4 Quartz as a Mineral – Its Properties, Formation and Provenance

4.1 General properties

To fully understand quartz, its properties, formation and provenance, it is necessary to make a distinction between minerals and rocks, and to clearly define the two. This distinction is particularly important in connection with the subdivision of quartz into sub-types, such as, macro-crystalline and crypto-crystalline varieties, as well as quartz-dominated rock forms (see below).

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, and a specific internal (crystal) structure. A *rock*, on the other hand, is a mountain-building aggregate of minerals (Pellant 1992, 16). Chemically, the mineral quartz is a silicon dioxide, and its formula is SiO^2. It is grouped within a general class of minerals known as *silicates* (Luedtke 1992, 7), including feldspars, pyroxenes and amphiboles, but quartz is without doubt the most diverse silicate in terms of varieties, shapes and forms, and, due to its mineralogical properties, it definitely represents the most knappable silicate. To confuse matters slightly, lithics analysts tend to refer to silicon-dominated raw materials as *silica* (eg Brown 1992), irrespective of whether they are silicate minerals or rock types (eg quartz, jasper, flint, chert, obsidian and quartzite). Silicates are estimated to make up approximately 59% of the Earth's crust, and quartz *c* 12% (Jensen 1973, 68).

The *crystal structure* of quartz (illus 38) is important to the way mineral forms of this material flakes and fractures:

> Structurally, quartz is a tectosilicate, and it contains corkscrewing helical chains of silicon tetrahedrons. The 'corkscrew' consists of four

Illus 38 Quartz crystals (Kongsberg, Norway)

> tetrahedrons, making three turns or twists (trigonal structure) in order to repeat the structural sequence. Each tetrahedron is rotated 120 degrees relative to one another and is aligned along the c-axis of the crystal. Each chain is connected to two other chains at each tetrahedron. This crystalline structure gives quartz many of its unique physical attributes. The tectosilicate structure of quartz and other silicates, with its trigonal symmetry, disrupts cleavage planes and allows a curved fracture quality (conchoidal fracture). This fracture quality is what essentially makes many of these [mineral forms] highly suitable as raw materials for the construction of stone tools (Abbott *et al* forthcoming).

Quartz may be divided into two general types, macrocrystalline and cryptocrystalline (or microcrystalline) varieties, based on the size of the individual crystals within a given quartz form. The crystals of the former variety are large and can be distinguished with the naked eye, whereas those of the latter are too small to see even by microscope (Luedtke 1992; Abbott *et al* forthcoming). Macrocrystalline quartz includes, *inter alia*, milky quartz, rock crystal, smoky quartz and rose quartz, and cryptocrystalline quartz includes flint, chert and chalcedony. As explained in the introduction, only macrocrystalline quartz is discussed in the present paper, and in the following text the term ’quartz’ refers to this variety.

A *cleavage* plane is a specific attribute associated with the crystal and atomic structures of a mineral and, in general, quartz is said to have none. This is not entirely true, as quartz cleavage can be induced by either electrical or thermal shock (Howard & Howard 2000; also Siiriäinen 1974), but this fact is, obviously, irrelevant to a knapper. *Fracture* has been defined as the manner in which a mineral breaks when cleavage is not well-developed (Howard & Howard 2000), and the principle fracture manifestations of quartz are intricate cracking and conchoidal, or sub-conchoidal, flaking (Lacaille 1938; Broadbent 1979, 50; Callahan *et al* 1992). The former, which is a genuine problem to quartz knapping, tends to produce cubic fragments in an uncontrollable fashion, whereas the latter allows the production of usually irregular, thick quartz flakes.

However, the quality of quartz fracturing, or flaking, differs from variety to variety, and it is possible that a prehistoric knapper therefore perceived the various quartz-types as different raw materials. Milky quartz, for example, mainly fractures in the intricate manner described above, but rock crystal (and the related smoky quartz) has excellent flaking properties, allowing the manufacture of exceedingly small regular microblades (eg Ballin 1998a), and quartz with a ‘greasy’ lustre (presented below) probably flakes as well as some coarser flint varieties (Ballin *et al* forthcoming).

Quartz veins tend to crack along three axes (for example, the vein at Cnoc Dubh, Lewis; Ballin 2004e), with one well-developed plane being parallel to the exposed surface, frequently forming actual layers, and two secondary planes running into the vein mass from the surface. This pattern does not represent cleavage planes, as quartz displays very weak (see above) cleavage (Howard & Howard 2000), and at present this habit is not well understood. In his discussion of quartz quarrying (Ballin 2004e), the author suggests that the three-dimensional cracking of quartz veins may be associated with the way hydrothermal fluids solidify. It has been suggested by several researchers (Powell 1965; Ballin 2004e) that this tendency to form secondary layers was a quality in quartz exploited by prehistoric quarriers and knappers in, first, mining the resource and, later, transforming it into blanks and tools.

Quartz is one of the hardest common minerals, and on Moh’s *hardness scale* (Table 15) it has been given the number seven of 10 possible (Pellant 1992, 25). As a general rule, minerals with higher Moh’s numbers will scratch those lower in the scale. The hardness of quartz is important to the flaking properties of the mineral, but it is also one of the factors defining quartz as a high-quality ‘tool-stone’, usable for most imaginable functions (scraping, shaving, chopping, drilling, cutting, graving, etc.).

Table 15 Moh’s hardness scale

Talc	1	Feldspar	6
Gypsum	2	Quartz	7
Calcite	3	Topaz	8
Fluorite	4	Corundum	9
Apatite	5	Diamond	10

The mineral quartz is also characterized by several other attributes, such as *colour*, *transparency/translucency* and *lustre*. These characteristics are of no importance to the practical application of quartz, but define a number of semi-precious sub-varieties. The most common natural variety of quartz, milky quartz, is white and translucent, and it has a vitreous lustre. It is quite possible that some of the quartz sub-varieties were appreciated by prehistoric people for their beauty or for symbolic, for example, totemic values (eg rock crystal and quartz with a ‘greasy’ lustre; see Section 8).

4.2 Formation of quartz sources, and general geological provenance

Quartz is a common, if not abundant, component of many igneous, metamorphic and sedimentary rocks, and, due to its resistance to weathering, it may form single-mineral sedimentary and metamorphic rock types (eg sandstone and quartzite). It is frequently found as large grains, crystals or veins in igneous rocks, like granite and granite pegmatites, and metamorphic rocks, like gneisses, but it also occurs as veins in sedimentary rocks, such as shale and sandstone (Neumann 1985; Howard & Howard 2000).

In addition to these primary geological sources, quartz may also be acquired from secondary (pebble) sources. In a previous paper (Ballin 2004e), the author discussed prehistoric quarrying in general, and sub-divided lithic raw material sources into the following groups:

- 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).

In prehistory, quartz was procured from all but intermediary sources, though quartz may occasionally be found in dolomites and limestones (sedimentary carbonate rocks; Howard & Howard 2000).

The mineral quartz may form in a number of ways, but most commonly it forms as crystallization in magmatic rocks, or as the solidification of hydrothermal fluids in various host-rock types. It is found in two forms, alpha-quartz and beta-quartz (for distinction, see Howard & Howard 2000), but as only alpha-quartz is staple at normal temperatures and pressure (all archaeological quartz is alpha-quartz), the following text applies the term 'quartz' as a synonym for this type of the mineral. Alpha-quartz (or low quartz) forms at temperatures lower than 573°, whereas beta-quartz (or high quartz) forms at temperatures between 573° and 867°. Given time, beta-quartz will invert or change its internal structure to that of alpha-quartz (Luedtke 1992, 7; Howard & Howard 2000).

In granite, quartz crystals formed at considerable depth in the Earth's crust. Its crystals are usually in the order of 5mm in diameter, but crystals several centimetres long are not uncommon (Pellant 1992). However, due to the relatively small size of the individual pieces of quartz, this form was of little relevance to prehistoric knappers. Pegmatite, on the other hand, has the same mineral composition as granite, but its crystals are larger than those of granite and therefore attracted some attention in early prehistory. In pegmatites, quartz crystals may be many metres long (Pellant 1992), and many of the well-known Scandinavian quartz extraction sites are pegmatite sources (eg the Gummark quarries: Broadbent 1973; Broadbent 1979; the Koppinkallio quarry: Kinnunen 1993).

However, most quarried quartz sources are veins. Veins are sheet-like areas of minerals which cut through existing rock structures (Pellant 1992, 18), and most of these formed from hydrothermal fluids (eg Jensen 1973, 159–60; Kourimsky 1995, 26). These hot fluids, containing concentrated volatile elements from the magma chamber, solidified in cracks and fissures of various host rock types. As the formation of prominent fissures generally coincides with active geological environments, large veins are frequently associated with specific geological features. Two forthcoming papers (Abbott *et al* forthcoming; Jones forthcoming) recognize three dynamic geological processes which, in their reaction with other local rocks, are responsible for a variety of culturally important silicates, such as quartz. These are the formation of:

1. diabase (in British English terminology: dolerite) dykes
2. granite plutons
3. fault zones.

Usually veins occur as complex series of seams that follow the fracture patterns of the rocks that were broken and shattered by the mountain-building processes (Howard & Howard 2000). Typically, deposition of quartz took place several times, interrupted by breakage and refracturing of the host rock.

Most quartz veins are limited, centimetre thick seams, but in the Ouachita Mountains (Howard & Howard 2000) veins in shale have been reported that measure '... several hundred feet in outcrop length and 60 to 100 feet in thickness', whereas an occurrence in the pegmatites of the Norwegian Froland/Risør area (Neumann 1985, 221) was reported as being '... close to 1km in length and several hundred metres in width' [translated by the author].

At higher metamorphic grades, quartz not orientated properly to the pressure is dissolved and those grains with the right orientation grows (Howard & Howard 2000). The quartz 'augen', or eyes, of some gneisses form in this manner (eg Pellant 1992, 214). In gneiss, quartz actually separates into bands, which are seen as light-coloured bands alternating with darker bands of mafic minerals (Fichter 2000). Though some of these bands may occasionally develop into substantial veins, most veins in gneiss were probably formed by the solidification of hydrothermal fluids.

Sandstone was formed when sand, deposited by wind, water or ice, was compressed into rock. Quartz is generally the main component, but sandstone usually also contains small amounts of feldspar, mica or other minerals. Some sandstones may contain a silica cement, binding the grains firmly. This type of rock has poor flaking properties and is of little relevance to the present discussion. Quartzite, on the other hand, forms by the metamorphosis of sandstone, and some quartzites are dense and knappable. The processes involved are either contact metamorphism of sandstone near a large igneous intrusion, or regional metamorphism in mountain-building zones.

It may be difficult, in some cases impossible, to distinguish hand-samples of saccharoidal ('sugary') quartz from samples of lightly altered quartzite. Saccharoidal quartz and quartzite both appear in fine-, medium- and coarse-grained forms, and the two forms of raw material may have the same texture. The main difference in these cases is the origin of the two types of material, where saccharoidal quartz derives from hydrothermal veins, whereas quartzite was formed by the alteration of sandstone. In contrast to saccharoidal quartz and quartzite, milky quartz is not grainy, but massive.

The pebble quartz exploited by Scottish prehistoric people was procured from two main sources, namely i) beach deposits (mainly coastal sites, such as Dalmore; Ballin forthcoming g), and ii) river gravels (mainly non-coastal sites, such as inland sites in Aberdeenshire, in combination with erratics; Ballin forthcoming c). Pebble quartz and vein quartz do not represent two 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.

4.3 Quartz varieties encountered in Scottish lithic assemblages (geological classification of quartz)

As indicated above, quartz is found in a number of forms, most of which only differ by their varying colours or grain sizes. Smoky quartz, for example, is a dark variety of rock crystal, but it occurs rarely in Scottish archaeological assemblages, and only in small numbers (eg eight pieces out of a total of 315 lithic artefacts at Fordhouse Barrow in Angus; Ballin forthcoming f). In 2002, amateur archaeologist Jim Crawford showed the author a substantial vein of rose quartz on one of the small islands west of Lewis, but it was unworked and unassociated by lithic artefacts or waste. In the following presentation, only Scottish quartz types commonly recovered as parts of archaeological assemblages are dealt with.

Few people have attempted to construct an archaeologically relevant classification system, covering the different variants of macrocrystalline quartz. Apart from the quartz classification presented and followed in this volume, the author is only familiar with one other system (namely that of Jones forthcoming). The two systems differ in their premises, as the system favoured by the author is based entirely on colour and grain size (geological attributes), whereas the system presented by Jones is based on opacity and fracture surface texture (geological and technological attributes). The definition of a sample's fracture surface texture is based on the quality and character of its flake scars.

The two systems are both logical in their structure, but they emphasize, and sub-divide, different quartz types. Jones sub-divides the broad group of milky quartz into three sub-types, whereas the system promoted by the author sub-divides Jones' 'sugar-quartz' into two sub-types with different grain sizes. The two typologies probably emerged as the products of different geological environments (Scotland, and The South Atlantic Slope, running from southern Virginia to Georgia, USA) and they attempt to answer different geological and archaeological questions. This makes it difficult to favour one system over the other in general terms.

However, in the Scottish archaeological reality, with many assemblages being characterized by variations in the broad category of grainy quartz, the classification sytem presented in Table 16's left column is thought to be the most useful quartz classification. In general terms, this classification may be the most convenient system, as it is based on simple visual attributes, and it is applicable in the majority of geological as well as archaeological contexts, whereas that of Jones requires the presence of manufactured flakes with fresh dorsal and ventral faces. Yet, in the future, it probably should be considered to sub-divide the broad category of Scottish milky quartz.

Table 16 The quartz types applied in the present volume compared with the ones suggested by Jones (forthcoming)

	Present volume	Jones forthcoming
Increasing grain size ⇓	Rock crystal	1. Crystal
	Milky quartz	2. Ice
		3. Milk glass
		4. Irregular
	Very fine-grained ('greasy')	5. Frosty
	Fine-grained	6. Grainy/sugary
	Coarse-grained	
	Quartzite	(7.) Quartzite

In the presentation of his quartz classification, Jones states:

> Inevitably, when a well-intended system is devised to pigeon-hole objects or artefacts that are part of a continuum, a multitude of miscreants arise that defy all attempts to be classified. Try to envision each of the [...] six groups [in Table 16, right column] as a continuum within itself, with one grading into one or more of another. This system is not linear; that is, the first category doesn't grade neatly into the second, the second into the third, etc. Realize, too, that a single outcrop of quartz will often contain several types; a hand-sample or artefact may even contain two distinct types (Jones forthcoming).

This statement also applies to the classification put forward by the author (Table 16, left column).

4.3.1 Rock crystal

Rock crystal is defined as '... colourless and transparent crystals of quartz' (in Jensen 1973, 24, translated by the author), but in the present

Illus 39 Rock crystal. Microblade from southern Norway

context it is suggested to simply define rock crystal as colourless and transparent quartz (illus 39). Actual crystals are not unique to this quartz variety and commonly occur in, for example, milky quartz environments. Though occasionally found as crystals, most rock crystal is recovered from veins dominated by milky quartz (Howard & Howard 2000).

Many massive (ie not grainy) forms of quartz are mixtures of rock crystal and milky quartz, but rock crystal is also found as lenses in very fine-grained ('greasy') quartz (eg at Shieldaig, Wester Ross; Ballin *et al* forthcoming). Eleven per cent of the quartz sub-assemblage from Lealt Bay, Jura (Ballin 2001b), is transparent quartz (273 pieces of 2477), but the composition of this collection varies from artefact category to artefact category. Eleven per cent of the debitage, and 22% of the cores, are rock crystal, but only 6% of the tools are in this material. At Lussa River (Ballin 2002b), also on Jura, 146 artefacts in rock crystal were recovered, but as this quartz sub-assemblage is huge (11,228 pieces), transparent quartz only makes up 1.3%. At both sites, crystals of transparent quartz appears to have been collected, as evidenced by flakes and cores with remaining dorsal crystal facets. These crystals appear to have had lengths of approximately 2.5–4.5cm.

In general, the way this material was used in Scottish prehistory is somewhat puzzling. Rock crystal is a very homogeneous material with fine flaking properties, and the arrises between the crystal facets of the actual crystal prism (rather than those of the terminal pyramids) would have functioned well as six 'pre-fabricated' guide ridges. However, the main approach to rock crystal in Scottish prehistory is to reduce it by the application of bipolar technique, practically shattering the crystals and nodules. In the Mesolithic of southern Norway (eg Ballin 1998a, 40), crystals of transparent quartz was collected (along with the related smoky quartz; Ballin 1998a, 85) for the manufacture of exceedingly narrow regular microblades for insertion into slotted bone points (illus 39). At Lealt Bay (Ballin 2001b), and at neighbouring Lussa River (Ballin 2002b), only two rock crystal tools were made per site, and three of those are scrapers.

4.3.2 Milky quartz

Milky quartz is defined as massive translucent (not transparent) quartz (illus 40). It is the main component of most quartz-bearing rock types, and, like rock crystal, it is occasionally found in crystal form. In prehistory, however, most milky quartz was acquired from veins or pebble sources.

The flaking properties of this quartz variety varies considerably, which is the background to Jones' sub-division of the resource into three sub-categories (ice, milk glass, and irregular; see above). This variation is partly due to the fluctuating qualities of the quartz itself (such as, more or fewer inherent planes of weakness), but many quartzes are also marred by impurities, such as intersecting planes of mica, chlorite or micro-crystals. The colour varies, with milky white varieties dominating, but, as indicated by Jones' terminology, some quartzes have colours and lustres more like ice, and quartz with a blue hue is not uncommon. In some Norwegian granites, blue quartz is found as a rock-forming mineral (Neumann 1985, 221), and at Bayanne on Yell, Shetland (Ballin forthcoming j), the exploited vein material appears to have been white with a relatively dull lustre near the surfaces, whereas the inner (less oxidized?) parts of the quarried material consisted of bluish-white quartz with a more 'waxy' lustre.

Milky quartz is the most widespread quartz form exploited in Scottish prehistory, and it is found on archaeological sites throughout the country. In the two main quartz-using geological areas, Shetland and the Lewisian of the Scottish Mainland/the Western Isles, milky quartz may be the dominant variety, but many assemblages are based on the combined use of massive and saccharoidal quartzes, and assemblages without milky quartz also occur. Most of the erratic quartz nodules collected by prehistoric people in

Illus 40 Milky quartz. Scraper from Kilmelfort Cave, Argyll

Illus 41 'Greasy' quartz. Flakes and blades from Shieldaig, Wester Ross

inland Aberdeenshire (Ballin forthcoming c) appear to be in milky quartz, which may be a fact based on this massive quartz form being more weather and erosion resistant than saccharoidal quartzes.

4.3.3 Very fine-grained quartz or 'greasy' quartz

This type of quartz is so fine-grained that it is impossible to see the individual grains without the use of a microscope. The grainy character of this resource is primarily experienced as a slightly rough surface texture, and it is most likely the presence of almost microscopic grains which creates the 'greasy' lustre of the raw material by altering the way light is reflected from it (illus 41). This form of quartz is thought to correspond to Jones' 'frosty quartz', which he describes in the following fashion:

> Increasing graininess of Types 1 and 3 (this paper, Table 16, right column) may result in this type. Very homogeneous with relatively obvious flake scars and correspondingly even edge, this quartz has the appearance of frosted or sandblasted glass. Grades into Type 4 and 6. Usually clear, white buff, pale green, or pink (heat-altered), and almost always translucent (Jones forthcoming).

The author chose not to refer to this quartz variety as 'frosty quartz' as this may allow the raw material to be confused with naturally wind-blown quartz (below), which is best described as having a frosted appearance (eg Ballin forthcoming h).

On Lewis, so-called 'greasy' quartz was preferred for better pieces, such as, arrowheads. As demonstrated (in Ballin forthcoming a), the Calanais ritual complex, 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 into Lewis, 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, for example, pitchstone 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

Illus 42 Fine-grained quartz. Core from Scord of Brouster, Shetland

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; Clemmer 1990). This distribution and use pattern corresponds well with that of pitchstone, where pitchstone found general use on the source island of Arran, whereas it was used sparingly, and in a selective, probably symbolically laden manner, further afield.

4.3.4 Fine-grained quartz

Most saccharoidal quartzes belong to this category of visibly grainy material (illus 42). It is generally white, and, at present, the distinction between this form of quartz and the following coarser variety is subjective, in the sense that the defining grain-sizes have not been quantified *precisely*. However, fine-grained quartz usually have visible grains in the size order of fractions of a millimetre, and it is relatively compact, whereas coarse-grained quartz occasionally reaches grain-sizes of more than a millimetre, and it is comparatively loose-textured. Consequently, the two resources have considerably different flaking properties, with fine-grained quartz usually flaking well and coarse-grained quartz less well.

Some collections are entirely in this material (such as Barvas 2, Lewis: Ballin 2003a), but mostly fine-grained quartz is found as a component of assemblages dominated by either milky quartz (eg Scord of Brouster, Shetland: Ballin 2007a), very fine-grained quartz (eg Shieldaig, Wester Ross: Ballin *et al* forthcoming), or coarse-grained quartz (eg Dalmore, Lewis: Ballin forthcoming g).

Illus 43 Coarse-grained quartz. Flake from Dalmore, Lewis

4.3.5 Coarse-grained quartz

At present, only one Scottish assemblage is known to be dominated by coarse-grained quartz (illus 43), namely Dalmore on Lewis (Ballin forthcoming g). Due to the poorer flaking-properties, and the fact that the large grain-sizes would not allow the production of 'proper' cutting implements (at Dalmore, a tool, which would have been a knife if manufactured in, for example, the fine-grained material of other quartz-bearing sites, would automatically become a saw), supplementary quartz forms (such as 'greasy' quartz) had to be imported into the site for the manufacture of finer tools.

The assemblage from Cruester on Bressay, Shetland (Ballin forthcoming e) included some coarse-grained quartz, in conjunction with the more numerous variants, milky quartz and fine-grained quartz. However, this type of quartz is exceedingly dense, unlike the Dalmore variant. With its steel-grey to purple colours, it is quite likely that the coarse-grained Cruester variant is actually a form of quartzite, not dissimilar to the material capping the Fordhouse Barrow in Angus (Ballin forthcoming f). As stated above, the main difference between the grainy forms of the mineral quartz and the metamorphic rock type quartzite is not so much appearance as geological formation.

4.3.6 Quartzite

No known Scottish assemblages are dominated by this resource (illus 44), and quartzite is mainly

Illus 44 Quartzite. Part of a raw nodule from Glentaggart, South Lanarkshire

recovered as individual flakes, hammerstones and anvils (cf the various Jura sites, eg Mercer 1980; also Claish by Stirling, Barclay *et al* 2002, 88). Only one assemblage includes substantial numbers of flaked quartzite, namely that of Fordhouse Barrow in Angus (Ballin forthcoming f), where it dominates the finds from the upper layers (49% quartzite, 43% flint and 8% other raw materials). In this case, the quartzite seems to have been scavenged by Later Bronze Age people from the Early Bronze Age capping of the Neolithic barrow, and in terms of formation the sub-assemblage may be compared to other post-mound assemblages from the later part of the Bronze Age (cf Ballin 2002a).

Most likely, this metamorphic raw material was acquired in the vicinity of the site, deposited in the mainly sedimentary Montrose area by either Lower Devonian streams (Cameron & Stephenson 1985, 18–21) or more recent glacial activity. The quartzite is relatively homogenous and dense, with few impurities, and it flakes relatively well, its considerable grain-size taken into consideration. Some pieces are grey, but many are in nuances of red, brown or purple.

4.4 Forms of 'altered' quartz

As a complement to the above geological quartz varieties, many Scottish assemblages include less easily identified quartz forms. These are frequently 'altered' types of the raw material, and they may have been altered either by natural agents (eg water or wind) or anthropogenically (eg exposure to fire).

4.4.1 Water-rolled quartz

Few water-rolled quartz objects have been encountered on Scottish sites, but this is probably more a case of such pieces being more difficult to identify than, for example, rolled flint objects. It is a well-known fact that fresh quartz artefacts are more difficult to recognize than fresh flint artefacts, and when worked quartz is abraded, for example after years in an active tidal zone, they rapidly acquire seemingly natural shapes.

This is probably the reason why the Mesolithic assemblages from Lussa River (which was transgressed in prehistoric times) and Lussa Bay (which represents a find location in an active tidal zone), both from Jura, differ in terms of quartz content. Where the lithic finds from Lussa River (Mercer 1971; Ballin 2002b) included *c* 33.7kg of quartz (an approximate quartz:flint ratio of 8:1), Lussa Bay did not include any quartz (Mercer 1970), though more than 4000 pieces of flint were found. All Mercer's other prehistoric assemblages from Jura contain some quartz (Mercer 1968; Mercer 1972; Mercer 1974; Mercer 1980). Another important detail is the fact that, though Mercer reports the recovery of many rolled flint objects from the quartz-bearing Lussa River settlement, he does not mention the recovery of any rolled quartz objects with a word. The different raw material composition of the two sites may simply be based on varying degrees of natural rolling of the artefacts, with the finds from Lussa Bay in the present tidal zone of Jura being more severely rolled than the finds from Lussa River, thus masking the worked character of these pieces.

4.4.2 Wind-blown quartz

Wind-blown ('sand-blasted') quartz occurs in two forms, namely (i) quartz nodules shaped by wind prior to collection by people, and (ii) quartz artefacts affected by wind after deposition. These two forms of altered quartz are represented by the finds from the St Fergus to Aberdeen Natural Gas Pipeline, Aberdeenshire (Ballin forthcoming c), and Rosinish on Benbecula (Ballin forthcoming h). Both types are characterized by a slightly frosted appearance and, though abraded, wind-blown pieces tend to be slightly more angular than pieces abraded by water action (illus 45).

The wind-blown artefacts from the inland sites along the Aberdeenshire pipeline probably represent reduced and modified erratic blocks, collected by later prehistoric people. The wind-blown pieces from Rosinish, on the other hand, were clearly 'sand-blasted' after their having been transformed into artefacts. They were recovered from a Beaker site in the Benbecula machair, and the site's general distribution pattern suggests some influence from natural forces. A basic distribution analysis showed that most of the artefacts are concentrated in three south-west/north-east orientated bands ('ridges') with find-poor bands ('valleys') separating them. The 'valleys' and 'ridges' run perpendicular to the main blow-out (Shepherd & Tuckwell 1977b, fig 1), and it is possible that these distributional features

Illus 45 Wind-blown erratic quartz from various sites in Aberdeenshire

owe their existence mainly to wind-erosion/dune-building, which may also have altered the surfaces of the worked quartz.

4.4.3 Burnt and heat-treated quartz

It is a well-known fact that flint, when exposed to fire, undergoes a number of distinct changes. Depending mainly on distance to the heat source and duration of the exposure, flint artefacts may change colour, lustre and weight, and they will, ultimately, crackle and disintegrate (Fischer *et al* 1979, 23). These alterations are used by lithics analysts to interpret assemblages and sites, and burnt flint has, *inter alia*, been used to suggest the presence of otherwise invisible hearths (Ballin forthcoming j), site maintenance (dumping of hearth material; Ballin & Lass Jensen 1995, 55), the destruction of prehistoric dwellings by fire (Fischer *et al* 1979, 22) and heat-treatment of flint nodules and blanks (Price *et al* 1982). As a consequence, the recording of burnt flint has become a standard part of post-excavation processing of flint assemblages. In contrast, burnt quartz (illus 46) is rarely recognized, reported, described or discussed and, as a result, analyses of quartz assemblages appear less fruitful.

However, a combination of experimentation and analysis of prehistoric assemblages suggests that burnt quartz *is* recognisable, although it may be more difficult to identify than burnt flint (Ballin forthcoming k). Two forms of burnt quartz were identified:

Illus 46 Burnt and unburnt bipolar cores from Rosinish, Benbecula

- The inspection of prehistoric quartz assemblages revealed that a large proportion of the quartz from post-Mesolithic sites has a yellow-brown colour. This material is generally characterized by pitted or 'peeled-off' surfaces (although not generally in a state of disintegration), and it has a sheen usually associated with heat-treated silica. In most cases, the on-site distribution of the yellow-brown objects was non-random (eg at Calanais, Dalmore and Rosinish) supporting the interpretation of this quartz form having been 'altered' in some way, probably burnt.
- Inspired by these observations, the author undertook a series of trials. The experimental burning of quartz showed that most quartz, when exposed to fire, undergoes the same basic alterations as flint, and the experimentally burnt quartz was generally characterized by (i) pitting and 'peeled-off' surfaces, (ii) a dull and opaque appearance (where fresh quartz tends to be clear and vitreous), (iii) various degrees of 'granulation' and disintegration, and (iv) occasional areas with either a reddish or a pink hue. This form has been identified in most quartz assemblages.

The tests managed to elucidate some of the distribution patterns (for details, see the individual archive reports or publications), whereas other observations remain unexplained, such as the extremely high burnt quartz ratios of some assemblages (Table 17).

Table 17 The burnt quartz ratio of a number of assemblages from the northern and western parts of Scotland

Assemblage	Period	%
Cruester, Shetland	LBA	65
Dalmore (Sharples), Lewis	EBA	53
Scord of Brouster, Shetland	EN/LN	41
Rosinish, Benbecula	EBA	38
Calanais, Lewis	LN/EBA	34
Burland, Shetland	EIA	22

As the yellow-brown pieces of quartz seems to be mainly associated with later prehistoric sites from the Northern and Western Isles, and not the Mesolithic sites of the western mainland and the Southern Hebrides, the author assumed that the burning of peat, particularly characteristic in Scottish later prehistory, might have caused the differences in appearance. It has not been possible to reproduce experimentally the yellow-brown colour of burnt quartz from the Northern or Western Isles, but the author believes this discolouration to be the result of either the accidental burning of quartz in peat fires, or the deposition of the burnt pieces in a peaty environment (eg in peat ash deposited in domestic middens). As the experimental burning of quartz in a peat fire did not produce the anticipated colours, the author expects the discolouration to probably be the combined result of (1) weakly developed 'granulation' due to the exposure of heat/fire, making the quartz slightly more porous, (2) deposition in iron-rich peat or peat ash and (3) time.

Heat-treatment of quartz is a hotly disputed subject (Flennikin 1981, 27, disputes the usefulness of heat-treating quartz, whereas Knight 1991, 44, suggests that, although heat treatment may not alter the quartz itself, the heat possibly alters minerals within it, thereby improving the working characteristics of the quartz), and at present the author is not aware of any Scottish or non-Scottish assemblages where this form of reduction was generally used. However, at Scord of Brouster (Ballin 2007a), one potentially heat-treated bifacial implement was identified. Curved knife CAT 2299 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. This suggests that some quartz blanks may have been subjected to heat-treatment. Experiments (Crabtree & Gould 1970, 194; Eriksen 1999) have shown that flakes from heat-treated silica nodules tend to become thinner than flakes from raw nodules, and it is possible that, at Scord of Brouster, blanks were heat-treated mainly as part of the production of bifacial implements (thinning). The fact that, at this location, many implements (eg many scrapers) had been burnt after their modification into tools indicates that heat treatment is not the main cause of the high burnt-quartz ratio of this assemblage (Table 17).