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***Session 3*. The Socio-Economic Implications of Non-Flint Raw Material Use**

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PRÉFACE

As a result of a small workshop on lithic technology held at the Department of Archaeology, University College Cork in 2002 organised by Professor Peter Woodman, we realised that we were working on projects at the time that involved the lithic analysis of a wide range of lithic raw materials (Laurent J. Costa had just completed his PhD on Tyrrhennian Mesolithic assemblages; Lotte Eigeland and Sven Erik Grydeland were carrying out research on Norwegian Mesolithic assemblages and Farina Sternke was working on the German Quartzite Palaeolithic). While these assemblages are spatially and chronologically separated, we encountered similar problems during their analysis, in particular with regards to the technological and typological descriptions of the respective lithic raw materials which happened to be almost exclusively non-flint raw materials. It is widely accepted that the known technologies and typologies based on flint cannot be directly projected onto non-flint assemblages. Unfortunately, previous research on specific non-flint raw materials was scarce, particularly in Europe (with a few exceptions in the UK, the Iberian Peninsula and Northern Scandinavia), while the African, Asian and Australian assemblages offered little comparison in terms of their technological and typological descriptions. As a result of this, each one of us adopted his/her own Do-it-yourself approach which included experimental replication to recognise and describe the different technological traits of the raw materials. As will be seen from the many similar approaches in this volume, experimental archaeology in its various forms has firmly taken centre stage in non-flint raw material research.

Upon the conclusion of our respective research projects, we decided that it would be of benefit to organise a meeting of like-minded researchers to assess and reflect upon the current progress of non-flint raw material research worldwide and to facilitate the exchange of information among those involved. Ultimately, the aim of this colloquium was to promote research into non-flint raw materials through the rejection of old prejudices and a propagation of new directions.

The 25 papers (63 authors from 4 continents and 16 countries) collated in this volume include most of the papers and posters presented at the colloquium C77 *The Use of Non-Flint Raw Materials in Prehistory – Old Prejudices and New Directions* at the XV. Congress of the International Union of Pre- and Protohistoric Sciences in Lisbon, Portugal, on 4th and 9th September 2006. The colloquium was divided into three different sessions, *Terminology and Methodology in Non-Flint Raw Material Studies*, *Non-Flint Raw Materials in Experimental Archaeology and Use Wear Studies* and *The Socio-Economic Implications of Non-Flint Raw Material Use*, which reflected the different interests of the organisers and discussed different sets of problems. Given the diversity of approaches to the study of non-flint raw materials, it is not surprising that some elements of the sessions overlap. This is also reflected in the individual contributions.

The different papers reflect various stages of research in their respective fields of investigation and archaeological periods in several regions of the world. Unsurprisingly, European contributions are the most numerous within this volume. Nevertheless, we believe that this volume can be regarded as an accurate reflection of current non-flint raw material studies.

Regarding the geographical distribution of non-flint raw material research, the contributions from North and South America as well as India are not entirely unexpected, since flint is absent or rather scarce in these regions. In Europe, non-flint raw material studies are more abundant in Northern Scandinavia and the Mediterranean region for similar reasons. With regards to the latter, we also accepted contributions which focused on obsidian, as we felt that research into this raw material, while having received more attention than other non-flint raw materials, will contribute to the overall field of non-flint raw material research.

It is clearly noticeable that archaeological research in Central and Western European countries, whose prehistoric records are commonly associated with the use of flint, increasingly focuses on non-flint raw materials, e.g. quartzites in Belgium, Germany and the Czech Republic, quartzite and other coarse-grained materials in France, rhyolites, Green Stones and Black Stones in Ireland and Green Stones and Black Stones Switzerland and obsidians in Poland. However, research areas commonly associated with the distribution of Baltic flint, such as Southern Sweden, Northern Germany, the Netherlands and Denmark (with the exception of Greenland), remain under-represented. This is despite the fact that non-flint raw materials were used throughout their respective prehistoric periods, in particular for the production and use of axes and other macro tools.

Regarding their chronological distribution, the articles present assemblages from the Middle Palaeolithic through to the Classical Mayan period and in two cases (Prous *et al.* and Prous *et al.*), even to the present.

The raw materials discussed include obsidian, rhyolite, sandstone, gabbro, quartzite, Yellow Silicified Wood, Black Stone, quartz, chert and many more.

The articles in this volume are grouped into three separate sections in accordance with the themed sessions of the colloquium. We accepted contributions in both, English and French. The articles are preceded by a short introduction by their respective session chairs.

It is important to remember that the contents of this volume reflect the current research progress within each individual country which can differ significantly depending on the research histories as well as the different technological and typological traditions followed.

We would like to thank the U.I.S.P.P. and the organisers of the Congress in Lisbon, who provided a venue for the colloquium and facilitated the publication of this volume. Finally, we thank all the participants and authors for their contributions and support.

The Editors

THE SCAR IDENTIFICATION OF LITHIC QUARTZ INDUSTRIES

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***Abstract**: Quartz is one of the main raw materials used by prehistoric communities from the Lower Palaeolithic to the Holocene. There have been difficulties in developing a proper technological analysis on this material proved difficult due to low morphological standardisation of the products, predominantly caused by the application of analytical criteria commonly used for flint (i.e. ringcracks, ripple marks and bulbs). Furthermore in classical typological studies, quartz is usually considered as a secondary lithic source and linked to opportunistic and simplistic knapping strategies. An experimental approach and archaeological comparison facilitates the identification of several types of knapping scars on quartz blanks. These can identify the impact points of the hammerstones and removal direction, allowing a correct technical analysis. In addition, the scars (radial fissures and fractures) are closely related to the petrological characteristics of quartz, its formation processes, morphostructural varieties and flaking mechanics. The technological analysis of quartz along these criteria has permitted the identification of different reduction strategies, showing a greater variability and complexity in the management of this type of lithic raw material.*
***Keywords**: Quartz, technical analysis, scars, raw materials*

***Résumé**: Le quartz est l'une des principales matières premières utilisées par les communautés préhistoriques depuis le Paléolithique Inférieur jusqu'à l'Holocène. Toutefois, les difficultés inhérentes à la perception des stigmates de taille sur les produits détachés de cette roche ont empêché l'étude approfondie de ces industries. L'application des critères de lecture du silex (identification de cônes, d'ondes de percussion, de bulbes, etc.) et les études typologiques ont fait que les industries du quartz sont traditionnellement considérées comme un recours lithique secondaire, preuve de stratégies opportunistes et peu élaborées. Par le biais d'une approche expérimentale et par la comparaison de matériaux archéologiques, nous avons pu identifier plusieurs stigmates de taille sur des supports en quartz. Ces stigmates permettent de discerner les points d'impact du percuteur et le sens du débitage des éclats et assurent une lecture technique correcte. Ces stigmates (fissures radiales, écrasement, etc.) sont directement liés aux caractéristiques pétrologiques, aux processus de formation, aux variétés morpho-structurelles ainsi qu'à la mécanique de fracturation du quartz. La lecture technique des quartz par l'identification de ces stigmates a permis de mettre en évidence différentes stratégies d'exploitation de ce matériau, démontrant ainsi une plus grande variabilité et une complexité dans leur gestion.*
***Mots clés**: Quartz, analysis technique, traces de percussion, matières premières*

INTRODUCTION

Quartz is traditionally considered to be a secondary raw material resource, because of its inferior knapping quality. Due to its high resistance to weathering, it is one of the most ubiquitous raw materials. This explains its high frequency on many Palaeolithic sites, but it is usually linked to expedient knapping strategies. In spite of its abundance, few technological and experimental studies on quartz have been carried out to-date. The petrological characteristics of quartz and the low standardisation of its products do not permit an easy technological reading. This situation is caused by the extrapolation of the technological criteria associated with other raw materials (e.g. quartz, basalt and quartzite) and the use of exclusively typological and morphological approaches to the classification of lithic industries. The low standardisation of quartz products prevents archaeologists from classifying and even recognising them as man-made tools in the typological sense.

Hence, few extensive and systematic studies have been carried out on quartz industries. Experimental and technological approaches are critical for an understanding of its behaviour and knapping characteristics. Subsequently, these data can then be compared to the archaeological record (Mourre 1996; Villar 1991a). The first step is to develop a correct technological reading of objects made on quartz to understand the technological and economic behaviour of the prehistoric communities who used them.

PETROLOGICAL CHARACTERISATION

Quartz is a mineral of the techtosilicate group (SIO_2). It is one of Earth's most frequent minerals and a component of sedimentary, metamorphic and intrusive rocks (e.g. sandstone, quartzite, granite). Its crystallisation can occur during all stages of magmatic cooling and metamorphic processes (Luedtke 1992).

Quartz is traditionally considered to be a homogeneous raw material, classified following its external aspect, colour and opacity. Two main types can be observed: hyaline and milky quartz (or vein quartz). This classification does not take the petrological characteristics into account; neither does it distinguish the different knapping qualities of the raw material. Thus, some white *sacaroid* or grainy quartz can be placed in the same category as the macrocrystalline type, whose mechanical behaviour is quite different. Due to this homogeneity, technological selection criteria and economic implications cannot be applied (de Lombera 2005; Llana 1991). For that reason, other authors prefer to adapt the geological and petrological classifications based on the formation processes of quartz (Mourre 1996). Two types of quartz are defined:

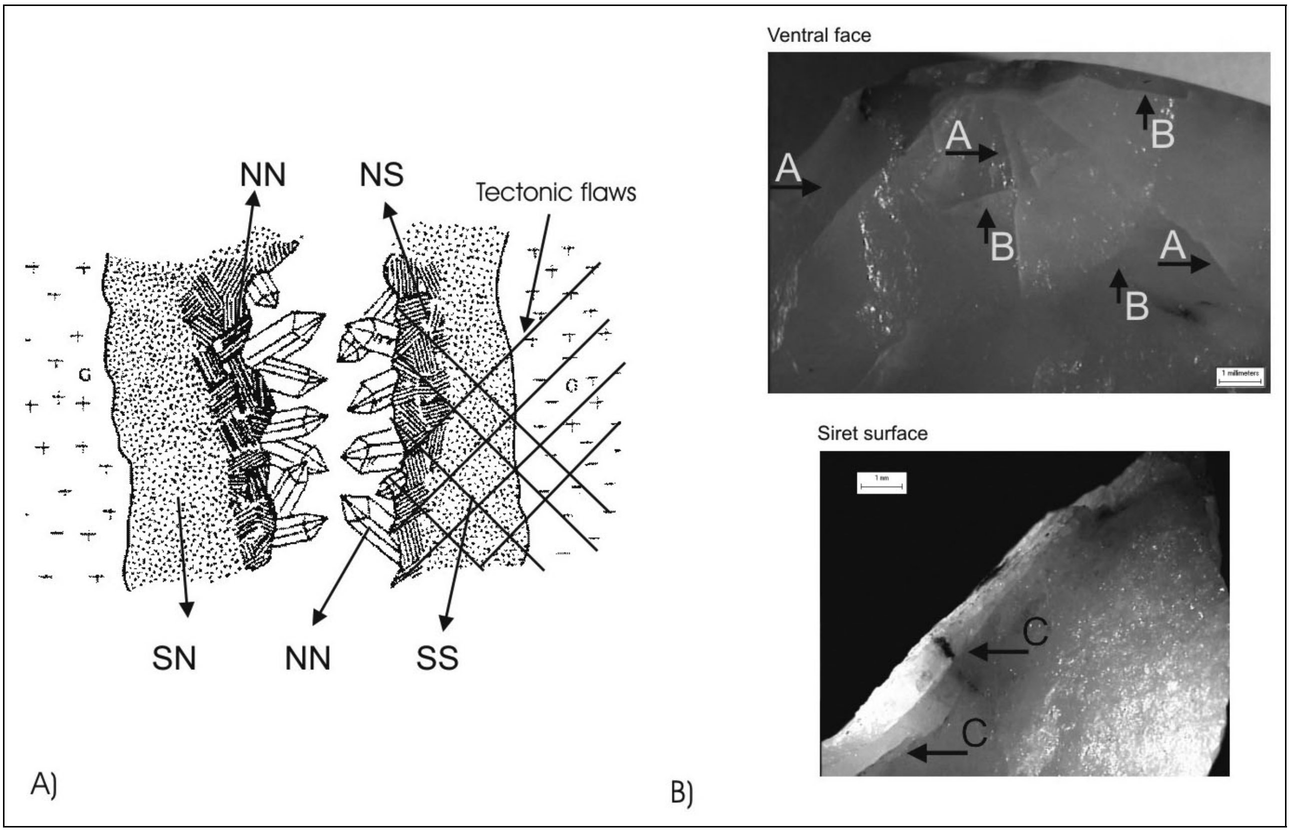


Fig. 1.1. A) Vein quartz formation and morphostructural groups (Collina-Girard 1997); B). The Hertzian model as observed in quartz. A: Radial fissures; B: Concentric fissures; C: Subsurface and parallel fissures

Automorphic quartz – when quartz displays its crystal structure, crystal faces can be identified. This is traditionally called *hyaline* or *translucent* quartz. It occurs in specific geological contexts such as hydrothermal and magmatic contexts. The different types of hyaline quartz (e.g. smoky) are produced by internal gas and liquid inclusions. The presence of crystallization cores, constant environmental conditions, a great span of time and space are required for its formation (Luedtke 1992).

Xenomorphic quartz – formed through the aggregation of several microcrystals, but macroscopically, has a solid structure. It presents an important polymorphy due to the crystal dimensions. This difference in crystal size is due to divergences in temperature, space, growing rates and core density during its formation (Luedtke 1992).

Differences in cooling rates, temperature and core density can occur in the same primary vein formation, therefore, different kinds of quartz textures can be observed. Usually in the outer part of a quartz vein, many small and microcrystals are produced at low temperatures (350º-400º C), with higher cooling rates and a higher presence of cores (rock impurities), thereby, creating a grainy texture. Conversely in the inner part of the vein, where the cooling rates are slower, larger crystals are produced (macrocrystalline texture or hyaline crystals). Therefore, a number of textures can be observed in the same quartz vein, or even in cobbles, and their mechanical properties differ considerably (Collina-Girard 1997). At the same time during formation, the tectonic forces can produce many internal flaws along with accidental breakages. Some authors (Martínez and Llana 1996) distinguish four morphostructural groups of quartz based on the presence/absence of these morphostructural variables (texture and internal flaws) (Fig. 1.1a):

Grain (G) – distinguishes grainy quartz (xenomorphic) from macrocrystalline quartz (automorphic). The first group can be subdivided into fine-grain or coarse-grain quartz.

Plane (P) – is applied to quartz with internal flaws or crystalline surfaces.

Following from this, quartz artefacts are placed into four morphostructural groups: NN (no grain, no plane), NS (No grain, plane), SN (grainy, no plane) and SS (grainy, plane). This morphostructural classification related to its formation and mechanical properties permits the recognition of the applied technological or economic criteria on the selection of quartz artefacts in accordance with the prevalent social needs of prehistoric communities (de Lombera 2005; Llana 1991; Seong 2004).

MECHANICAL PROPERTIES

Formation processes and the petrological nature of quartz determine its mechanical properties. Firstly, quartz is not a homogeneous raw material due to the presence of internal flaws and crystalline surfaces which cause unintentional breakage. Only the upper part of large quartz crystals (apices) can be regarded as homogenous. Quartz possesses conchoidal as well as uneven fracture characteristics and its strength is identical to flint (7 in Mohs scale). Hence, the resistance of quartz cutting edges is similar to flint, but its low elasticity leads to premature edge breakage and rounding, although this implies an unintentional small degree of resharpening of the cutting edges which actually prolong its efficiency (Bracco and Morel 1998). Quartz anisotropy depends on the crystalline structure and its orientation, as was suggested by Novikov and Radililovsky (1990):

Cleavage: Due to the crystalline structure debilities, oblique directions are the preferential breaking planes on quartz crystals. They are observable in some laminar hyaline cores on Upper Palaeolithic and Mesolithic sites (Villar 1997) and as a result of breakage during natural fires (Ramil and Ramil, 1996).

Diaclases: Internal flaws are caused, for example, by internal impurities, gas-liquid inclusions and tectonic forces. This factor is related to the material homogeneity rather than anisotropy *sensu stricto*.

The cleavage planes in quartz are not as developed as in schist and do not affect the knapping methods to a great extent, although they induce a preferential breaking direction (as seen in laminar reduction) and interfere with the Hertzian fracture mode (Novikov and Radililovsky 1990). Therefore, internal flaws and homogeneity are the dominant limiting factors in quartz knapping. Even the reduction of hyaline crystals is restricted to the apex part, thereby, avoiding the flawed and impure roots. On macrocrystalline quartz (NN and NS), cleavage may be due to the absence of typical Hertzian scars (bulbs, ripple marks), but on grainy quartz (SN and SS), the anisotropy cannot be explained in such a way. Firstly in grainy quartz (as in sandstone), the breakage plane does not pass through the crystals, but follows its surfaces, consequently, crystal anisotropic characteristics do no affect the breakage plane (Andrefsky 1998). Following from this, grainy quartz may develop some typical characteristics of Hertzian fracture such as bulbs (*isotropie de compensation*) (Mourre 1996). Secondly, the grainy texture can absorb the strength of the percussion force more efficiently, increasing its elasticity. In that sense, internal flaws or diaclases can be avoided, producing less broken flakes and fragments and providing a better reduction control during knapping sequences. Hence besides homogeneity and the presence of internal flaws (Plane), morphostructural characteristics (Grain) must be taken into account. Thus, the morphostructural groups are seen as a reliable method to classify different quartz varieties.

PERCUSSION MARKS: A TECHNOLOGICAL SIGNATURE ON QUARTZ

The absence of a correct technological reading of quartz blanks prevents good technological studies of archaeological assemblages, since reduction and configuration strategies cannot be identified in a reliable way. An experimental study was carried out to determine and identify percussion marks on quartz blanks. For this experimentation program, fifteen vein quartz cores were reduced by hard hammer percussion and 308 flakes were analysed. The observed criteria were applied in an analysis of the quartz lithic assemblage of two Iberian Middle Pleistocene sites, Locus I from As Gándaras de Budiño, Galicia (n=380) (Vidal 1982) and La Juería, Catalunya (n=339) (Gómez *et al.* 2006), to confirm them and to measure their reliability against the archaeological record. Impact points were identified on 80 and 85 percent of archaeological quartz implements, respectively (de Lombera 2005). The statistical data from Locus I appear to be more representative in this study due to its greater variability of quartz morphostructural groups.

The technological criteria, such as bulbs, ripple marks, bulb scars and Hertzian cones, used in archaeological research are based on the conchoidal fracture of flint, allowing for the identification of impact points, ventral faces, retouch, the direction of removals and diachrony, so that diacritic schemata can be described (Cotterell and Kamminga 1987). The first distinction is made between detached pieces (positive bases) and flaked pieces (negative bases). Due to the petrology of quartz, the application of these flint criteria for scar identification can be misleading (Mourre 1996; Villar 1991a). Commonly, straight and smooth faces are considered to be the ventral sides on quartz implements. In the case of two smooth faces, the presence of cortex is used to identify the dorsal face. Finally, the thickest part of the implement is considered to be the striking platform and the thinnest the distal end (Villar 1991b). However, these criteria are not reliable, because they can change the technological orientation and interpretation and some knapping techniques cannot be identified (such as bipolar reduction). The technological reading of cores is based on the presence of cortex or cleaner surfaces and negative scars. The removal direction is more problematic, as no ripple marks and ridges are marked, therefore, diacritic schemes are difficult to describe. Only when removals are deep and step or hinge terminations occur, the removal direction can be easily identified. During the experimentation on quartz, impact points were observed on negative and positive knapping surfaces. Some of these were already identified in previously, but were generally disregarded (e.g. Mourre 1996; Villar 1991a).

Quartz mechanical breakage follows the Hertzian model, although it is not as pronounced as in flint. Similar to siliceous rocks, the percussion force spreads three–dimensionally through the object. Contrary to flint however, a distinct Hertzian cone is not created, but the

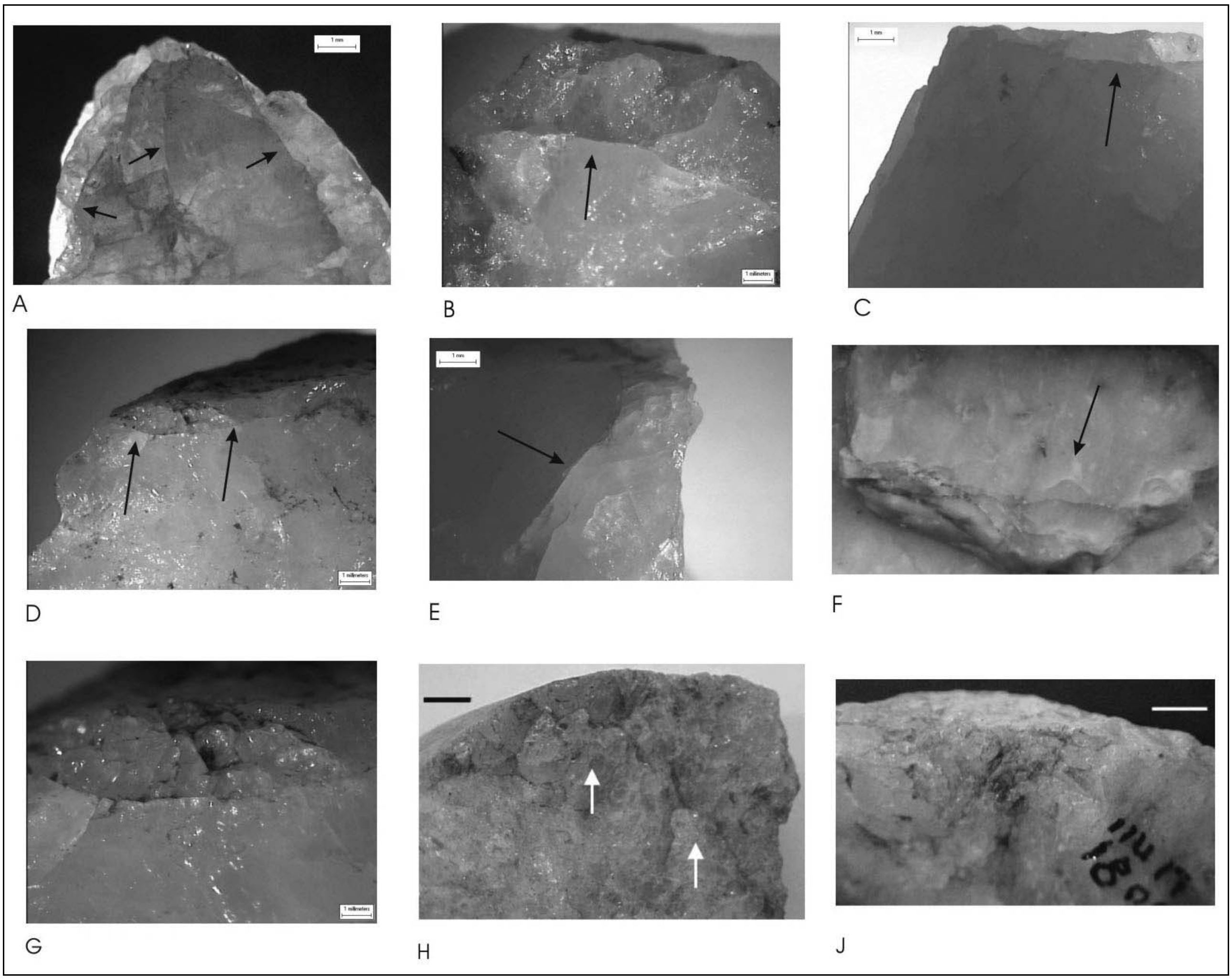


Fig. 1.2. Percussion marks. A: Radial fissures; B: Step; C and D: Transverse fissures; E and F: Striking platform fissures; G: Splintering; H: Scales; J: Edge battering. Figures D and G show material from the archaeological site of La Juería; H and J from *Locus* I de As Gándaras de Budiño (de Lombera 2005). Figures H and J scale = 5 mm

force manifests itself in three-dimensional internal flaws in the tangential and perpendicular planes (Fig. 1.1b). This is the cause of frequent *siret* fractures. The internal flaws can determine posterior removals, which can cause new breakage paths and knapping mistakes (*notion de précontrainte*) (Mourre 1996). However, the observed three-dimensional flaw planes are also present on percussion marks. As a consequence of this propagation force model, several isolated or related scars or percussion marks can be recognised on the negative and ventral faces (Fig. 1.2):

1. Radial Fissures (FIS): These are the result of the radial propagation of the impact force. Their length can be measured in millimetres or even centimetres depending on the percussion angle, strength and quartz morphostructure. They can also be recorded on the lateral surfaces of *siret* fractures which create lateral hinges.
2. Proximal Fissures (Fpr): These are transverse and subsurface fractures which occur close to the impact point. They are the result of the fracture mechanics and low elasticity of quartz and cause proximal step fractures.
3. Striking Platform Fissures (Fct): These are concentric and radial fissures which are located beside the percussion point and are caused by partial Hertzian cone cracks created during hard hammer percussion. They appear on the striking platforms of the flakes and core cornices. On core cornices, they can relate to small concavities on the edge (negative Hertzian cones), also called the overhang.
4. Steps (ESC): These are caused by the low elasticity and breakage propagation model of quartz. The impact point leading to a small removal will leave a small scar behind.
5. Splintering (AST): This is the result of several radial and proximal fissures and which are usually shorter than 2 mm. Splintering is observed in macrocrystalline quartz (NN, NS) and is the result of hammerstone impacts.

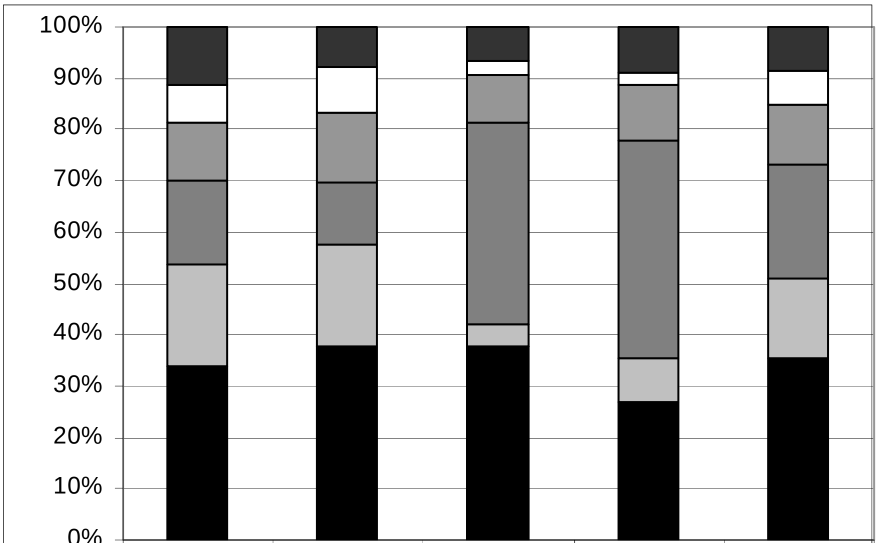
6. Edge battering (MCH): On grainy quartz (SN and SS morphostructural groups), percussion points result in a whitish area which is caused by microstriae, quartz dust and partial Hertzian cones formed during the percussion and hammerstone impact. These partial Hertzian cones can be distinct or more diffuse based on the quartz morphostructure, therefore, edge battering is only shown as a whitish area in some varieties of grainy quartz. However, postdepositional effects and weathering can lead to the creation and possible misidentification of edge battering.

7. Scales (ESC): These are micro-flakes which form on ventral and scar surfaces. Breakage surfaces on quartz are not homogeneous, especially on grainy pieces, and internal flaws, gas or liquid inclusions and even crystal shapes create small secondary flaking paths parallel to the main fracture. When these are developed, they can create bulb scars or secondary micro-flaking, if incipient, they form scales which point to the percussion point. Ventral and negative scar surfaces can display many natural microfractures which can also be created by previous removals and are mixed with genuine scales. Hence, scales cannot be used as reliable diagnostic criteria, although they may be regarded as indicative of knapped surfaces.

DISCUSSION

A clear relationship exists between the aforementioned percussion marks and the morphostructure of quartz. Although these scars are present in all quartz types, the inherent morphostructure determines the appearance and association of some of them. As was shown previously, vein formation processes affect the characteristics of quartz, for example, the degree of grain compactness, internal flaws and thermal impact. As a result of this, a certain degree of variability in the scar formation in different varieties of vein quartz can be observed, but these varieties also share the same traits.

The main association occurs between edge battering and SS, as well as SN morphostructural groups, while splintering is related to NN and NS groups (Figure 1.3). Contrary to NN and SN ones, the presence of internal flaws acts as a cumulative factor that increases edge battering on NS and SS groups. The inverse relationship between splintering and edge battering suggests that they are different examples of the same phenomenon which is closely related to morphostructural characteristics. As shown previously, edge battering is produced by percussion impacts of the hammer on the surface of the



	NN	NS	SN	SS	Media
Fct	11,25	7,78	6,7	8,89	8,46
Fpr	7,5	8,98	2,70	2,22	6,56
ESC	11,23	13,77	9,46	11,11	12,02
MCH	16,25	11,98	39,19	42,22	22,13
AST	20	19,76	4,05	8,89	15,30
FIS	33,75	37,72	37,84	26,67	35,52

Fig. 1.3. Morphostructural groups and percussion marks on quartz from the archaeological site of Locus I de As Gándaras de Budiño, N= 380 (de Lombera 2005)

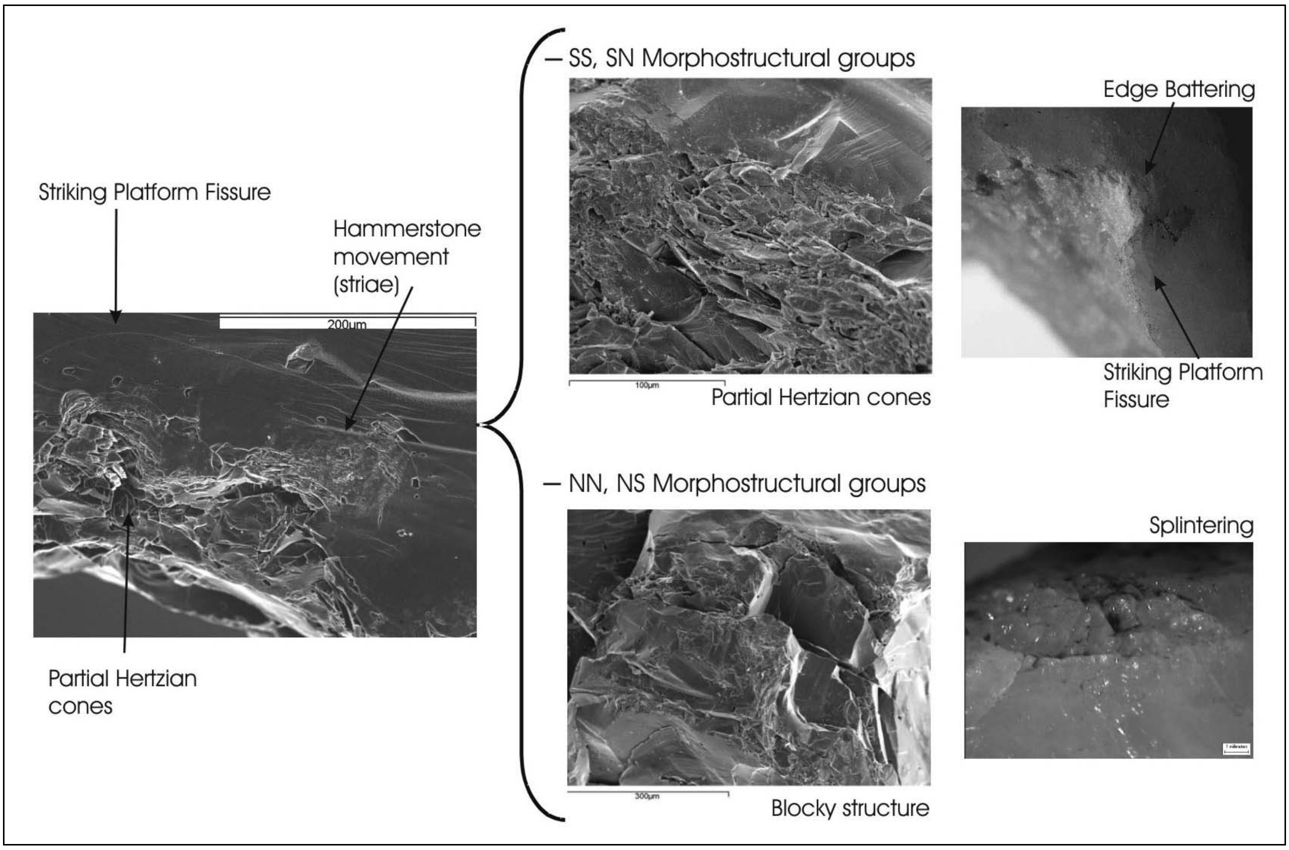


Fig. 1.4. The relationship of fracture mechanics and quartz morphostructure with percussion marks

striking platform, creating partial Hertzian cones (Fig. 1.2j and 1.4). On macrocrystalline quartz (NN and NS), successive radial and transversal fissures occur (splintering) due to its low elasticity, forming a blocky structure around the impact point (Fig. 1.2g and 1.4). Both are partial Hertzian cones manifested in different ways. Regarding the other percussion marks, radial fissures are represented in high percentages in all groups (about 35 to 40 percent). Proximal fissures are related to NN and NS groups, while steps and striking platform fissures, although less constant, are closer to macrocrystalline quartz varieties, especially to those with internal flaws (NS).

Scar formation is closely linked to percussion mechanics and the petrological characteristics of quartz. Proximal and radial fissures, as well as steps are caused by an insufficient elastic response to the percussion and breakage propagation model. This group, although present in all quartz types, is related to macrocrystalline quartz, showing lower percentages in SN and SS groups. This appears to be the result of the grainy texture which absorbs the percussion force more sufficiently, increasing its elasticity and provoking fewer fissures or cracks and roughly following the conchoidal fracture model (*isotropie de compensation*) (Mourre 1996). Similar to these percussion marks, microwear traces on quartz reflect these petrological characteristics: the poor response of quartz to high pressure provokes the formation of subsurface damage and a high degree of edge fracturing rather than abrasive processes (Derndarsky and Ocklind 2001; Knutsson 1988).

The other scar group is related to hammerstone impact during percussion. Proximal fractures and partial Hertzian cones are produced on the striking platform. One of these parallel cracks will dominate and form the flake breakage plane, while the others create secondary breakage planes leading to micro-flaking which can manifest itself as a small cascade of proximal step scars (Cotterel and Kamminga 1987: 687). On positive fractures, i.e. flakes, a small concavity on the impact point is formed instead of a bulb. This can be observed when the flake is refitted to its scar. Here, the morphostructure plays an important role. On grainy quartz, these scars are related to edge battering, while they are related to splintering and blocky structures on macrocrystalline quartz (Fig. 1.4). Scales are formed when incipient micro-flakes and secondary breakage planes are produced on ventral surfaces.

CONCLUSION

The low elasticity and resistance of quartz blanks to percussion (tenacity) create a particular group of percussion marks, i.e. proximal and radial fissures as well as steps. Morphostructure plays an important role, but some differences are also related to the texture of the quartz. Grainy textures increase elasticity and decrease the occurrence of fissures and cracks. Conversely, these petrological characteristics cause the appearance of scars related to specific fracture mechanics that can be also observed in flint blanks, such as partial Hertzian cones and micro-flaking. However, they are closely related to the morphostructure of quartz, e.g. edge battering and splintering. All these criteria must be taken into account for the development of a reliable technological analysis of quartz implements that will facilitate an overall understanding of the economic and social selection processes at work and an exploration of their relationship to the variability of prehistoric quartz industries.

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