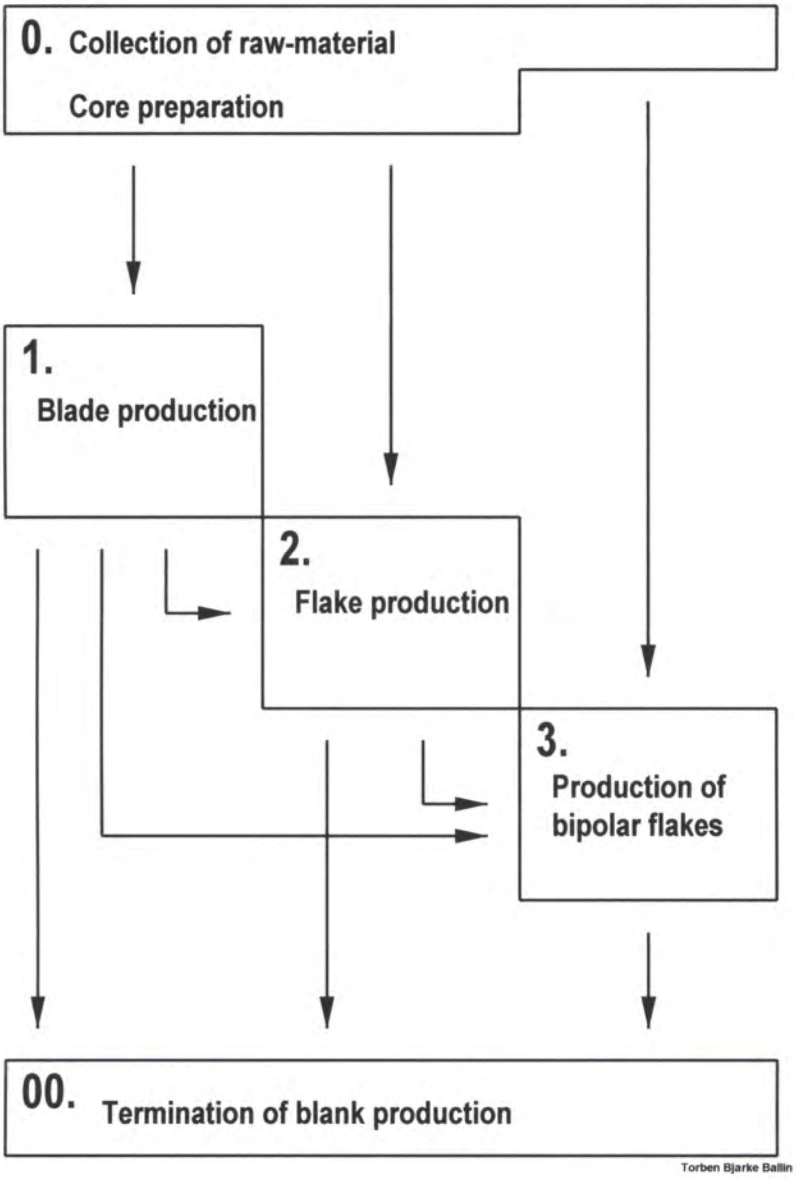
6 Technological Approaches (Operational Schemas)

6.1 Introduction

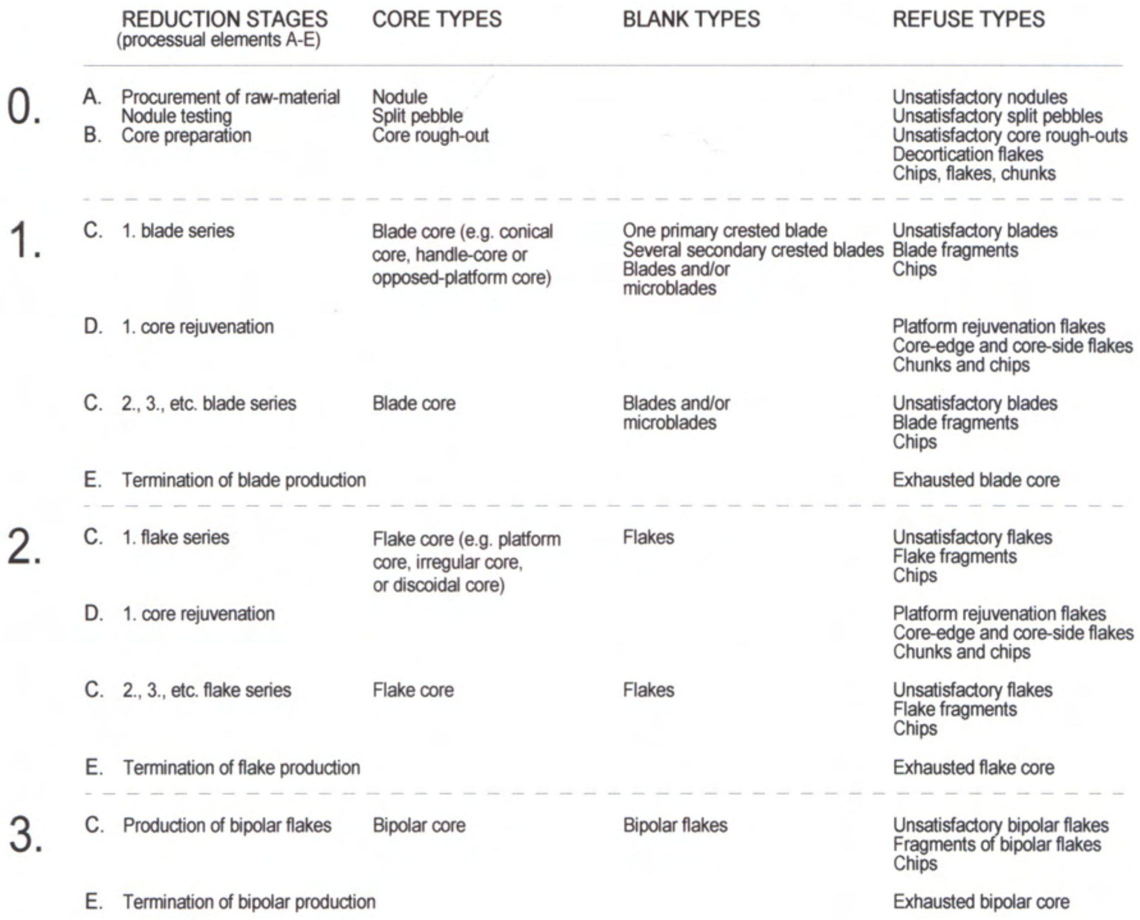
The following discussion of the technological aspects of quartz production presents Scottish quartz technology in terms of its various operational schemas (*'chaîne opératoire'*; Leroi-Gourhan 1965; Lemonnier 1976; Eriksen 2000, fig 1), as experienced through the available assemblages (Section 2.4 and Section 3). The discussion is based, mainly, on the approach outlined in the presentation of the Later Bronze Age quartz assemblage from Bayanne on Yell, Shetland (Ballin forthcoming j). The basic elements, or stages, of a complete operational schema (a 'master' schema) are shown in illus 47 and illus 48.

6.2 Procurement of quartz

As demonstrated in Section 4, quartz occurs in a number of forms, such as, rock crystal (or one of its coloured variants), milky quartz, various types of saccharoidal quartz and the meta-sedimentary rock



Illus 47 The modules and sequences of most operational schemas. For detailed explanation and discussion (see Ballin forthcoming m)



		REDUCTION STAGES (processual elements A-E)	CORE TYPES	BLANK TYPES	REFUSE TYPES
0.	A.	Procurement of raw-material Nodule testing	Nodule Split pebble		Unsatisfactory nodules Unsatisfactory split pebbles Unsatisfactory core rough-outs Decortication flakes Chips, flakes, chunks
	B.	Core preparation	Core rough-out		
1.	C.	1. blade series	Blade core (e.g. conical core, handle-core or opposed-platform core)	One primary crested blade Several secondary crested blades Blades and/or microblades	Unsatisfactory blades Blade fragments Chips
	D.	1. core rejuvenation			Platform rejuvenation flakes Core-edge and core-side flakes Chunks and chips
	C.	2., 3., etc. blade series	Blade core	Blades and/or microblades	Unsatisfactory blades Blade fragments Chips
	E.	Termination of blade production			Exhausted blade core
2.	C.	1. flake series	Flake core (e.g. platform core, irregular core, or discoidal core)	Flakes	Unsatisfactory flakes Flake fragments Chips
	D.	1. core rejuvenation			Platform rejuvenation flakes Core-edge and core-side flakes Chunks and chips
	C.	2., 3., etc. flake series	Flake core	Flakes	Unsatisfactory flakes Flake fragments Chips
	E.	Termination of flake production			Exhausted flake core
3.	C.	Production of bipolar flakes	Bipolar core	Bipolar flakes	Unsatisfactory bipolar flakes Fragments of bipolar flakes Chips
	E.	Termination of bipolar production			Exhausted bipolar core

Illus 48 Complete operational schema ('master schema'), including all modules of illus 5A (the numbers in the left column refer to this figure). For detailed explanation and discussion (see Ballin forthcoming m)

form quartzite, which is pure silica (compressed quartz grains). These varieties of raw material are found in a wide range of geological contexts, but in terms of procurement, the most important distinction is that of vein and pebble sources (Ballin 2004e). The specific type of source defines whether quartz was collected, quarried, or acquired in the form of exchange. Based on Binford's work (Binford 1976; Bindford 1979), Morrow & Jeffries suggested three classes of procurement (Morrow & Jeffries 1989; also see Eriksen 2002, 45), namely (i) embedded procurement, where raw material is simply collected along the way as the group moves through the landscape, with other tasks defining the group's movements; (ii) direct procurement, where raw materials are acquired in connection with organized visits to the sources (this would usually take the form of quarrying, but could include visits to particularly rich quartz gravels, or fields of erratics; eg Ballin 2004c; Ballin d); and (iii) indirect procurement through exchange networks within and outwith the social territory (for discussion of prehistoric territorial structures, see Ballin 2007b). A fourth variety may be seen as a post-Mesolithic sub-form of direct procurement, where the group, or family, chose to settle immediately adjacent to a major source, instead of constantly having to organize procurement trips to it.

6.2.1 *Embedded procurement*

There is little evidence of Scottish quartz having been acquired as embedded procurement, although it is quite possible that the individual pieces of worked quartz found on sites outwith the quartz province (that is, in north-east, south and central Scotland) were collected in an unstructured manner. Many of these nodules may have been collected at gravel sources (eg river banks), as the group passed these during its daily movements, but erratics may also have been exploited (eg FERG Sites 4–5: Ballin forthcoming c). Due to the amounts of quartz needed by prehistoric man to cover the daily replenishment of lithic tools (partly as a result of this resource flaking in a more irregular fashion, subsequently having a lower than average tools-per-nodule ratio), in conjunction with the considerable weight of the required raw material (Broadbent 1979, 190), it is most likely that quartz procurement was a more focused activity.

6.2.2 Direct procurement

Owing to the amounts of quartz needed, as well as its weight, it is thought that most quartz-bearing Scottish sites were located immediately adjacent to their main sources, or these sources are situated within a traditional catchment area (as defined by Vita-Finzi & Higgs 1970), that is, an area with a radius of no more than 10km. This hypothesis definitely holds true on the island of Lewis in the Western Isles (Table 19), where the main quartz source of the individual coastal settlement is either a shingle beach in front of the site, or a vein quartz quarry in the immediate hinterland (such as Cnoc Dubh: Ballin 2004e).

The same holds true at Scord of Brouster on Shetland (Ballin 2007a), where it was argued that the recovered quartz was procured from a number of sources. The material adhering to the artefacts (sandstone, feldspar and steatite/chlorite) defines the exploited raw material forms as mainly vein quartz. The sandstone indicates the use of local veins, as the area around Gruting Voe is completely dominated by Old Red Sandstone (Mykura 1976, 52). The large feldspar crystals points to the use of veins from areas of igneous (granite) or metamorphic rock (gneiss), whereas steatite and chlorite indicate the exploitation of veins from areas of metamorphic rock. The nearest known outcrops of granite or gneiss are at 6–10km distance towards the south (the Sandsting Complex) and east (east of the Walls Boundary Fault: Mykura 1976, figs 9–10), whereas the steatite/chlorite may derive from the metamorphic zone east of the Walls Boundary Fault (Mykura 1976, plate IV). Most probably, all quartz was procured within the site catchment area of the Scord of Brouster site. 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 7km (Broadbent 1979, 190).

However, the Shetland and Western Isles assemblages mainly date to the post-Mesolithic period. Most Mesolithic quartz assemblages have been discovered in the region of the Southern Hebrides/west mainland Scotland, where later prehistoric assemblages are scarce. Most of these assemblages are chronologically mixed, and many were recovered decades ago, in ways we today would characterize as unsatisfactory (Section 3). There are, nevertheless, some indications as to where the quartz was acquired. It seems that, on the mainland, most resources were quarried at veins, though supplemented by some pebble quartz (eg Kilmelfort Cave: Saville & Ballin forthcoming; Shieldaig: Ballin *et al* forthcoming), whereas the island assemblages are largely based on pebble quartz (eg Lealt Bay: Ballin 2001b; Lussa River: Ballin 2002b). The mainland veins have not yet been located, but the pebble sources are without doubt the local gravel deposits in the tidal zone, or on the raised beaches (see for example Mercer 1971, fig 4).

The specific quarrying techniques have been discussed previously (Ballin 2004e). In this paper, it is suggested that the choice of approach was generally determined by the combination of the factors:

(i) source type (hardness of matrix and source location in relation to the ground surface)
(ii) type of material (mineral or rock)
(iii) the presence or absence of inherent layers parallel to the exposed surface.

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; Luedtke 1992, 125), that is, by the use of hammerstones and the successive detachment of raw material layers (resulting in the stepped appearance demonstrated by Ballin 2004e, 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).

As mentioned above, no Scottish procurement sites based on the extraction of pebble quartz are known. A paper on a number of locations in the vicinity of the John H Kerr Dam in the Piedmont Province, Virginia (Brockington 1992) discusses the finds from several pebble extraction sites, as well as the organization and character of these sites. Brockington mainly focuses on the identification of the four main locations as representing a foraging or logistical form of economic organization (corresponding to Binford's 1980 residential and logistical mobility). The following conditions should be met (modified after Espenshade 1986):

Foraging assemblages (residential mobility)

1. Tool diversity should be high, including tools unrelated to lithic reduction.
2. Caching of site furniture should be present.
3. Exhausted tools should be present, as 'gearing up' occurs at these base camps.
4. Storage vessels (in later assemblages) should be found (high pottery counts).
5. Non-quartz lithic artefacts should be a strong minority.

Logistical assemblages (logistical mobility)

6. Tool diversity should be low especially in non-lithic manufacturing categories.
7. Low site furniture counts.

Table 23 Foraging or logistical conditions by site (Brockinton 1992, 96). * = inconclusive

Site	Conditions									
	1	2	3	4	5	6	7	8	9	10
44MC176						x	x	x	x	x
44MC175						x	x	x	x	x
44MC174	x		x	*	x		x		*	
44MC173						x	x	x	x	x

8. Few exhausted tools should be present.
9. Storage vessels should be absent (low pottery counts).
10. Lithic assemblage should be almost pure quartz.

In Table 23, Brockington shows how most of his sites clearly fall into the logistical category, and, most likely, the pebble extraction sites were visited on an occasional basis. It is not, however, possible to say whether they were exploited in the form of embedded (unfocused) or direct (focused) procurement.

Though some crystals may have been acquired in the form of embedded procurement, it is most likely that crystals of milky quartz and rock crystal were acquired in connection with visits to known veins, where knappable crystals formed in cracks between quartz layers. If rock crystal did have symbolic connotations in parts of prehistoric Scotland (eg Lealt Bay; Section 2.4.2, Section 4.3 and Section 7), it is possible that they were procured in connection with targeted visits to veins specifically aimed at providing this visually impressive material.

6.2.3 Indirect procurement

On Lewis, one form of quartz appears to have been preferred for, for example, arrowheads, namely the so-called 'greasy' quartz. As shown in Table 19, the Calanais ritual complex (Ballin forthcoming a), and its central megalithic tomb, is dominated by homogeneous milky quartz, but the site's barbed-and-tanged arrowheads are mainly in quartz with a greasy lustre. At Dalmore (Ballin forthcoming g), 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. 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* forthcoming). 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 100km.

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 reinforcing, alliances (Gould 1980, 155). In cases, where the use of a lithic resource is associated with symbolic values or style (Ballin 2007b), 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 (According to Polly Wiessner, style is '…formal variation in material culture that transmits information about personal and social identity'; Wiessner 1983, 256). 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 19th-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-organized 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 clans, 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 formalized and quarry access more open, as suggested in Bruen Olsen & 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* 10,000–3800 14C 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).

6.3 Core preparation and rejuvenation

As illustrated by Table 25 and illus 49, most assemblages pre-dating the Bronze Age are dominated by bipolar cores, whereas most assemblages post-dating this watershed are dominated by platform cores. This does not necessarily mean that assemblages dominated by a specific core type are also dominated by the technique associated with that core form (eg bipolar cores/bipolar technique) – many bipolar cores frequently represent the last stages of exhausted platform cores, and assemblages dominated by bipolar cores may largely have been manufactured in platform technique.

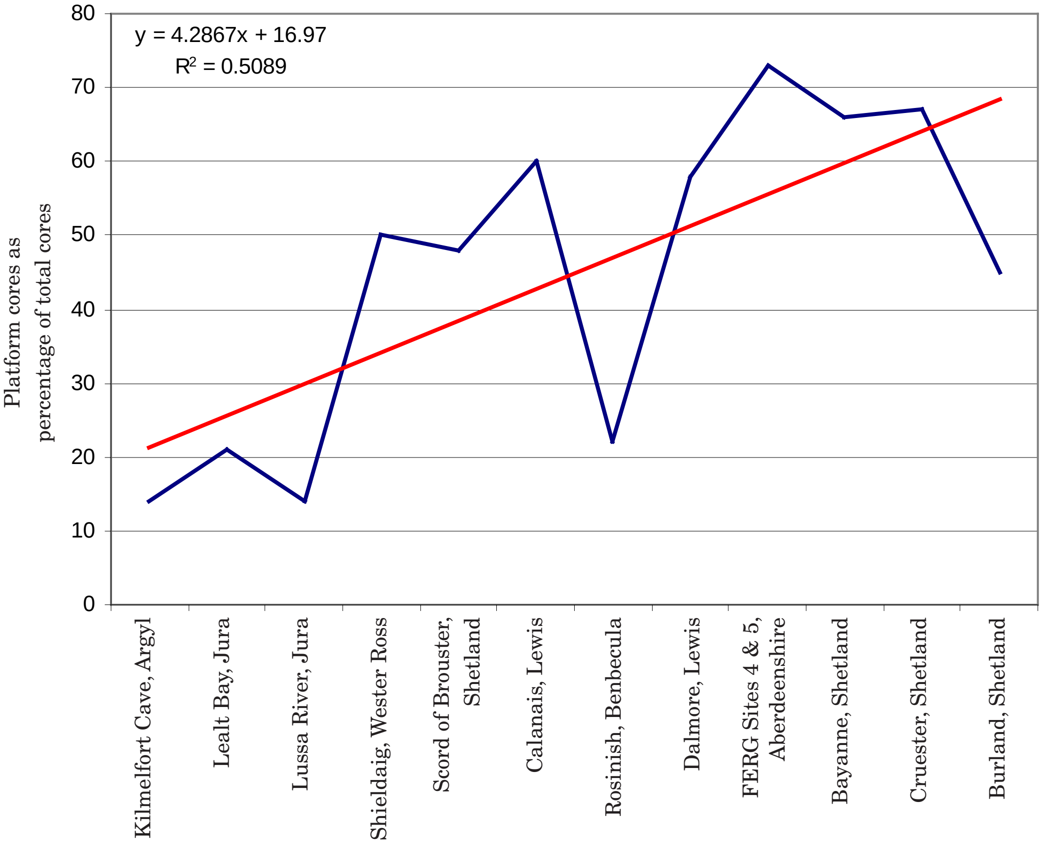
Table 24 Core preparation and rejuvenation flakes in the analyzed quartz assemblages

	Crested pieces	Platf. rejuv. flakes
Kilmelfort Cave, Argyll	5	0
Lealt Bay, Jura	2	0
Lussa River, Jura	1	0
Shieldaig, Wester Ross	8	1
Scord of Brouster, Shetland	0	0
Calanais, Lewis	0	0
Rosinish, Benbecula	1	0
Dalmore, Lewis	0	0
FERG Sites 4 & 5, Abd.shire	0	0
Bayanne, Shetland	4	2
Cruester, Shetland	2	0
Burland, Shetland	1	0

However, as not all assemblages analysed in connection with the present project were subjected to detailed attribute analysis of their blanks, the cores represent the best consistent indicator of the applied percussion techniques, and it must be assumed that the lower the proportion of platform cores, the lower the likelihood of encountering core preparation flakes or core rejuvenation flakes. As shown in illus 47, nodules were not prepared before commencement of bipolar production, and core rejuvenation was not carried out during bipolar production (illus 48), apart from the occasional re-orientation of the cores.

Table 24 lists the number of crested pieces and platform rejuvenation flakes discovered in connection with the examination of the project's selected assemblages. It is obvious that crested pieces are few, and platform rejuvenation flakes are almost entirely absent. In comparison, the Mesolithic chert assemblage from Glentaggart in South Lanarkshire (Ballin & Johnson 2005) includes 15 crested pieces and five platform rejuvenation flakes (of 384 flakes and blades), and the Late Neolithic flint assemblage from Area 1/Grid J at Stoneyhill in Aberdeenshire (Ballin forthcoming i) includes 11 crested pieces and four platform rejuvenation flakes (of 577 flakes and blades).

The only quartz assemblage with substantial numbers of preparation flakes is Shieldaig with



Illus 49 Platform cores as a percentage of the total number of cores, by assemblage. The assemblages are listed in chronological order, starting with the oldest (Kilmelfort Cave)

eight crested pieces and one core tablet. This assemblage consists of almost equal amounts of milky quartz and 'greasy' quartz (*c* 1300 and 1800 flakes and blades), but only one crested piece is in milky quartz, with all other preparation flakes being in 'greasy' quartz. It is apparent that the common quartz forms are not well-suited for 'sophisticated' details, such as core preparation, and the use of cresting and platform rejuvenation in connection with the reduction of 'greasy' quartz is clearly a consequence of this raw materials superior (compared to other quartz forms) flaking properties. As mentioned above, it is quite likely that prehistoric people would have perceived 'greasy' quartz as an independent raw material, unrelated to quartz in general.

The use of limited cresting on some sites in northern and western Scotland may largely be the product of three conditions:

1. extensive use of platform technique
2. the access to quartz in the form of large 'plates'/blocks (from veins) or large pebbles
3. widespread use of flint or flint-like raw materials, allowing technical elements from one operational schema (one raw material) to be transferred to another operational schema (another raw material) simply as a matter of technological tradition.

Bayanne and Cruester, both later prehistoric assemblages from Shetland, are examples of Points 1–2, whereas Kilmelfort Cave, Lealt Bay, Lussa River and Shieldaig, all Mesolithic assemblages from the Scottish west coasts, and characterized by widespread use of flint, may be examples of Point 3 (however, see discussion below, in Section 6.4). The detachment of core tablets requires either large cores which will allow the detachment of more than one flake or blade series, thereby making core rejuvenation relevant (Bayanne and Cruester), or access to quartz with exceptionally good flaking properties, like 'greasy quartz' (Shieldaig), allowing well-controlled detachment of relatively thin core tablets from small cores.

Though crested pieces *proper* are rare in quartz assemblages (with cresting being defined as dorsal ridges formed by the detachment of small flakes perpendicular to the main flaking direction), some degree of alternative ridge formation occasionally took place. At Bayanne (Ballin forthcoming j), crude crests were made by simple crushing, leaving characteristic battered arrises. These plainer crests functioned in the same way as the

Table 25 The selected assemblages, their ratios of platform and bipolar cores, quartz ratios, and dominant quartz forms. The assemblages are listed in chronological order, starting with the oldest (Kilmelfort Cave)

	Number		%				
Assemblages	**Platform cores**	**Bipolar cores**	**Platform cores**	**Bipolar cores**	**Quartz ratio**	**Quartz ratio**	**Dominant quartz form**
Kilmelfort Cave, Argyll	1	6	14	86	45	Below 50%	Vein
Lealt Bay, Jura	6	22	21	79	24		Pebble
Lussa River, Jura	27	167	14	86	89	Between *c* 70% and 100%	Pebble
Shieldaig, Wester Ross	31	31	50	50	87		Vein
Scord of Brouster, Shetland	46	50	48	52	100		Vein
Calanais, Lewis	6	4	60	40	74		Vein
Rosinish, Benbecula	16	57	22	78	99		Pebble
Dalmore, Lewis	35	25	58	42	93		Pebble
FERG Sites 4 & 5	11	4	73	27	68		Erratics
Bayanne, Shetland	35	18	66	34	100		Vein
Cruester, Shetland	6	3	67	33	99		Pebble
Burland, Shetland	17	21	45	55	100		Vein/pebble

more sophisticated traditional crests, that is, as a directional guide for the force detaching the first blank of a blank series.

6.4 Blank (primary) production

6.4.1 Platform or bipolar technique?

Quartz blank production (Modules 1–3 in illus 47 and illus 48) may take many forms, but the most significant technological choice made by the prehistoric knapper was whether to rely mainly on platform (free-hand) technique or bipolar (hammer-and-anvil) technique. Table 25 presents a crude overview of these basic technological choices made in Scottish quartz knapping. As shown in illus 49, bipolar technique apparently dominates the earlier industries, and platform technique the later industries, and some assemblages of intermediate age are characterized by approximately equal proportions of platform and bipolar cores.

As the earliest collections consist exclusively of material retrieved from sites in the Southern Hebrides and west mainland Scotland, the later collections of material mainly from the Western Isles, and the latest collections entirely of material from Shetland, it is possible that this trend is not a wholly accurate reflection of technological change through Scottish prehistory, from predominantly bipolar to predominantly platform technique. With reference to the uneven chrono-geographical distribution, it is possible that this trend instead reflects local raw material availability, with some assemblages being based on vein quartz and some on pebble quartz, the local pebbles may be available in different sizes, and the quartz may have been supplemented by other silica introducing different approaches to lithic reduction (cf Thorsberg 1986, 10; Ballin 1999a, 20).

It is highly likely that the size and shape of the available nodules or blocks/plates influenced preferences. It is generally accepted, that small pebbles are ill-suited for platform technique (eg Callahan 1987, 63; Finlayson 2000, 105), as:

- they do not contain sufficient mass to allow the necessary decortication and preparation of platforms, flaking-fronts and platform-edges
- due to their small size and curved exterior, primary blows tend to glance off these pebbles
- small pebbles have so little mass that a blow tends to move the hand and pebble, rather than detach a flake.

The reason why, for example, the Lussa River assemblage is dominated heavily by bipolar technique and the Cruester assemblage by platform technique may largely be the fact that the available pebbles are relatively small along the eastern shores of Jura and larger along the shores of Bressay, in Shetland.

Apart from the worked quartz from Kilmelfort Cave, which is dominated by bipolar technique, assemblages based on vein quartz are mainly dominated by platform technique. This is probably a result of vein quartz mostly being procured in the form of relatively large blocks or plates (Ballin 2004e), allowing the core preparation required by this approach. Powell suggests that, to prehistoric knappers, the tendency of vein quartz to form natural layers (cf Ballin 2004e) was a desired attribute in this material: ‘Because of the flat-sided nature of quartz [...], the quarriers were able

Table 26 Flatøy XI. Attributes for blades in flint and quartzite

Attributes	**Flint**	**Quartzite**
Width (mm)	7.0	6.3
Thickness (mm)	1.7	1.9
Platform width (mm)	3.6	3.6
Platform depth (mm)	1.2	1.4
W:Th ratio	4.1	3.3
Platform W:D ratio	3.0	2.6
Striking-angle (degrees)	83.5	76.7
Dorsal arriss index	1.68	1.48

to secure a wide range of pieces having roughly parallel sides. These constituted natural cores, with ready-made striking and anvil platforms (Powell 1965). In this respect, Scottish rock crystal (clear quartz, mostly acquired in crystal form) constitutes an exceptional case, as this material is particularly well-suited for platform technique, having six ready-made crests, but Scottish knappers chose only to reduce this resource by the application of bipolar technique. One may suspect that the purpose of this enterprise was to, mainly, produce shiny, iridescent shatter rather than functional implements and that, in Scotland, this end-product had symbolic meaning.

It is possible, in the cases of mixed flint-quartz assemblages, that operational elements could be transferred from the reduction of one raw material to the reduction of another. This, however, requires ideological, or non-functional, considerations to be the knapper's main concern, and in most technological matters this obviously was not the case. Most raw materials have distinctly different flaking properties, requiring different reduction methods. The synchronous exploitation, in the Late Mesolithic of west Norway, of flint and quartzite followed different operational schemas, even within the same assemblages (manufactured by the same craftsmen?), and the author assumes that the individual knappers adapted their approaches to the raw material at hand. Table 26 presents key attributes for flint and quartzite microblades from the single-occupation site of Flatøy XI (Ballin 1999b).

The three main values in Table 26 are the W:Th ratio, the W:D ratio, and the striking-angle. These values indicate that, in the Flatøy assemblage, quartzite bladelets are generally thicker than the contemporary flint bladelets, they have deeper platform remnants, and their average striking-angle is more acute. In all likelihood, this reflects adaptation to the fact that the fine-grained Norwegian quartzite is more brittle than flint. As a result, quartzite bladelets are more prone to experience platform collapse, and in an attempt to counteract this weakness, the prehistoric knapper positioned the punch further from the platform-edge of the quartzite cores, giving the bladelets greater thickness and a higher W:D ratio. Due to the tendency of blades to curve along their long axes, positioning the punch further from the platform-edge would usually cause the quartzite cores to be used up earlier, and, to avoid premature abandonment of the core, this seemingly small change of the operational schema had to be combined with a change in general core shape. Consequently, the quartzite cores were given a more pyramidal shape with more acute edge-angles, whereas the flint cores of Flatøy XI tend to be bullet (conical) shaped. The difference in the average number of dorsal arrises mainly signify that, on Flatøy XI, quartzite bladelets are slightly less elegant than their flint counterparts, with fewer parallel dorsal ridges (for discussion of this attribute, see Ballin 2004b).

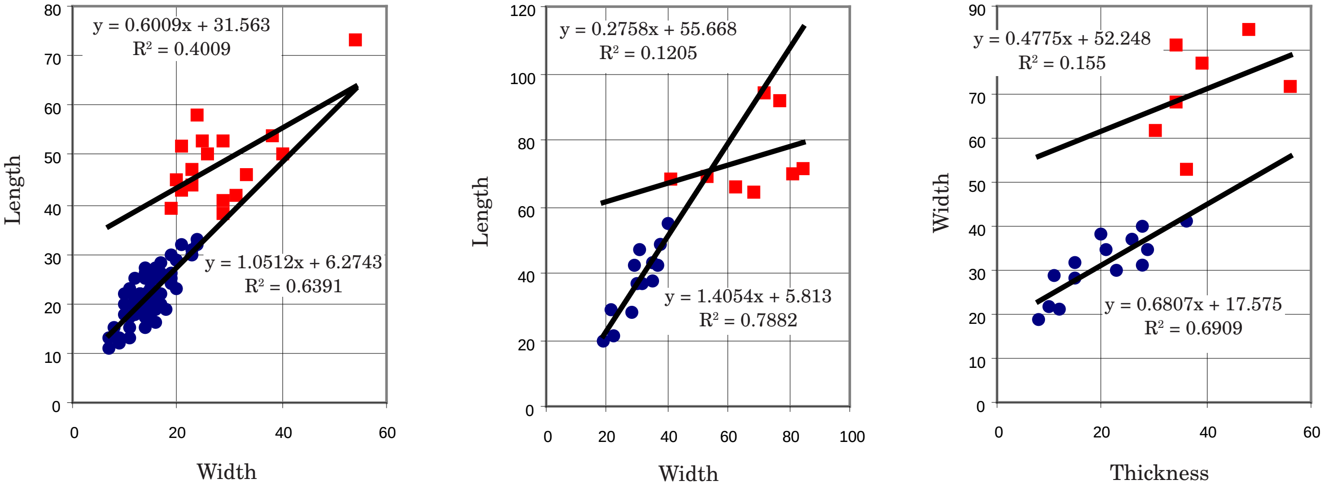
Or to sum up: in all probability, most raw materials, including the various quartz forms, were probably reduced in ways tailored to the specific flaking properties of those resources. This is not to say that ideological or non-functional considerations never entered the technological realm of prehistoric people. In the Late Mesolithic of southern Norway, groups in the east chose to produce microblades from handle-cores, whereas groups in the west preferred to give microblade cores conical shape (Ballin 2004b). Both regions are dominated by flint use (with increasing use of quartzite through the Late Mesolithic of west Norway); in both cases flint was procured in the form of small beach pebbles; and the two methods appear to be equally effective. In the west-Norwegian example, the author suggested (Ballin 2004b) that the two core types functioned as stylistic elements, and identified people as belonging to one of two ?ethnic groups.

6.4.2 The role of bipolar technique in the operational schema

However, quartz knapping was more than simply a question of choosing between platform and bipolar technique. Analysis of the operational schemas of the selected assemblages have shown a variety of technological combinations, with bipolar technique being applied at different stages and for different purposes. Generally, the bipolar approach was used for:

- initial quartering
- general reduction
- final reduction of small platform cores which, due to their low mass, could not be reduced any further by the application of free-hand percussion.

As shown in illus 49, all selected quartz assemblages have a platform and a bipolar component, that is, none was produced by the application of one technique only. The degree to which bipolar technique was used for quartering, general reduction, or final exhaustion may mainly have been a question of nodule or



Illus 50 The length:width of the flakes, and the length:width and width:thickness of the bipolar cores from Burland. The flakes and bipolar cores obviously represent two different populations; in each diagram a trendline has been inserted, and a correlation coefficient (R2) calculated, for each population

block size, with large pieces requiring quartering, medium-sized nodules might allow some platform reduction without quartering but with final small platform cores requiring exhaustion by the application of bipolar technique, whereas small pebbles can only be reduced by bipolar technique, making this approach the main form of reduction.

Quartering by bipolar technique was definitely an element of the operational schema at Burland on Trondra, Shetland (Ballin forthcoming d), where it has been possible to characterize the schema in some detail. The assemblage is based on combined vein and pebble quartz, which was collected or quarried in nodules or blocks of up to 150mm, but probably with average sizes of approximately 100mm. The individual debitage and core types cluster metrically to form separate size categories (illus 50). Most likely, this is an expression of a phased operational schema, with large flakes and cores representing waste from the first stage of the reduction process ('quartering'), whereas the smaller pieces represent the last step (discarded blanks and totally exhausted cores). Between the initial and final stages of this operational schema, quartz flakes were probably manufactured in platform-on-anvil technique (resulting in bruised apexes). Though the Burland industry is based on few and very simple technological choices, it clearly represents a planned process or operational *schema*.

A number of assemblages, such as those from Dalmore, Lewis (Ballin forthcoming g) and Bayanne, Shetland (Ballin forthcoming j), were largely produced by the application of platform technique. Quartering does not seem to have been an integral part of the operational schema, although it may occasionally have taken place, and bipolar technique was mainly used in connection with the final exhaustion of spent platform cores. In connection with the analysis of the Dalmore lithics, the presence of severely battered apexes led the author to suggest the presence of a three-phased operational schema, with one technique replacing another: free-hand platform technique → platform-on-anvil technique → bipolar technique proper. This approach (illus 51) has been described in detail (Callahan 1987, 60, fig 97), and tested by comparison of quartz debitage from Middle Swedish Stone Age sites with debitage from experimental assemblages.

At Bayanne, vein quartz was quarried in the form of large plates which, judging from the refitting of incomplete sequences of plate fragments may have been in the size order of up to 200–300mm. At Dalmore, pebbles were collected in sizes of up to 150–200mm, with one core rough-out having a greatest dimension of 146mm. But instead of quartering the raw nodules, these were carefully prepared and transformed into large single-platform cores.

In illus 49, the assemblage from the Beaker site of Rosinish (Ballin forthcoming h) constitutes an exception from the general trend. Assemblages of similar age (for example, Bayanne and Dalmore) are all dominated by platform technique, or they have roughly equal proportions of platform and bipolar cores, whereas the finds from Rosinish are noticeably dominated by bipolar pieces. Most likely, this is a consequence of the available quartz pebbles generally being in the size order of approximately 80–120mm, or somewhat smaller than the raw nodules or blocks from Bayanne and Dalmore. In this case, bipolar technique represents the main reduction approach (from splitting the pebbles to their final abandonment), with little quartering having taken place.

The general operational schema of the Mesolithic assemblages does not differ noticeably from that of Rosinish: bipolar technique appears to have been the dominant approach, from start to finish, with no

Table 27 The tool ratios of a number of quartz-bearing 'multi-material' assemblages

Site	Quartz (%)	Flint (%)	Mylonite (%)	'Greasy' quartz (%)
Calanais, Lewis	5	20	27	
Dalmore, Lewis	1	8	5	
Rosinish, Benbecula	1	62		
Kilmelfort Cave, Argyll	2	26		
Shieldaig, Wester Ross	1	13		2
FERG, Aberdeenshire	4	12		

quartering having been necessary. The pebble size was not estimated in the reports, but as the average length of the two pebble-based assemblages' bipolar cores (Lealt Bay and Lussa River) is approximately 28mm, against an average length at Rosinish of 36mm, it must be assumed that the beach pebbles on the east coast of Jura are even smaller than on Benbecula. However, the bipolar cores from the two vein-based assemblages (Kilmelfort Cave and Shieldaig) are even smaller, with an average length of *c* 26mm and, though there is no evidence of quartering in the form of broken-up and discarded blocks or plates, raw quartz must have been quartered before the production of miniscule microblades and microliths commenced. The reason for the small artefact sizes at Kilmelfort Cave and Shieldaig is not the size of the raw material blocks, which could probably be delivered from the quarry in whatever size was necessary, but the wish to produce very small implements, that is, a microlithic tradition.

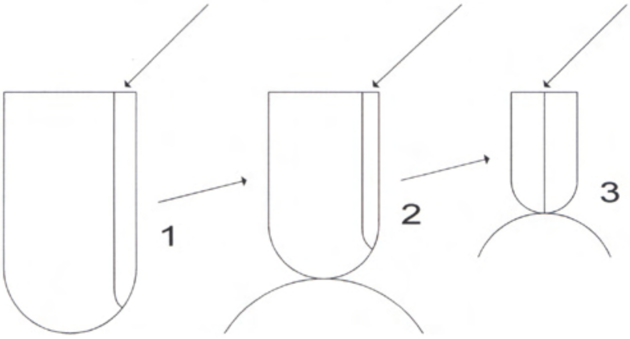
In general, the understanding of prehistoric operational schemas would increase noticeably if attribute analysis of blanks was carried out as part of a methodological 'standard package', aiming at analysis of complete smaller assemblages and, in the case of larger assemblages, analysis of samples (*c* 100 pieces; cf Ballin 2004b). However, attribute analysis is relatively time-consuming and this may not always be possible.

6.5 Tool (secondary) production

When comparing quartz assemblages with assemblages produced in flint or flint-like raw materials, the quartz assemblages are usually found to be characterized by (i) relatively low tool ratios and (ii) little diversity. Below, these two points are discussed in detail, and attempts are made to explain the observed differences.

6.5.1 Tool ratios

As, in Scotland, many older quartz and flint collections were recovered, or published, in less standardized ways than one would expect today (see table 1, in Saville & Ballin 2000), it is almost impossible to compare like with like. The most sensible way to explore the tool ratios of different raw materials is therefore by comparison of sub-assemblages within quartz-bearing 'multi-material' assemblages, such as the finds recovered from sites in the Western Isles and the Southern Hebrides/west mainland Scotland. The ratios of the individual site assemblages (Table 27) are not directly comparable, as excavation procedures differed; the finds represent different prehistoric periods, as well as different local (ie geological) settings; and where most assemblages in Table 27 are from settlement sites, one is from a ritual complex (Calanais; Ballin forthcoming a).



Illus 51 The main stages in the Dalmore operational schema (a simplified version of Callahan 1987, illus 97)

It is, however, quite clear that the quartz component of these geologically mixed assemblages always has the lowest tool ratio, with this ratio occasionally being dramatically lower (eg Rosinish: quartz 1%, flint 62%). Within Lewis, the relative ratios of the quartz, flint and mylonite sub-assemblages appear to be more or less fixed, with the quartz tool ratio being in the size order of approximately one-fifth or one-quarter of the flint tool ratio, or the mylonite tool ratio. At Shieldaig, the tool ratio of 'greasy' quartz is roughly twice that of ordinary quartz.

6.5.2 Assemblage composition

In general, Scottish quartz assemblages display a limited selection of formal types, whereas assemblages, or sub-assemblages, in flint and flint-like materials frequently display a fuller range of tool types. In most cases, quartz assemblages are characterized by a marked dominance of scrapers (Scord of Brouster: 75% of the tools), supplemented by a small number of arrowheads or microliths (if any), some retouched pieces, and individual specimens of other tool types. Uniquely, the quartz assemblage from Scord of Brouster also includes 12 curved knives – a formal type only known from two other Scottish sites (Camster Long, Caithness: Wickham-Jones 1997; Druim Arstail, Oronsay: Wickham-Jones *et al* 1982). Assemblages in flint and flint-like raw materials, for example in east, central and south Scotland, mostly include a slightly smaller proportion of scrapers, though scrapers usually dominate the tools, supplemented by relatively high numbers of arrowheads/microliths, as well as several serrated pieces, burins, piercers, truncated pieces, and – occasionally – larger bifacial pieces, like plano-convex or foliate knives.

6.5.3 Possible explanations

The marked differences in tool ratio and tool group diversity may be due to a combination of factors, with the following probably being the most important:

- Quartz tools are more difficult to recognize than tools in most other lithic raw materials.
- Quartz blanks were frequently usable as tools, without further modification.
- Most quartzes tend to flake in more irregular ways than other silica.
- Economical differences between some quartz-dominated and some flint-dominated assemblages.
- Visually distinctive raw materials were frequently associated with non-functional, or symbolic, values (Gould 1980; Clemmer 1990).

Recognition

The claim that quartz tools are more difficult to recognize than tools in other silica is almost considered a truism by lithics specialists. In connection with a blindtest, in which archaeologists were asked to identify experimentally produced quartz tools, it has been demonstrated (Lindgren 1998, 99) that, frequently, quartz tools were not recognized, or, occasionally, a familiar shape led people to identify unretouched pieces as tools (see discussion of quartz artefact typology, above).

The need for modification

The generally low number of, for example, piercers and burins in quartz may relate to the fact that many quartz blanks are in the form of cubic shatter (‘chunks’), with strong corners, points, and edges. These parts of the blanks were immediately usable as piercer-tips, burin-edges, and edges of planes and scrapers, whereas the working-parts of the thinner and more delicate flint tools needed strengthening by modification to prevent immediate damage to the implement.

This view is partly supported by Bradley’s examination of quartz artefacts from Tougs, Shetland, revealing that most unmodified utilized pieces had been used for scraping, and one for piercing (Bradley 1986). Knutsson’s use-wear analysis of quartz flakes from the Bjurselet site in Sweden (Knutsson 1988, 124–8), showed that 26 pieces had clear wear marks, with 11 thin flakes having been used for cutting, whereas three sturdier pieces were used for grooving, four thick flakes were informal planes, two had been used as piercers, two as ‘whittling knives’ (a sub-form of planes?), three as scrapers, and one was an informal saw.

Flaking properties

Due to the generally poorer flaking properties of quartz (Callahan *et al* 1992; Knuttson 1998, 75), most quartz reduction is characterized by a lower degree of control and a tendency to produce chunks or irregular, thick flakes. This predisposition poses a problem to the production of finer tools, which may usually be produced by the application of invasive retouch, that is, the detachment of very small, narrow thinning-flakes. Bifacial arrowheads *are* known in ordinary quartz forms [eg the barbed-and-tanged arrowhead from Biggings on Papa Stour, Shetland (Ballin 1999c)] but, on the Western Isles, a high proportion of quartz arrowheads are in the more versatile ‘greasy’ quartz, or they were manufactured in flint or mylonite.

It is possible that, on Shetland, where quartz alternatives are scarce, it was attempted to improve the flaking properties of quartz by heat-treatment (cf Section 4.4.3; Gonick 2003). At Scord of Brouster (Ballin 2007a), this is suggested by one curved knife, which retains an unmodified, superficially burnt area in the central part of either face, whereas the peripheral zone of the piece – which appears unburnt – has been modified by the bifacial detachment of thin flakes. Experiments (Crabtree & Gould 1970, 194; Eriksen 1999) have shown that flakes from heat-treated silica nodules or flakes tend to become thinner than flakes from raw nodules. It is possible that the tell-tale signs of this approach, such as a particular type of sheen acquired during the treatment (Eriksen 1999, 189), is obscured by the naturally reflective surfaces of most quartz forms.

Economical differences

It is obvious that the available quartz assemblages do not represent an even distribution of sites throughout Scotland, or throughout Scottish prehistory, as the various Scottish regions are either dominated by early, intermediate, or late material. In his comparison of the Scord of Brouster quartz assemblage with Neolithic lithic assemblages throughout the country, the author suggested that some of the compositional differences between Scotland's Neolithic flint and quartz assemblages may be products of the fact that many flint assemblages from the eastern, central and southern parts of the country are from inland sites, whereas most of the quartz assemblages from the north and west are from coastal sites.

As little, or no, organic material has been preserved from most Neolithic sites of Scotland it is difficult positively to demonstrate differences between the economies of the various sites, but it is evident that economical differences must have existed between these two groups of sites. It is logical to associate a 'semi-diagnostic' type such as the serrated piece (which is generally rare in quartz assemblages) with inland sites, as detailed use-wear analysis has demonstrated that this type may mainly have been used for the processing of plant material (Juel Jensen 1988; Juel Jensen 1994).

Symbolic values

The high tool ratio of north and west Scotland's alternative silica, as well as the more diverse assemblage composition of these resources, may be explained by one of two possible scenarios, or a combination of the two:

- In comparison to common quartz forms, alternative silica, such as flint, mylonite and 'greasy' quartz, generally have superior flaking properties.
- These alternative, frequently visually distinctive, silica may have been associated with other than functional values.

It is not possible to decide which of the two scenarios is the dominant one without carrying out a detailed analysis of these matters. It is, however, most likely that an explanation of the observations would include a combination of the two. Most ethnographic analyses of raw material procurement and use indicate that many, or even most, raw materials were associated with some symbolic, or non-functional, values (eg Gould 1980). Congdon writes about the role of white chert in Tosawihi Shoshone beliefs:

> The white chert has a symbolic value as a material and is a physical expression of their identity. Chert from the quarry has religious value as a source of spiritual power and forms an integral part of Western Shoshone religious practice and expression (Congdon 2000, 10–17).

The distribution of 'greasy' quartz, in conjunction with the composition of assemblages in this raw material, clearly define 'greasy' quartz as a material with symbolic connotations. In the area immediately adjacent to the likely source(s) (eg Shieldaig; see Section 2.4.2) assemblages include all tool types, but further from the source(s) the material in question only includes a very select set of artefact types. In the case of, for example, Lewisian assemblages with imported 'greasy' quartz, the 'greasy' quartz sub-assemblages only include more elaborate prestige implements, in most cases exclusively arrowheads. The preference on Lewis for 'greasy' quartz as a material for arrowhead production, and the acceptance at Shieldaig of this quartz form in general tool production, must reflect the existence of different prehistoric belief systems in the 'donor' and 'recipient' areas.

Even though the exact sources of the Lewisian mylonite are not yet known, the geological realities of that island (Smith & Fettes 1979, fig 3) suggest that this raw material was quarried in eastern Lewis partly for use on sites in western Lewis. At some distance from the quarries, this resource seems to have been used in very much the same way as 'greasy quartz', that is, for the production of a selected number of tool types. Flint and bloodstone appear to have been used in a slightly less restrictive manner than pitchstone, 'greasy' quartz and mylonite, and, in these cases, the functional aspect of the lithic selection process may have been dominant.

Overall, the different applications of the quartz alternatives (due to its deviating appearance and qualities it has been chosen to include 'greasy' quartz in this group) suggest that probably all lithic raw materials were associated with symbolic values, with these values differing from raw material to raw material, and with the balance of perception shifting from mainly functional to mainly symbolic. The use of ordinary quartz forms may largely have been based on functional considerations, and pitchstone, mylonite and 'greasy' quartz (away from the main source) largely on ideological considerations, with flint and bloodstone representing more equal mixtures of functional and ideological considerations. Generally, preferred raw materials reflect the identity of the user ('style', see above; also Wiessner 1983; Gebauer 1988), either by identifying him as belonging to a particular social group (band/extended family, lineage, clan or tribe), or by identifying alliances between groups (White & Modjeska 1978; Bruen Olsen & Alsaker 1984, 96; Sassaman *et al* 1988, 80).