiss above the vein.

Corbelled shielings are of unknown construction date, but continued to be used until the late nineteenth century (Strachan 1999; Crawford 2003) – the other stone structures cannot be dated without further investigation, and finds of datable material (diagnostic artefacts or structures, or organic material for radiocarbon dating). The agricultural remains are of unknown date as well. It is therefore not possible at present to relate any of these features to the quartz vein at Cnoc Dubh. The vein itself, and the activities associated with it, cannot be dated more precisely than to the period before the abandonment of flaked lithic technology, which on Lewis may have happened in the Late Bronze Age / Early Iron Age.

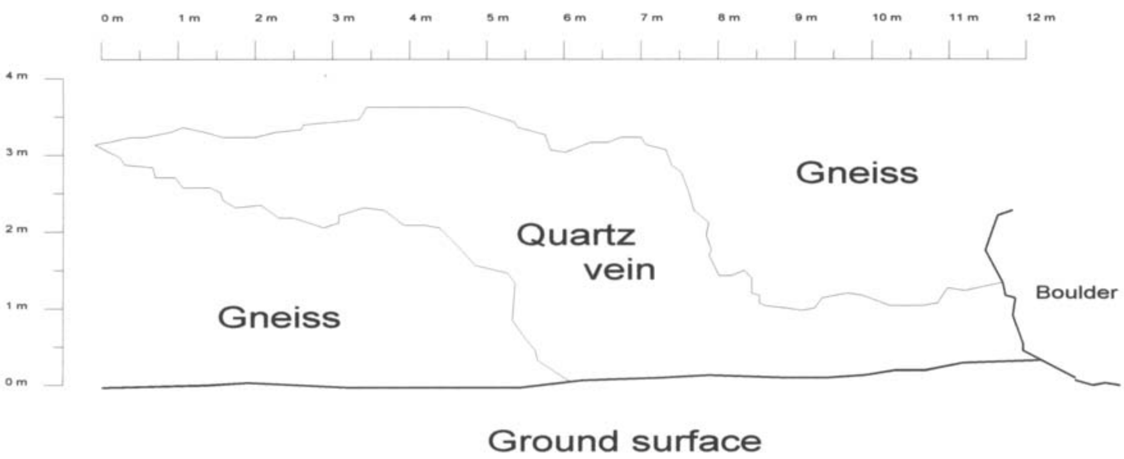
4 The quartz vein

The Cnoc Dubh quartz vein consists entirely of homogeneous white milky quartz and would, in prehistoric time, have presented a valuable source of lithic raw material. The rock matrix, in which it is embedded, is typical grey or silvery Lewisian gneiss (Smith & Fettes 1979). The vein is not particularly large, measuring approximately 12 m from north-east to south-west. Its height varies between *c*. 0.3–0.5 m at the north-eastern and south-western ends and *c*. 3 m at its widest point, that is, slightly south-west of the centre. The shape of the vein is like a recumbent, reversed S, starting in the north-east at 3 m+, curving down to ground level in the middle, and terminating in the south-west slightly above ground level (Illus 4). The shape of the outcrop is somewhat obscured by a cover of lichen but, viewed from the stone circle Ceann Hulabhig in the afternoon sun, the white quartz of the vein is clearly visible.

Though assumed to have been exposed to the weather for millennia, the quartz is well-preserved. It does, however, show signs of some exterior alteration, mainly in the form of slightly frosted surfaces. Frosted surfaces are characteristic of, for example, quartz artefacts from the deflation zones of the Western Isles machair (eg, the finds from Rosinish on Benbecula [Ballin in prep. c] and Barvas 2 on Lewis [Ballin in prep. f]).

It is impossible to estimate the size of the vein in precise cubic measures, but an approximate measure of the quarried material is obtainable. The vein has mainly been worked in the most extensive, central part and in the area between the centre and the south-western terminal, resulting in prominent overhanging steps of gneiss (Illus 5). Measured from

Illus 5 View of the central part of the vein with its prominent overhangs.



Illus 4 Sketch of the Cnoc Dubh quartz vein.

the outermost part of the overhang to the innermost part of the worked vein (*c* 4.5 m from the south-western terminal), one achieves an estimate of *c* 1 m of quartz which has been removed. As the worked part of the vein has a length of approximately 4–5 m, it is reasonable to assume that up to 3 m^3 of quartz may have been quarried. For comparison, the estimated amount of rhyolite extracted from the Mount Jasper outcrop, USA (Gramly 1984, 12) was 30–40 m^3; rhyolite from the Bømlo outcrop, SW Norway (Alsaker 1987, 76) was 150–230 m^3; greenstone from the Hespriholmen outcrop, SW Norway (Alsaker 1987, 77) was *c*. 427 m^3. Though neither Broadbent 1973 & Broadbent 1979 nor Cantley 2000 attempt to estimate the cubic measures of the worked quartz veins they investigated, these outcrops appear to have been of sizes comparable to that of the small Cnoc Dubh vein.

5 Evidence of exploitation

During the initial inspection of the vein, it soon became clear that it had been exploited by prehistoric people. The main revealing attributes are:

- 'stepping'
- circular impact scars, and
- denticulated 'platform-edges'

5.1 Stepping

This attribute is based on the fact that vein quartz develops so-called 'planes of weakness' along three axes, which together form an approximately cubic, three-dimensional breakage pattern. It is tempting to call these planes 'cleavage planes', but a cleavage plane is a specific attribute associated with the crystal and atomic structures of a mineral, and quartz, as a mineral, is defined as having none (Pellant 1992, 86–7). It is a well-known fact that smaller pieces of quartz fracture in an irregular or conchoidal manner, and not along cleavage planes (contrary to, for example, feldspar), whereas larger bodies of quartz (eg, veins) tend to split along the planes of weakness described in the text. These planes may be products of the way hydrothermal silicious fluids solidify.

At Cnoc Dubh, the most prominent of the three planes is the plane running parallel to the surface (Plane 1), with the other two planes (Planes 2 and 3) being less well developed and running either vertically or horizontally from the surface and into the vein. In practice, Plane 1 separates the quartz vein into a number of relatively thin (2–15 cm), vertical, layers. In his presentation of the quartz quarry at Samp Mortar Reservoir, Connecticut, Bernard Powell suggests that, to prehistoric knappers, this tendency to form natural layers was a desired attribute in quartz:

> 'because of the flat-sided nature of quartz [. . .], the quarriers were able to secure a wide range of pieces having roughly parallel sides. These constituted natural cores, with ready-made striking and anvil platforms. It was a simple matter to set such pieces down on a nearby ledge, and begin at once to detach flakes through either direct or indirect percussion. Analysis of the refuse leaves little doubt that this was one of the main activities of the quarriers' (Powell 1965).

Between the various layers of quartz, the adjoining surfaces frequently develop a coating, probably deposited by fluids. In the local area, this coating varies between yellow, orange, red and brown (probably iron compounds), and the presence of coated surfaces in an

Illus 6 The vein's stepped appearance.

Illus 7 Stepping developed due to exploitation of a novaculite resource in the Ouachita Mountains (Ouachita National Forest), Hot Springs, Arkansas (Etchieson 2000).

assemblage usually defines quartz artefacts as being based on vein quartz, and not pebble quartz. In previous papers, the author has referred to these surfaces as 'contact faces' (Ballin 2002), as they were – erroneously – interpreted as representing the contact zone between the vein and the rock matrix. This contact zone is, instead, characterized by the intermixing of quartz and rock (in the present case, mainly feldspar from the gneiss; at Scord of Brouster on Shetland the quartz from the contact zone is mixed with sandstone [Ballin in prep. d]).

As particularly the south-western half of the vein has been exploited, the stepped appearance is most pronounced in this part (Illus 6). The main reason for the occurrence of stepping is the division of the vein into vertical layers, combined with the fact that the use of a hammerstone makes it impossible to detach blocks of quartz any closer to an edge of a previous layer than the radius of a hammerstone in a clenched fist (probably approximately 50–100 mm; see Illus 14). Parallels to this phenomenon are known from other lithic quarry sites, for example the jasper quarry at Valle Lagorara in northern Italy (Negrino 1998), and novaculite quarries in the Ouachita National Forest in Arkansas, USA (Etchieson 2000: Illus 7 here).

5.2 Attributes associated with the reduction of the vein

On several points, the quarrying of quartz – or any other lithic raw material – from bedrock outcrops (that is, *not* pebble sources) corresponds to the reduction of lithic cores. In principle, a quartz vein is a large, irregular core which is being gradually reduced. As the purpose of this process is to remove large blocks, or plates, of raw material for further reduction in front of the vein or elsewhere, and not to form delicate blanks or tools, the main approach is hard direct percussion. As a consequence, the reduced vein displays attributes similar to the characteristics associated with hard-hammer core reduction, such as, circular impact scars (incipient cones) and denticulated edges ('platform-edges').

Reduction of cores is based on the principle that lithic raw materials, like glass, break in a conchoidal (that is, 'shell-like') fashion when struck. If, for example, a slab of glass or flint is struck perpendicular to the surface, this may detach a solid Hertzian cone (resembling a shell), whereas an oblique blow to the edge of a lithic raw material slab (or core, or vein) releases a flake. The parent piece shows a concave fracture, and the flake's ventral face (where it was attached to the parent object) is convex (Oakley 1967, 9; Inizan *et al.* 1992, 33; Whittaker 1994, 12).

5.2.1 Circular impact scars

Circular impact scars, or incipient Hertzian cones, are found at numerous spots on the vein surface. They can be sub-divided into two groups, namely 1) impact scars in the centre of surfaces (Illus 8, 9), and 2) impact scars near worked edges (Illus 10, 11 & 12).

Illus 8–9 Impact scars of Type 1.

Illus 10–11 Impact scars of Type 2. Illus 10 illustrates how an unsuccessful attempt was made at detaching a large plate (a corner).

Those two groups represent different functions relating to the reduction of the vein.

The former group is the by-product of attempts at 'breaking through' one of the natural quartz layers described in Section 5.1, thus forming an edge from which the reduction of that particular layer could continue in a structured manner. The fact that these scars, or incipient cones, are still present at the centre of an unbroken quartz surface testifies to unsuccessful penetration of the layer being targeted.

The latter group is the by-product of the actual procurement of quartz blocks or plates, which would, at a later stage, be shaped into cores for the primary (blank) production. These impact scars are associated with the denticulated edges discussed in Section 5.2.2. Though a denticulated edge is the product of successful reduction of the vein, each circular impact scar associated with it represents a failure to detach a specific part of the targeted layer.

5.2.2 Denticulated edges

The denticulated edges (Illus 11, 12 & 13), forming the 'flaking front' of each individual quartz layer, owe their general delineation to the fact that reduction of quartz veins is based on rather crude, hard percussion techniques, contrary to the techniques generally associated with the reduction of lithic cores. In many cases, the detachment of flakes from a core involves sophisticated details, such as general preparation of the platform-edge (trimming or abrasion) or preparation of individual flakes or blades (platform isolation) (Whittaker 1994, 104–

Illus 12–13 Denticulated edges.

05). The general preparation of a platform-edge usually removes salient points along the edge, which subsequently acquires an either rectilinear or regularly convex shape. The worked edges of a quartz vein layer correspond to the platform-edges of plain, unprepared quartz cores reduced by the application of direct, hard percussion: they are wavy or denticulated.

6 Extraction techniques

At some point of time in prehistory, inhabitants of Lewis discovered the Cnoc Dubh quartz vein and realized its potential. The absence of loose material ('scree'), in front of the vein *before* construction of the sheep pen (James Crawford, *pers comm*), compared to the sizeable slopes of scree immediately north-east of the vein (Illus 2), suggests that some clearing of the site took place either prior to the exploitation of this resource, or as part of the ongoing reduction of the vein.

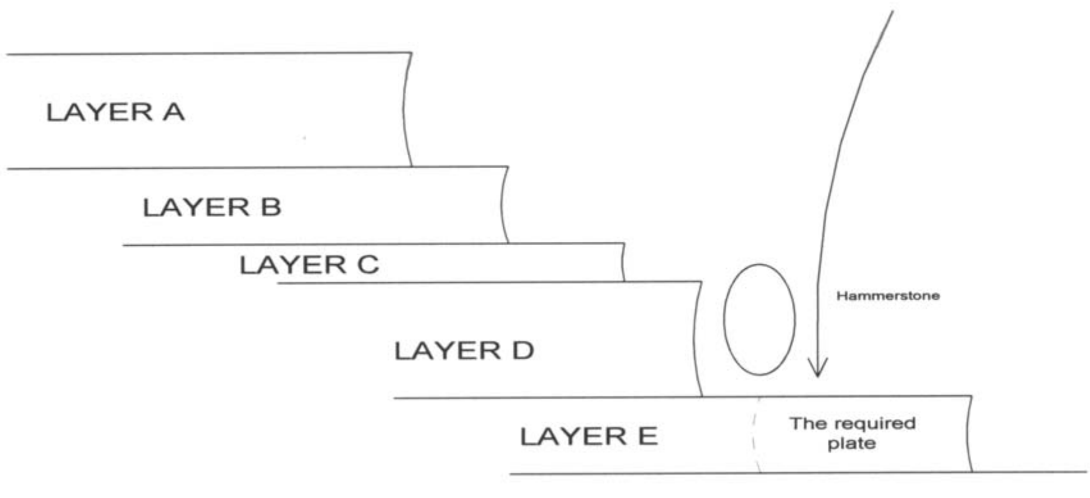
In the first case, scaffolding would have been required to reach the highest points of the seam, but wooden scaffolding has been documented from, for example, the flint mines of Grimes Graves (Saville 1981, viii; Russell 2000, 106) and would have been a possible option for the prehistoric quarriers of Cnoc Dubh. In the second case, removal of the scree would have been a staged process, following the gradual exhaustion of quartz at higher levels.

Based on probably millennia-old experience in quartz procurement and quarrying, the 'miners' of Cnoc Dubh were familiar with the tendency of quartz veins to form distinct vertical layers. Consequently, their first aim was to break through the outermost layer to acquire a working-edge from which blocks and larger plates of quartz could be detached. This was achieved by viciously pounding the outer layer in various places till it broke at one of the targeted points. Clusters of large circular impact scars, or incipient cones (Illus 8, 9, 10, 11 & 12), testify to cases in which the outer layer did not give way, probably because the quartz at that point was too dense. The generally large size of these scars, and thereby the Hertzian cones hidden beneath the surface, demonstrates the violent force applied to, first, open new layers and, later, detach blocks of quartz from the vein.

The moment a layer had been penetrated, production gained momentum and the quartz layer would be gradually 'peeled back' until those working the edges of that layer met resistance from, for example, the rock matrix, or areas of unworkable quartz (either too dense or too crumbly quartz). Then the next layer would be pounded until an opening developed, and this new layer was reduced, and its edges pushed as far towards the edges of the previous layer as possible. Due to the size and shape of hammerstones, it was not possible to completely 'peel back' Layer B to the edges of Layer A, and a step developed (Illus 14; also Illus 6, Illus 7).

This process continued, layer by layer, until the bottom of the vein had been reached, or until it had become impossible to detach more raw material due to the development of steps. In theory, a quartz vein may have been abandoned in prehistory *not* because all available quartz had been exhausted *but* because the technology did not allow further production (the use of hammerstones and the subsequent development of stepping). This technical problem could have been dealt with by removing parts of the rock matrix and attacking the vein from the sides, but this did not happen at Cnoc Dubh (nor at the Italian jasper source of Valle Lagorara; Negrino 1998, fig. 1.3). At the Lewisian site, the vein was abandoned when the entire lower half of the vein had been exploited and stepping had developed from the central part of the vein to its south-western terminal (Illus 6).

A number of auxilliary approaches may have been



Illus 14 General extraction procedure. The illustration shows the natural vertical layering of the vein, and how plates of quartz were detached; seen from above.

applied, which it has not been possible to prove or test, such as the use of wedges. Wedges could have been used in two ways, either to separate the peripheral quartz from the surrounding matrix, or to prise out blocks, or plates, of quartz from the various layers. The former use is unlikely, as the peripheral quartz has, in many places, fused with the adjacent gneiss, forming a relatively compact quartz-gneiss hybrid material. The latter use of wedges is quite possible, as the Cnoc Dubh quarriers could have made use of the various cracks between the vertical layers, or the secondary vertical and horizontal cracks running from the surface and into the vein. However, the main technique for releasing quartz from the vein would have been hammering the surface in the way described earlier, and demonstrated in Illus 8–14.

In his presentation of the quartz quarries at Gummark in northern Sweden, Broadbent suggests that fire-setting formed part of the approach of the local quarries (Broadbent 1973; Broadbent 1979). This claim is based on the discovery of soot and charcoal in connection with the outcrops. In his paper on the quartz quarry at Samp Mortar Reservoir, Connecticut, Powell 1965 rigorously refutes this: 'use of fire as a quarrying technique [of quartz] has a dubious reputation in the literature, and most authorities deny that it was ever used'. As fire-setting has not been reported from other quartz quarries, and as experiments (Ballin in prep. e) regarding the effect of fire on quartz suggest that direct fire makes this material disintegrate (thereby rendering it useless to a knapper), the author favours Powell's view. It is possible that the soot and charcoal reported by Broadbent simply derive from the quarriers' domestic fireplaces.

7 Discussion

7.1 The date of the Cnoc Dubh quarry

As briefly touched upon earlier (Section 3), it has not been possible to date the events at Cnoc Dubh more precisely than to the 'period of flaked lithic reduction' in general. On Lewis, this means within a time-frame encompassing the Neolithic and Bronze Age periods, possibly including the Early Iron Age.

At present, the worked vein cannot be dated directly, for example via diagnostic attributes associated with the quarrying process, as no other Scottish quartz quarries have been analysed and published. Indirect dating via diagnostic core or tool types would require excavation of the area in front of the rock face and vein, but due to the construction of a sheep pen in this area, the potential tailing pile is today inaccessible.

It is possible that future examination of the various structures around the knoll, for example the oval structure north of Cnoc Dubh, or investigation of the area around the beehive structure (as indicated by James Crawford's excavation; Section 2) may indicate a date of the quarry, as it is likely that the worked vein is associated with a nearby activity area or settlement. As argued in Section 7.3, the distance between quartz sources and prehistoric settlement is generally expected to be relatively short.

7.2 Quarrying of quartz compared to the quarrying of other lithic raw materials

When comparing quartz quarrying to the mining of other lithic raw materials a number of distinctions may be helpful. Firstly, the procurement of raw materials from different types of locations may require different approaches, and the following distinctions are suggested:

- Open pebble sources (river banks / beaches / erratics)
- Covered pebble sources (glacial till, fossil river-beds and fossil sea-shores)
- Intermediary sources (mainly chalk sources)
- Bedrock outcrops (veins, dykes, and sills)

Material from open pebble sources is usually collected directly from the surface, whereas material from covered pebble sources may demand some degree of digging or mining. These sources frequently result in the creation of pits or even pitted landscapes (eg, Saville 1995). It is proposed to class material from Cretaceous chalk and some soft limestone/dolomite locations (mainly flint and chert) as intermediary sources, as the parent rock is noticeably softer than other igneous, sedimentary and metamorphous rocks, but considerably harder than, for example, glacial till. The acquisition of material from these sources varies from collection of loose material in front of chalk cliffs, over teasing out nodules of the cliff face, to actual horizontal or vertical underground operations (Saville 1981; Weisgerber 1987; Rudebeck 1987; Schild 1987; Herne 1991).

Raw material from bedrock sources (eg, granite, gneiss, sandstone) usually takes the form of veins, dykes or sills (eg, jasper, pitchstone/obsidian, rhyolite, dolerite). It is possible to further sub-divide vein sources into vertically exposed seams and horizontally exposed seams. Whether a vein represents a vertical source or a horizontal source has apparent implications for the distribution pattern of the individual site, as an associated artefact scatter (tailing pile, activity area) may be either in front of the vein (Cnoc Dubh) or on top of it (Richburgh Quarry [Cantley 2000] and Gummark Loc. III-IV [Broadbent 1973; Broadbent 1979]).

In most cases, these sources are noticed because they reach the surface, from where they are then initially exploited. At a later stage, when the superficial parts of the outcrops have been exhausted, the sources may be followed underground, first as simple undermining of a rock face (eg Negrino 1998, 103) or the creation of pits (Torrence 1984, 54) and, later, actual adits (Gramly 1984, 12) or shafts (Stocker & Cobean 1984, 85) may be formed. The latter occurred relatively rarely in prehistoric times, due to the hardness of the rock. Quartz was acquired from all but intermediary sources. Quarrying of quartz from pebble sources, though probably one of the more frequent forms of quartz procurement, has rarely been described in the archaeological literature, though Brockington 1992 presents a number of quartz pebble quarries from Virginia.

In connection with the above discussion of raw material sources, various mining forms were briefly mentioned. They may be listed in the following, logical fashion (cf. Weisgerber 1987):

- Surface quarrying: simple surface collection
- Surface quarrying (horizontal): pitting
- Surface quarrying (vertical): the formation of overhangs
- Underground quarrying (horizontal): adit mining
- Underground quarrying (vertical): shaft mining

Table 1 A number of Neolithic and Bronze Age settlement and ritual sites along the west coast of Lewis, their individual distances, and dominant quartz types

Assemblage	Reference	Approximate distance	Dominant quartz variety
Barvas 2	Ballin in prep. f		Fine-grained and milky quartz, pebble source
		14.5 km	
Dalmore	Ballin in prep. b		Coarse-grained quartz, pebble source
		10.0 km	
Olcote	Warren forthcoming		Fine-grained and milky quartz, vein and pebble sources
		2.0 km	
Calanais	Ballin in prep. a		Milky quartz, vein source
		3.5 km	
Cnoc Dubh	[this report]		Milky quartz, vein (quarry)
		16.0 km	
Berie Sands	Lacaille 1937		Fine-grained quartz, vein source

A third distinction may be relevant to the present discussion, namely that of minerals and rocks. A mineral is composed of an orderly arrangement of certain elements which makes it possible to present it in the form of a representative chemical formula (in the case of quartz and related silica: SiO^2), and a specific internal (crystal) structure. Flint and chert (crypto-crystalline varieties of quartz) are technically classified as chemical sediments, that is, types of rock, but their general properties are very much similar to those of minerals, and in the present context they ought to be grouped with mineral raw materials of the silica group (cf. Luedke 1992). A rock, on the other hand, is a mountain-building aggregate of minerals (Pellant 1992, 16). In the present context, the main difference between the two types of stone is that minerals are usually solid, whereas rocks are more or less grainy. This means that, in many instances, mineral raw materials from bedrock sources have to be pounded out of the parent rock by the use of hammerstones (as, for example, the quartz at Cnoc Dubh) whereas, in many cases, it is possible to detach blocks of rock raw materials from their matrix by the use of fire (eg greenstone, rhyolite and Cumbrian tuff; Alsaker 1987, 76–7; Bradley & Edmonds 1993, 95). This process works by heating an area of, for example, a dyke, followed by rapid cooling, thereby creating cracks and fissures allowing the detachment of relatively large blocks or plates of material.

Two of the most important sources to prehistoric Scottish axe-makers, the Cumbrian tuff (from the Great Langdale 'axe factories') and the Perthshire hornfels (from Creag na Caillich, near Killin), were exploited in ways differing noticeably from the approach witnessed at Cnoc Dubh. First of all, the operational schema of the quarrying of tuff and hornfels was not based on the detachment of successive layers of raw material as these sources are essentially massive. Consequently, the two rock types were mainly 'flaked' off the walls of the quarries, leaving huge conchoidal flake scars (Bradley & Edmonds 1993, plate 5.1).

The main reports on the two source areas (Bradley & Edmonds 1993; Edmonds *et al.* 1992) both refer to the mined products as 'large blocks' and 'massive flakes', with the 'blocks' probably owing their more irregular shape to 'pre-existing lines of weakness' (Edmonds *et al.* 1992, 92). Due to the different technological approach, the tuff and hornfels quarries did not acquire a stepped appearance, but have quarry walls characterized by large concave areas, as illustrated in the Creag na Caillich report (Edmonds *et al.* 1992, illus 14). The use of fire played a major role in the procurement of Cumbrian tuff (Bradley & Edmonds 1993, 95), whereas the Perthshire hornfels appears to have been acquired without fire-setting (Edmonds *et al.* 1992, 92).

The choice of approach must have been generally determined by the combination of the factors 1) source type (hardness of matrix and source location in relation to the ground surface), 2) type of material (mineral or rock), and 3) the presence or absence of inherent layers parallel to the exposed surface (described in Section 5.1 in connection with the presentation of the Cnoc Dubh vein). It appears that quartz extraction from vein sources is carried out in more or less the same fashion as the extraction of related silica, such as jasper and novaculite (a form of chert: Luedke 1992, 125), that is, by the use of hammerstones and the successive detachment of raw material layers (resulting in the stepped appearance demonstrated by Illus 6 & 7). The matrix is too hard to allow the use of antler picks (as in the procurement of flint from Cretaceous chalk; Barber *et al.* 1999; Russell 2000), and the raw material is too solid to allow the use of fire (as in the procurement of greenstone and rhyolite; Alsaker 1987, 76–7), or the raw material would be damaged by the use of fire (quartz would disintegrate).

7.3 Quartz sources and settlements

Usually, quartz sources are divided into vein and pebble locations, with the former being quartz veins fixed in a rock matrix, whereas the latter constitute beach and river sources of loose, rounded quartz pebbles (typically including gravel and cobble-sized pieces). The two forms of quartz do not represent inherently different quartz types, as pebble quartz is only vein quartz which has been detached from its original matrix and subsequently abraded and rounded by one of a variety of water media.

Comparison of assemblages from neighbouring prehistoric sites along the Lewisian west coast suggests that quartz sources were fairly local in relation to the Neolithic and Bronze Age settlements. As shown in Table 1, the dominant quartz type of each assemblage usually differs from the dominant quartz types of the assemblages from adjacent sites. All the sites in Table 1 are situated close to the coast, and the pebble sources of Barvas 2, Dalmore and Olcote are most likely the beaches immediately next to these sites. The exact distance between settlement and quarry, in the cases of the vein quartz dominated sites of Calanais, Cnoc Dubh (quarry) and Berie Sands, is unknown, but the distances between the individual locations suggests that it may be as much as 10 km (though the author expects it to be much less).

The relative closeness of quartz sources and prehistoric settlements was discussed by Broadbent who suggested that, due to the amounts of quartz needed by prehistoric man to cover the daily replenishment of lithic tools, as well as the considerable weight of the required lithic raw material, most quartz sources were probably situated within a traditional catchment area (Broadbent 1979, 190) as defined by Vita-Finzi & Higgs 1970, that is, an area with a radius of no more than 10 km.

In northern Sweden, Broadbent examined a complex of settlement sites (Lundfors) and quartz quarries (Gummark), where the settlements were separated from a cluster of quarries by approximately 7 km (Broadbent 1979, 190). Recent re-examination of the quartz from the Scord of Brouster settlement site on Shetland (Ballin in prep. d) demonstrated that, in this case, a number of veins were exploited; the main vein(s) were probably situated within a catchment area with a radius of *c* 5 km (quartz with adhering sandstone), and supplementary quartz supplies were transported across distances of no less than *c* 6 km (quartz with adhering feldspar from granite or gneiss) (Johnstone & Mykura 1989). As the dominant quartz type of the Calanais assemblage is milky quartz, like the quartz of the Cnoc Dubh quartz outcrop, it is plausible that the worked quartz from Calanais was procured from the Cnoc Dubh vein, approximately 3 km away.

7.4 Ownership of / access to quartz sources, and quartz exchange

The generally close proximity of settlements and quartz sources in the Neolithic and Bronze Age of Lewis suggests that, most likely, these raw material sources were in the ownership of individual families, and the families' *main* quartz resources were probably not, or rarely, accessed by other people, or exchanged. This does not mean that quartz was not exchanged at all, but just that the geological resolution of most quartz analyses has been too low to allow more detailed studies. In the present paper, the author has distinguished between a number of quartz sub-types (Table 1) but, generally, lithics analysts tend to lump all quartz sub-types into one main category. As Abbott states, this is ' . . . like a faunal analyst putting all furry animal remains into a 'mammal' category without separating them by specific name, genus and/or species' (Abbott 2003, 106). In doing so, a great deal of valuable information is lost.

On Lewis, one form of quartz appears to have been preferred for, for example, arrowheads, namely the so-called 'greasy' quartz (probably an ultra fine-grained form of this material). As shown in Table 1, the Calanais ritual complex, and its central megalithic tomb, is dominated by homogeneous milky quartz (Ballin in prep. a), but the site's barbed-and-tanged arrowheads are mainly in quartz with a greasy lustre. At Dalmore, further to the north, seven out of 15 quartz arrowheads are in 'greasy' quartz, though the dominating variety of that site is coarse-grained quartz (Ballin in prep. b). It is quite possible that this preferred arrowhead material was imported, but presently it is not possible to say from where. No Lewisian sites are dominated by 'greasy' quartz, and only one site on mainland Scotland is known for the presence of greater quantities of this material – Shieldaig in Wester Ross (Ballin *et al.* in prep.). Given the distances across which pitchstone, for example, was traded (Williams Thorpe & Thorpe 1984; Ness & Ward 2001), it is not impossible that Shieldaig, or other sites or quarries in that general area, is the main source of 'greasy' quartz, particularly if it had some symbolic, for example totemic, connotation. As the crow flies, the distance from Shieldaig to the Lewisian west coast sites is approximately 100 km.

At the present time, Shieldaig is the only known assemblage where 'greasy' quartz has been employed in the production of the full range of lithic tools whereas, in assemblages dominated by other quartz varieties, this quartz form was mainly used to manufacture arrowheads and, in some cases, more sophisticated knives. It is quite possible that this state of affairs purely reflects the fact that 'greasy' quartz has better flaking properties and, as a consequence, was saved for the production of more complex, invasively retouched lithic tools (a mainly functional view is favoured by McNiven in his analysis of the technological organization and settlement pattern of prehistoric Tasmania; McNiven 1994), but it is just as likely that this quartz type had some inherent symbolic meaning to prehistoric people in Scotland (totemic association between people and raw materials has been demonstrated in anthropological research by, *inter alia*, Gould 1980, 141–59 and Clemmer 1990).

When a lithic raw material is accessed or exchanged in primitive societies, whether this resource has mainly functional (eg White & Modjeska 1978) or symbolic (eg Gould 1980) connotations, access/exchange is mostly restricted to kinship-related individuals (Sassaman *et al*. 1988, 80), but non-kinship based access/exchange does also take place, creating, or re-inforcing, alliances (Gould 1980, 155). In cases, where the use of a lithic resource is associated with symbolic values or style (Ballin forthcoming: according to Polly Wiessner, style is '. . . formal variation in material culture that transmits information about personal and social identity' [Wiessner 1983, 256]), the frequency of that raw material usually drops abruptly at the borders of that specific social territory, but quantification of the lithic raw material distribution across Scotland (raw material composition of the various assemblages, region by region) is still to be carried out. The analysis of raw-material fall-off curves throughout northern Britain may allow the construction of an, at least rudimentary, territorial structure of early prehistoric Scotland.

However, in the investigation of the use and exchange of quartz and lithic materials throughout Scotland, it is probably necessary to distinguish between sites and assemblages from different periods, as symbolic values and access/exchange patterns are likely to have varied over time. The rules of access and exchange ought to vary between, for example, highly mobile hunter-gatherer communities with relatively loosely defined and, occasionally, overlapping territories, and sedentary farming communities with more precisely defined territories and stricter perceptions of land-rights and ownership of quarries and other resources. Exceptions are, nevertheless, known, and in nineteenth century Australia the Kalkadoons, a hunter-gatherer tribe, were fiercely territorial about their homeland and its quarries (Hiscock 2001). However, it is uncertain whether the well-organised and militaristic Kalkadoon society arose as a result of their prehistoric mining activities, and the associated complex trading patterns, or whether the socio-economic structure of this Australian tribe was a response to European expansion.

In this light, one probably ought to distinguish between the Mesolithic sites and assemblages of Scotland on one hand, and Neolithic/Bronze Age sites and assemblages on the other. The distribution patterns witnessed in connection with the post-Mesolithic lithic material from the Western Isles are most likely an expression of ideas about landrights typical of farming communities, such as the tendencies of quartz sources to almost exclusively supply individual families or farms. In the Neolithic/Bronze Age period, the exchange of the better quartz variety with a 'greasy' lustre may mainly have been linked to lineages, or the tribe (in geographical terms: the social territory), though some inter-lineage or inter-tribal trade may have occurred (as possibly in the case of Scottish pitchstone exchange). The Scottish pitchstone distribution, in particular, paints a picture of generally more complex, regulated exchange, possibly even in the form of 'proper' trade.

In the more egalitarian hunter-gatherer societies, ownership to lithic resources was probably less formalised and quarry access more open, as suggested in Bruen Olsen and Alsaker's analysis of West Norwegian rhyolite, greenstone and diabase sources (Bruen Olsen & Alsaker 1984; Alsaker 1987). They suggest that, in the Norwegian hunter-gatherer period (*c* 10,000 – 3,800 C-14 years uncal BP), lithic resources may have been 'exploited directly, and on open terms' by the people populating a social territory (Bruen Olsen & Alsaker 1984, 96). This assumed difference between Mesolithic and post-Mesolithic access/exchange signals a change in emphasis, from generalized reciprocity to balanced reciprocity (Sahlins 1972, 199).

8 The Cnoc Dubh quarry and future comparative work

As part of the investigation of the prehistoric quartz quarry at Cnoc Dubh, the author intended to compare the site with other Scottish procurement sites. It was thought that, in an attempt to define attributes diagnostic of quartz quarrying, and to understand the on-site organisation of the procurement process, comparison with other Scottish quarry sites might be relevant. However, many lithic outcrops have been visited repeatedly by geologists and amateur knappers (eg, the Arran pitchstone outcrops and the baked mudstone seam above the An Corran site on Skye) and, today, it would probably be impossible to distinguish between modern pick-axe marks and prehistoric impact points (in his presentation of a chalcedony quarry in Nova Scotia, Michael Deal writes: ' . . . decades of visitations by geologists and rockhounds have resulted in the defacement of the bedded deposits by metal picks . . . ' [Deal 1989]). It is therefore the author's hope that the Cnoc Dubh quarry will in some way be protected, thus making future comparative analyses possible. The matter of scheduling is presently being considered by Historic Scotland.

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