stones

current stone age research in northern europe

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Occasional Papers in Archaeology 81
Series aditor: Anders Kaliff
Technical editor: Påhl Sundström
Department of Archaeology, Uppsala university
ISSN 1100-6358

Printed with grants from SAU´s Research Fund

Printed by Fyris Tryck AB

Uppsala 2023

UPPSALA
UNIVERSITET

OPIA 81

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anecdotal papers

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Blind-testing the quartz microwear method

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Abstract

Blind tests have had an important role in the history of functional studies. They have been essential for both demonstrating the accuracy of functional interpretations and for discovering methodological pitfalls, including the problem of equifinality in microwear formation. Functional method for quartz has been in place since the late 1980s, mainly thanks to the pioneering work done by K. Knutsson. While the initial methodological efforts and subsequent archaeological applications have shown that the use of prehistoric quartz tools can be reconstructed in detail and that quartz assemblages can therefore contribute significantly to our understanding of past technologies and behaviours, the strength of the method has never been formally demonstrated through blind testing.

We present here the results of a two-part single-analyst blind test involving 25 tools made of xenomorphic (vein) quartz and used either hand-held or hafted for different tasks. The test was aimed at a preliminary evaluation of the performance of low and high magnification approaches as well as their combination. The results are used to discuss the challenges involved in the analysis, and different solutions are proposed for meeting them in future studies.

Keywords: quartz, microwear, blind tests

Introduction

Modern use-wear analysis of quartz tools builds largely on the high magnification method developed by Kjel Knutsson in the 1980s by the means of extensive experimentation and innovative analytical approaches (Knutsson 1986; 1988). While the microscale has been explored in depth thanks to the integration of scanning electron microscopy from the start, and its continuing application (Borel *et al.* 2014; Knutsson 1988; Ollé *et al.* 2016), stereomicroscopic analysis that focuses on different forms of edge damage visible under low magnification has received considerably less methodological attention despite early efforts (Broadbent & Knutsson 1975) and subsequent applications (e.g. Rankama and Kankaanpää 2011). Other less explored fields include impact damage on quartz projectiles, which has only recently become addressed through experiments (de la Peña *et al.* 2018; Fernández-Marchena *et al.* 2017; Pargeter *et al.* 2016; Rots *et al.* 2017; Taipale & Rots 2018), and hafting wear, for which studies are even rarer (Clemente-Conte *et al.* 2016; de la Peña *et al.* 2018; Rots *et al.* 2017).

To evaluate the current capabilities and future prospects of the quartz use-wear method, we designed a two-part single-analyst blind test. Blind-testing has a long history in lithic use-wear analysis, the early part of which gave it a rather bad reputation due to low scores (Newcomer *et al.* 1986; Unrath *et al.* 1986; for a discussion, see e.g. Evans 2014; Odell 2003). In more recent days, however, the value of less-than-perfect test scores has been acknowledged, and blind tests are viewed as useful tools for improving methodologies by locating possible areas of weakness as well as underexplored aspects (Evans 2014; Rots *et al.* 2006).

The blind test presented here is, to our knowledge, the first one published on xenomorphic quartz. It focuses on the basic aspects of tool use, but also includes a preliminary evaluation of hafting wear. It is structured so that it allows an independent evaluation of the potential of the low magnification method. This approach has been tested up to now only through a comparison of low and high magnification results on a set of archaeological quartz tools (Taipale 2012; Taipale *et al.* 2014), and therefore deserves a more formal evaluation in an experimental setting.

Blind test set-up

The blind test was designed by VR. All the tools in it are made of xenomorphic (vein) quartz (Mourre 1996; Rodríguez-Rellán 2016) and were knapped, hafted and used by CL. The experimental details are summarised in Table 1. The test included both used and unused tools. This is a crucial element in any blind test set-up, but was judged particularly important here given that quartz is known to show above-average amounts of edge damage from production, which may or may not cause confusion during analysis. It was also decided to include both projectiles and other tools in the same test, which is something that, to our knowledge, has not been done in a blind test before. The test was taken in 2018 by NT, who had been trained in high magnification analysis of quartz tools for a period of seven

Tool ID	Action	Duration	Worked material	Hafted
1	fibre production	00:30:00	linden bark	no
2	adzing	00:20:00	wood	yes
3	-	-	-	-
4	grooving	00:25:00	dry bone	no
5	-	-	-	-
6	projectile (arrowhead)	shot until fracture	composite target	yes
7	-	-	-	-
8	-	-	-	-
9	drilling	00:20:00	dry antler	yes
10	scraping	00:30:00	dry wood	yes
11	-	-	-	-
12	-	-	-	-
13	splitting	00:20:00	reed	no
14	projectile (arrowhead)	shot once	composite target	yes
15	-	-	-	-
16	butchering	00:20:00	meat	no
17	perforating	00:20:00	dry willow	no
18	-	-	-	-
19	-	-	-	-
20	butchering	00:30:00	meat	yes
21	projectile (arrowhead)	shot 4 times	composite target	yes
22	-	-	-	-
23	cutting	00:15:00	dry bone	no
24	-	-	-	-
25	scraping	00:30:00	dry hide	yes

TABLE 1. Experimental details for the blind test tools (time format hh:mm:ss). The target used in the projectile experiments consists of an animal skeleton encased in ballistic gel and covered with fresh hide.

months in 2012, but had not previously attempted to identify exact worked materials. In the preceeding years she had mainly worked on flint and other cryptocrystalline rocks with the exception of two studies that focused on quartz projectiles. No additional training or practicing took place before the quartz blind test, but a small reference collection produced earlier (Taipale 2012) as well as material from experiments focusing on notch formation and projectiles (de la Peña et al. 2018; Taipale & Rots 2018) was available to the analyst during the test, together with published literature (Knutsson 1988). The tools were handed to NT after cleaning and without providing any information about their use (or lack thereof).

Given that the test is, as far as we are aware, the first one made on quartz, the main goal was to evaluate the accuracy of tool use interpretations. The analyst was asked to report if the tool was used or not, in which activity, on which type of material (relative hardness: soft/medium-hard/hard), and on which material specifically (e.g. hide, bone, wood), and whether the tool was hafted or not. She was also asked to report the confidence level of each interpretation (1= uncertain, 2, = moderate, 3 = certain).

Hafting wear on quartz has not been systematically studied up to date, and the inferences here are based on what is known of hafting wear on flint (Rots 2010a) and on the observations made in the context of a recent study involving quartz (de la Peña *et al.* 2018). Detailed interpretations (hafting arrangement, haft raw materials) were not attempted at this stage.

To assess the low magnification approach (employing a stereomicroscope) and the high magnification approach (employing a metallurgical microscope) as well as their combination individually, the test was set up so that the tools were first examined under low magnification and the resulting interpretations handed in separately. The high magnification interpretations represent inferred tool use as if there were no prior stereomicroscope observations whenever such a separation was possible. Finally, an interpretation that combined observations from both parts of the test was recorded. This final interpretation balanced the low magnification and high magnification data to the analyst's best judgement and was done for each case separately without systematically giving privilege to one method or the other.

For the first part of the test, a Zeiss Discovery.V12 stereomicroscope (magnifications up to 120×) was used. The analysis in the second part was done with a Zeiss AxioImager metallurgical reflected light microscope equipped with DIC. The relevant tool edges were screened using mostly 200× magnification, and locations with possible wear features were examined more closely by going up to 500×.

Scoring

The test has been scored by evaluating separately the accuracy of the interpretation for 1) presence/absence of use-wear (used/unused), 2) action, 3) the relative hardness of worked material, 4) worked material, and 5) hafting (present/absent). For each correct identification, one point has been given. If the answer was partly right, for example "drilling or perforating", or "medium-hard or hard", 0.5 points have been given, whereas an entirely wrong answer has got a 0. The analyst was advised to express a possible preference of one alternative interpretation over another in rough percentages (e.g. "drilling or perforating, 60-40") where possible. In this case, 0.6 points would be given for a tool used for drilling. For hard materials (dry bone and antler) identified as medium-hard (wood, soaked antler, fresh bone) and vice versa, 0.25 points have been given to account for the successful distinction between soft and hard materials. Projectiles are excluded from worked material scoring since the exact contact materials (skin, ballistic gel, bone) could not always be recorded.

Results

The overall outcome of the test is good, with correct and partially correct answers accounting for 23/25 for the combined approach. The test results are summarised in Table 2. The interpretations made during the test are listed in the appendix (Table A1) together with the features that led to the interpretations (Tables A2-A3).

The results are very promising for low magnification analysis. High magnification analysis yielded the highest number of entirely correct interpretations and a slightly higher average score than low magnification analysis, but the standard deviation is also clearly higher for the former meaning that the two extremes (scores of 0 and 5) were the most frequent in this part of the test. The combined approach managed to correct some of the errors made in the two parts of the test, but not all of them. However, the average score is highest of the three and the standard deviation smaller than for high magnification, which demonstrates that the combined approach performs better than either of the methods alone. Below we will discuss the results of the different test sections. We particularly focus on the errors made, since these are the most interesting part from the point of view of further training and methodological development.

Used vs unused

The number of successful identifications in each section of the test is presented in Table 3. Out of the 11 unused pieces (eight retouched, three unretouched), six were correctly identified as unused during the low magnification analysis, eight during the high magnification part, and again eight when the two approaches were combined. From these counts, it is clear that both retouch and associated microscopic features caused confusion during the analysis.

In contrast, only one used tool (#1) was misjudged as unused in the final conclusion, and even this piece was noted to show ambiguous edge damage under low magnification and limited microwear under high magnification.

The lower overall score for the high magnification part is due to the above-mentioned issues with production wear, and the presence of projectiles in the test sample. Altogether three projectiles, all hafted on arrows, were included in the test. These pieces are the most radical examples of discrepancy between low and high magnification results, and in fact the main source of unreliability of high magnification analysis in this test.

All three projectiles were successfully identified during low magnification analysis – even if with varying degrees of confidence – whereas in the absence of diagnostic microscopic traces associated with the impact damage, none of them would have become detected as used if only high magnification observations had been available.

The only other tool that was missed by high magnification analysis was #4 that showed very limited microtraces, which

	Correct (/25)	Partially correct (/25)	Wrong (/25)	Average score per tool (/5)	Standard deviation
Low magnification	1	22	2	2.74	1.433
High magnification	10	9	6	2.84	2.114
Combined	9	14	2	3.13	1.774

TABLE 2. Summary of blind test results

	Used/unused (/25)	Action (/25)	WM relative (/22)	WM (/22)	Hafting (/25)
Low magnification	19	14.55	11.25	1	22
High magnification	17	14.25	12.75	11.75	15
Combined	19	16	11.25	11	19.5

TABLE 3. Test scores in each section for different analytical methods. WM relative=relative hardness of worked material, WM=exact worked material. For these categories, projectiles (n=3) are excluded.

led to the conclusion that the edge damage was intentional retouch.

In addition to the projectiles, also #22 gave a total score of 0 in high magnification analysis. This piece has extensive recrystallization planes that seriously limited the possibilities of observation. During the test it was noted that the piece should have been excluded from the second part of the test, but since wood-like striations (e.g. Knutsson 1988: fig. 46b,85a; Knutsson *et al.* 2015:fig.3g) were encountered on the short stretch of edge that could be analysed, the interpretation "wood" was offered. This choice represents a "high risk, high gain" mentality that can be considered interesting for test purposes, but admittedly would be questionable in archaeological analysis. In this case, it resulted in one of the worst failures in the test.

Type of tool use

After excluding the pieces for which the identification failed due to the problems in separating between used and unused pieces described above (n=6 for low magnification and n=8 for high magnification), two erroneous interpretations remain for both parts of the test, and concern the same tools. In addition, for #23, no interpretation of use motion could be offered during the first part of the test.

For #13 (splitting reed), the worked material was defined as medium-hard during low magnification analysis, and the tentative interpretation was that the edge was used in both transverse and longitudinal motions. The linear features observed under high magnification confirmed this. The interpretation is not incorrect apart from the fact that the worked material was thought to be harder (medium-hard), which led to the use of terms "scraping/shaving" and "sawing" (Table A2). The used edge is relatively strong, with an angle around 45 degrees, and was not considered to be easily damaged by soft material. A closer examination of the edge damage, however, shows that it is dominantly bending-initiated (Fig. 1a) which should have served as a clue to the relative hardness even though the analyst had never analysed tools used in this kind of activity before.

The second tool that caused confusion is #17, a retouched perforator. It was used for perforating dry willow but was in both parts of the test misinterpreted as a grooving tool. In the first part, the error is probably due to the mix of retouch and use-wear (step-terminating scarring leaving the edges partly undercut, heavy abrasion) that was mistaken as edge damage from grooving. The damage to the dorsal ridges is limited. Together these features create a false impression of edge damage focused on the dorsal side which makes the wear pattern from perforating poorly visible on this piece. In the second part of the test, the orientation of the linear features (oblique instead of parallel to the long axis of the tip) was noted as peculiar, but the final interpretation was that this was due to the choice to use the tip slightly asymmetrically with respect to the long axis due to morphological specifics.

Relative hardness of worked material

As before, the success rates in this section are largely brought down by the failures in separating between used and unused pieces. When these pieces and the projectiles are excluded, the scores are 11.5/17 for low magnification, 12.75/17 for high magnification, and 11.25/17 for combined. The remaining loss of points is mainly due to the difficulty in distinguishing between medium-hard materials (in the test, wood) and hard materials (in the test, dry antler and dry bone), a problem that persisted throughout the test. This is probably due to the fact that not enough time and care were taken during the analysis to evaluate scar attributes and edge damage patterning. In their low magnification analysis of

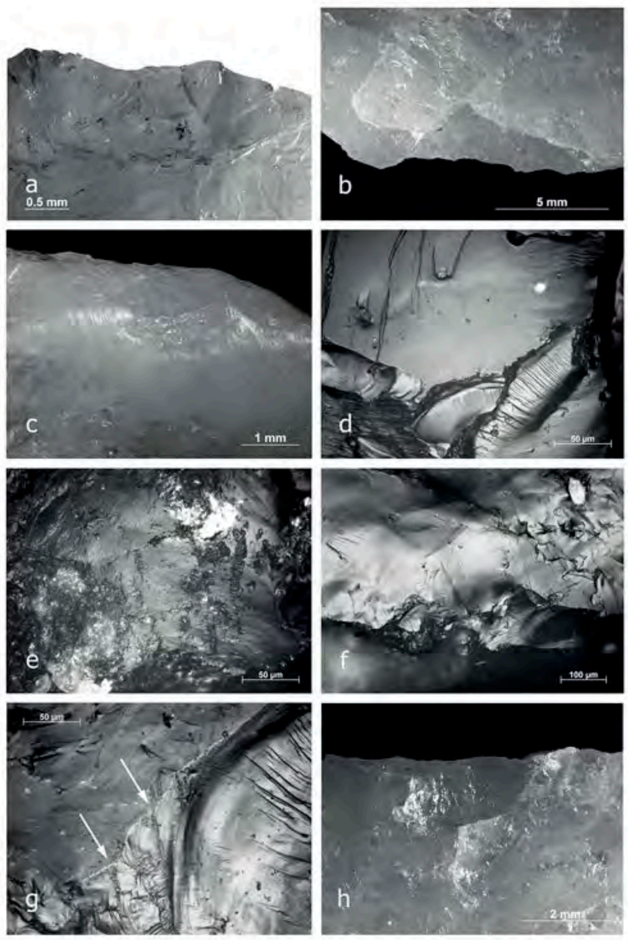

FIGURE 1. Microwear observed in the blind test. a. Edge damage with varying orientations on blind test tool #13, used for splitting reed (63×). b. Ventral step-terminating edge damage on tool #2, used for adzing dry wood (16×). c. Heavy edge rounding on scraper #25, used on dry hide (40×). d. Limited microwear from grooving dry bone (tool #4, 500×). e. Production wear (sandstone hammer) confused with use-wear (tool #8, 500×). f. Wear from splitting reed, misidentified as bone/antler (tool #13, 200×). g. Hafting wear on hide scraper #25: edge damage associated with striations (arrows) (500×). h. Bending-initiated edge damage with abrupt and fissured terminations on the cutting edge of projectile #6 (32×).

quartz scrapers used on hide, wood and bone, Broadbent and Knutsson (1975) concluded that wood scrapers showed features absent on bone scrapers and vice versa. The confusion between medium-hard and hard worked materials in the present test most probably stems from the analyst's limited experience in interpreting quartz tools used in craft activities using low magnifications only.

Worked material

It is obvious that only high magnification analysis can identify exact worked materials, with the low magnification part of the test receiving a score of 1/25 in this section, and high magnification and combined parts both 11.75 points. The most successful identifications in this respect were #2 (adzing dry wood), #23 (cutting dry bone), and #25 (scraping dry hide) (for edge damage from adzing, see Fig. 1b; for the microwear pattern on a wood adze, see Knutsson 1988:fig.33a (used on fresh wood); for bone wear, see Knutsson 1988:figs.18a, 37a-b, 38a, 48b, 49b, 56c, 67; Knutsson *et al.* 2015:fig.3g; Ollé et al. 2016: fig. 11a-c; for dry hide wear, see Fig. 1c and Knutsson 1988:figs.27a,29a; Knutsson *et al.* 2015:fig.3d).

To explain the otherwise relatively low scores in this test section, eight tools are worth a discussion. They remain after the exclusion of correct identifications of worked material mentioned above (n=3) and one partially correct identification of worked material ("meat/fresh hide" for #16 used on meat), the correct identifications of unused pieces (n=8), the projectiles for which the exact identification of contact material was not realistic (n=3), and the pieces where high magnification observations were too limited for reliable identifications due to recrystallization planes (n=2).

The remaining eight pieces represent three different types of error. The first category consists of two tools (#1 and #4) where microwear was nearly absent, and one tool (#9) where it was too limited to allow a confident identification. Tool #1 is the piece used on linden bark on which linear features could not be found even in post-test analysis and that therefore was practically impossible to characterise in terms of exact worked material. Tool #4, used for grooving dry bone, has already been discussed above and shows very limited microwear at best (Fig. 1d) probably due to the chipping of the edges towards the end of its use. Tool #9, used on dry antler and said to have been used on wood, showed discontinuous striations (see Knutsson 1988: 70–73, 90–92) that led to the wood interpretation but with a fair degree of hesitation. It is obviously not advisable to draw conclusions on the worked material on the basis of presence/absence of a single trace type (see Knutsson 1988; Knutsson *et al.* 2015). For this reason, this misidentification can be viewed as a case where an interpretation based on limited evidence was pushed too far. Confusion between wood and bone/antler is also common in published blind tests on flint (Evans 2014:figs.2–3).

The second category consists of tools where production wear was mistaken for use-wear (n=2). Tool #7 was retouched with a bone hammer, and the resulting wear was misidentified as wear from scraping or planing hard or medium-hard material, "possibly wood". The other tool (#8) was retouched with a sandstone hammer, which resulted in heavy abrasion of the partly obtuse-angled edges. This pattern was considered rather strange under low magnification, but the discovery of a multitude of irregular striations (see Knutsson 1988:70–71,90–92,figs59–60; Knutsson *et al.* 2015:figs 7a,c,d,f) and sleeks (Knutsson 1988:93–94, fig.56d; Knutsson *et al.* 2015:figs3h,7j) under high magnification (Fig.1e) led the analyst to propose that the scraper was used on dry antler.

The last category represents failures in the overall analytical procedure. Tool #20 was used for butchering, and was tentatively interpreted as used on wood. Here, the more accurate low magnification interpretation (projectile/knife used on soft material) was abandoned because of the microtraces even though their pattern was rather ambiguous. While an overlap between the two has been demonstrated (Knutsson *et al.* 2015:fig.4), #20 illustrates the analyst's failure to put together all the functional evidence rather than difficulties in separating between the two worked materials.

Tool #13 was used for splitting reed. This activity is not represented in the reference material but the error here was already made on the level of relative hardness of the worked material that was identified as medium-hard. Due to the slightly odd nature of the edge damage, the high magnification observations became overemphasised in the final interpretation, which – after excluding wood – arrived at "possibly antler or bone" due to the dominance of irregular striations (Fig.1f). Again, the inference was made on limited evidence, and some of the evidence was ignored.

For #17, the failed identifications are due to the interrelatedness of the errors made during low and high magnification analyses. The action (perforating) was misinterpreted as grooving, and the worked material (wood) was misinterpreted as bone/antler. It is probable that the nature of the activity led into the formation of microwear that is less diagnostic than what could be expected from grooving, and as a result wood was ignored as an option. In the case of #2, in contrast, the worked material (also dry wood) could be correctly inferred even though the activity (adzing) is absent in the current reference sample. It seems that when the use motion is well understood, the possible anomalies in the microwear pattern can be accounted for, and the worked material identified despite the variability in traces.

Hafting

Once the unused pieces are excluded, the proportion of correct hafting identifications (hafted/hand-held) for different parts of the test are 12/14 for low magnification, 6/14 for high magnification, and 9.5/14 for combined. Interestingly, of the eight hafted pieces included in the test, all could be identified with low magnification but only two (#2 and #25) with high magnification, resulting in a combined success rate of 5.5/8. This, however, does not mean that high magnification analysis should be abandoned in the study of hafting, since only detecting a combination of low magnification and high magnification features allows *reliable* identification of hafted tools. The scores therefore reflect the relative frequency of diagnostic combinations, documented in the test on #25 (hide scraper) (Fig. 1g) and #2 (wood adze), both of which received confidence level '3', with the average for hafting being 2.04. In addition to this matter, the lower score for high magnification is due to the difficulties in identifying projectiles or confirming projectile use, and the near lack of hafting traces on the resin-hafted armatures.

Results in context: recurrent issues and possible solutions

Source of error 1: production wear

The most significant source of error in the test are knapping-related traces confused as use-wear. This error type accounts for 5/6 of the mistakes in identifying used vs unused pieces in the low magnification part, and for 3/8 and 2/5 in the high magnification and combined parts, respectively. It also understandably contributes to the loss of points in the other test sections.

The misleading production wear consists mainly of 1) sometimes extreme crushing and abrasion of retouched edges, visible under low magnification, and 2) groups of linear features associated with surface cracking and abrasion, visible under high magnification (Fig.1e). While the analyst's initial training included the examination of retouched pieces prior to use, the traces on them do not resemble the heavy type of production wear encountered in the blind test. Knapping wear can vary considerably according to the type of retoucher as well as between knappers (Rots 2010b), which means that it is essential to familiarise oneself with the *variability* in production-related traces. This was clearly not done sufficiently before the blind test, and the errors made can therefore be attributed to the lack of experience and suitable reference material. These issues are sorted out by further experimentation and training. This error type does not therefore question the validity of the method as such, but nevertheless singles out a possible source of error, production wear, that is already becoming addressed in studies dealing with quartz (de la Peña *et al.* 2018).

Source of error 2: analytical failure caused by human error

The second recurrent type of error in the test is linked to unsuccessful application of the microwear method. This struggle can be further divided into two categories, 1) working on a set of observations that is too limited for reliable interpretations, and 2) failing to combine all the functional data into a well-balanced interpretation. These two are often interlinked.

The first category is particularly well illustrated by #22 in the case of which the analyst decided to propose an interpretation based on a limited number of high magnification features on a short stretch of the tool edge. Tool #9 discussed in the context of worked materials is a further example of pushing the interpretation too far on limited evidence.

The second category mainly concerns cases where too much weight was given to high magnification observations due to the lack or ambiguity of edge damage. Tool #13 represents such a case. The edge damage that was not heavy enough for the inferred worked material (bone/antler) (Fig.1a) was neglected in the final interpretation, and the (limited) high magnification evidence (Fig.1f) became overemphasised. Tool #22 can also be cited here: the edge damage was all production-related and not typical of use, but the high magnification evidence (striations) took over, which eventually resulted in a total score of 0 for this piece.

These issues have to do with the skill level of the analyst and lack of consistency in the analytical strategy. Two solutions can be proposed. First, in reporting analysis results, limitations and inconsistencies experienced during the work should be stated in a transparent manner (e.g. attaching a confidence level to each interpretation, together with a comment on what affects it) (e.g. Rots *et al.* 2006; Unrath *et al.* 1986). This is a standard procedure followed by many, if not most, use-wear analysts. In analysing archaeological material, it is useful to make an explicit distinction between reliable interpretations (i.e., ones supported by several strands of evidence) and so-called educated guesses (Evans 2014; Rots *et al.* 2006).

Secondly, in cases where the use-wear features are ambiguous, or low and high magnifications seem to contradict, it is advisable to follow a rigorous procedure of objectively describing all the evidence available, and then pausing to evaluate where the contradiction lies exactly, and re-evaluating the evidence after. When working on pre-defined hypotheses, features become more easily ignored and others overemphasised.

Since all the errors discussed in this section have to do with the analyst drawing too hasty conclusions usually on the basis of a single trace type, these errors, like the ones in the previous category, cannot be attributed to true methodological problems but rather to the lack of experience in identifying worked materials. Even if high magnification analysis is viewed as its own entity, use-wear diagnostics are based on *combinations* of features (Knutsson 1988), a principle that was clearly not respected consistently throughout the test.

Source of error 3: projectiles

The three projectiles included in the test show a fair share of evidence of impact under low magnification. None of them, however, have microscopic linear impact traces (MLITs; Moss 1983; Fischer et al. 1984; for quartz, see Taipale & Rots 2018). This means that if edge damage would have been ignored and only high magnification features sought for, identifying the three projectiles would have been impossible. It does not, however, mean that all projectiles showing low magnification evidence suggestive of impact (see Fig. 1h) can be *reliably* identified as projectiles, especially if only individual features are considered (Coppe & Rots 2017; Rots & Plisson 2014). Even if low magnification proved successful in this case, preferably both a convincing low magnification pattern and MLITs should be documented before inferring projectile use.

Preliminary experimental results suggest that the frequency of MLITs on quartz projectiles varies considerably according to raw material qualities, hafting arrangement and the material(s) the projectile came into contact with (Taipale & Rots 2018:tables 5–7). This means that analysis relying heavily on high magnification can risk missing a significant number of quartz armatures, which is well illustrated by the test results. This makes projectiles the only recurrent source of error that truly has to do with the frequency and quality of microwear, and therefore the reliability of the high magnification method. Projectiles, however, were not included in Knutsson's (1988) original experimental investigation, and have only very recently been addressed from an experimental point of view in published literature (de la Peña *et al.* 2018; Fernández-Marchena *et al.* 2017; Pargeter *et al.* 2016; Rots *et al.* 2017; Taipale & Rots 2018). They therefore represent an important avenue for future research.

Discussion

The overall success rate for the test is 54.8% for low magnification, 56.8% for high magnification, and 62.6% for the combined approach. For all methods, it can be considered acceptable in comparison to the average, 42.7%, calculated from published blind tests on flint (Evans 2014), but low in comparison to some scores (e.g. Rots *et al.* 2006). However, for a first test on quartz, taken by an analyst who had not previously made a serious attempt at distinguishing among different worked materials, the results can be considered very promising. The power of blind tests is in identifying pertinent issues and addressing them through methodological improvements, an approach that has yielded higher scores in tests taken in a sequence by the same analyst (Evans 2014; Rots *et al.* 2006).

Blind test situations and archaeological analysis differ from each other in several respects (see e.g. Evans 2014). One of them is that unlike archaeological assemblages, sets of blind test tools do not represent functional wholes where dominant activities would be represented by several tools and tools would be linked with each other in a logical way. While a significant complicating factor, taphonomy, is usually absent in blind tests, the lack of contextual information replaces it as a possible source of confusion. In this respect, blind test tools represent the same situation as archaeological artefacts found out of context. This should be taken into account when evaluating blind test scores, and especially when making statements about the usefulness of an individual method for archaeological science in general.

In the case of this particular test, it is evident from the discussion in the previous sections that the relative proportions of successful identifications should not be straightforwardly taken as estimates of the overall performance of the three methods. The errors made have to do with the level of experience of the analyst and/or the lack of suitable reference material, or weakly developed research areas (projectiles and production wear). In contrast, several successful and detailed identifications made in the test demonstrate the potential of the method originally developed by Kjel Knutsson (Broadbent and Knutsson 1975; Knutsson 1988). Apart from the pitfalls in identifying projectiles and separating between production and use-wear, the test did not reveal any methodological problems that would not have been acknowledged in earlier works.

Of special interest is the relatively high – and more importantly rather stable – performance of low magnification analysis throughout the test. This method has not been systematically developed through experimentation in quartz studies apart from the above-mentioned study by Broadbent and Knutsson on scrapers (Broadbent and Knutsson 1975). Especially given that the low magnification analysis in the current blind test took place independently from high magnification analysis, the number of correct identifications is encouraging, and the method is obviously worth further exploration. It is evidently crucial for the identification of quartz projectiles, and also succeeded in identifying hafting in the test sample (cf. Rots 2010a; Rots *et al.* 2006). In addition, the microwear evidence collected in the test serves as further proof of the existence of diagnostic hafting wear (analogous to that on flint) on quartz tools, and encourages further research into the specificities of prehensile wear formation on this raw material.

It is clear, however, that neither of the methods performs individually as well as they do combined. An approach that integrates low and high magnifications has been preferred in flint studies for some time, and has also recently found advocates among analysts working on quartz (de la Peña *et al.* 2018; Ollé *et al.* 2016; Rots *et al.* 2017; Taipale *et al.* 2014; Taipale & Rots 2018). This test confirms the success of the combined approach, which means that future work should be primarily directed towards making the most of the potential of both low and high magnification analysis.

Conclusions

The single-analyst blind test involving 25 quartz tools demonstrated the potential of both low and high magnification methods, and clearly shows that when combined, these methods yield better results than when used independently. The test confirms that the high magnification method originally developed by K. Knutsson (Knutsson 1988) is successful in identifying exact worked materials when strict analytical criteria are applied. The failures in this part of the test can be explained either by limited wear development or analytical errors, with the latter relating to lack of experience or referential basis, or to inconsistencies in the analytical strategy.

Apart from factors related to skill and experience, the errors made during the test are mainly due to two issues: (1) our present understanding of production wear, its variability and its overlap with use-wear is limited, and (2) the identification of projectiles using high magnification alone is often impossible due to the low relative frequency of MLITs.

On the basis of the test results, we propose that future research is guided towards a more comprehensive integration of production and hafting wear into quartz microwear studies, and towards applications that combine low and high magnifications and thus exploit the full potential of the analytical tools developed since the 1970s.

Acknowledgements

This paper builds on the efforts of two pioneers in quartz studies, Kjel Knutsson whose groundbreaking work laid the foundations of the functional method, and Helena Knutsson who has applied and continuously improved the method through the analysis of a substantial amount of archaeological material. NT wishes to thank both of them for their investment in her initial training. We would also like to thank Kjel for his encouragement to test the possibilities of the low magnification method, which partly inspired the present blind test.

This research was funded by the European Research Council under the European Union's Seventh Framework Programme (FP/2007-2013)/ERC Grant Agreement Nr. 312283). Noora Taipale's work is also supported by the Kone Foundation (grant number 088817), and Veerle Rots is indebted to the Fund for Scientific Research (FNRS-FRS).

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Appendix

*Table A1. Use and hafting details for the blind test tools and interpretations made during the blind test. WM=worked material, CL=confidence level of the interpretation (1–3; in cases where separate levels were given for different parts of the interpretation, an average is given), ?=no interpretation. Line marked with * represents a projectile in the case of which low magnification evidence could not be overlooked during high magnification analysis even though diagnostic high magnification features were not found.*

Low magnification									
Actual use				**Blind test interpretations**					
ID	**Action**	**Worked material**	**Hafted**	**Used**	**Action**	**WM relative hardness**	**Worked material**	**Hafted**	**CL**
1	fiber-making	linden bark	no	?	NA	NA	?	yes	1
2	adzing	wood	yes	yes	percussion	hard/medium-hard	?	yes	3
3	-	-	-	no	-	-	-	no	2
4	grooving	dry bone	no	yes	grooving	medium-hard	?	no	3
5	-	-	-	yes	planing/scraping	hard/medium-hard	?	no	3
6	projectile	NA	yes	yes	projectile	contact with hard material?	?	yes	2
7	-	-	-	yes	scraping/planing	hard/medium-hard	?	yes?	2
8	-	-	-	yes	scraping/planing	medium-hard (abrasive?)	?	no	1
9	drilling	dry antler	yes	yes	drilling/perforating (60-40)	hard/medium-hard	?	yes	2
10	scraping	dry wood	yes	yes	scraping	hard	?	yes	3
11	-	-	-	yes?	NA	soft	?	no	1
12	-	-	-	no	-	-	-	no	3
13	splitting	reed	no	yes	scraping; sawing?	medium-hard	?	no	2
14	projectile	NA	yes	yes	projectile	NA	?	yes	2
15	-	-	-	yes?	grooving?	hard/medium-hard?	?	no	1
16	butchering	meat	no	yes?	projectile/knife (50-50)	soft	?	yes?	1
17	perforating	dry willow	no	yes	grooving; scraping	hard	?	no	3
18	-	-	-	no	-	-	-	NA	2
19	-	-	-	no	-	-	-	NA	3
20	butchering	meat	yes	yes	projectile/cutting (55-45)	soft	?	yes?	1
21	projectile	NA	yes	yes?	projectile?	NA	?	yes?	1
22	-	-	-	no	-	-	-	no	2
23	cutting	bone	no	yes?	no interpretation	NA	?	yes?	1
24	-	-	-	no	-	-	-	no	2
25	scraping	dry hide	yes	yes	scraping	dry hide (soft)	dry hide	yes	3

High magnification									
Actual use				**Blind test interpretations**					
ID	**Action**	**Worked material**	**Hafted**	**Used**	**Action**	**WM relative hardness**	**Worked material**	**Hafted**	**CL**
1	fiber-making	linden bark	no	no	-	-	-	yes?	2
2	adzing	wood	yes	yes	percussion	medium-hard	(dry) wood	yes	2.7
3	-	-	-	no	-	-	-	no	3
4	grooving	dry bone	no	no	-	-	-	no	2
5	-	-	-	no	-	-	-	no	2
6	projectile	NA	yes	no*	-*	-*	-*	no*	1
7	-	-	-	yes	scraping/planing	hard/medium-hard	wood?	no	2
8	-	-	-	yes	scraping/planing	hard	(dry) antler? cannot exclude bone	no	2
9	drilling	dry antler	yes	yes	perforating/drilling (50-50)	medium-hard	wood?	?	2
10	scraping	dry wood	yes	yes	scraping; observations limited	hard	(hard; observations limited)	?	NA
11	-	-	-	no	-	-	-	no	2
12	-	-	-	no	-	-	-	no	3
13	splitting	reed	no	yes	shaving (planing), intermittent longitudinal use?	medium-hard/hard	antler or bone?	no	2.3
14	projectile	NA	yes	no	-	-	-	no	3
15	-	-	-	no	-	-	-	no	3
16	butchering	meat	no	yes	cutting	soft	meat/(relatively) fresh hide	yes?	2.3
17	perforating	dry willow	no	yes	grooving	hard	bone/dry antler	no	2.5
18	-	-	-	no	-	-	-	no	2
19	-	-	-	no	-	-	-	no	3
20	butchering	meat	yes	yes	cutting (mainly longitudinal, partly oblique)	medium-hard	wood?	no	2.25
21	projectile	NA	yes	no	NA	NA	NA	no	2
22	-	-	-	yes	sawing/cutting	medium-hard/hard	wood? not enough observations	no?	1.3
23	cutting	bone	no	yes	sawing/cutting (80-20)	hard	bone	no?	2.25
24	-	-	-	no	-	-	-	no	2
25	scraping	dry hide	yes	yes	scraping	soft	hide	yes	3

Combined low and high magnification									
Actual use				**Blind test interpretations**					
ID	**Action**	**Worked material**	**Hafted**	**Used**	**Action**	**WM relative hardness**	**Worked material**	**Hafted**	**CL**
1	fiber-making	linden bark	no	no	-	-	-	yes?	2
2	adzing	wood	yes	yes	percussion	medium-hard	(dry) wood	yes	2.7
3	-	-	-	no	NA	-	NA	no	3
4	grooving	dry bone	no	no	-	-	-	no	2
5	-	-	-	no	-	-	-	no	2
6	projectile	NA	yes	yes	projectile	contact with hard material?	-	yes	1.5
7	-	-	-	yes	scraping/planing	hard/medium-hard	wood?	yes	2
8	-	-	-	yes	scraping/planing	hard	(dry) antler/bone	no	2
9	drilling	dry antler	yes	yes	perforating/drilling (50-50)	medium-hard	wood?	?	2
10	scraping	dry wood	yes	yes	scraping	hard	observations impossible	yes	2.5
11	-	-	-	?	?	?	?	no	NA
12	-	-	-	no	-	-	-	no	3

13	splitting	reed	no	yes	shaving (planing), intermittent longitudinal use?	medium-hard/hard	antler/bone?	no	2.3
14	projectile	NA	yes	?	projectile	NA	NA	?	1
15	-	-	-	no	-	-	-	no	3
16	butchering	meat	no	yes	cutting	soft (good holding properties)	meat/(relatively) fresh hide	yes?	2.3
17	perforating	dry willow	no	yes	grooving	hard	bone/dry antler	no	2.5
18	-	-	-	no	-	-	-	no	2
19	-	-	-	no	-	-	-	no	3
20	butchering	meat	yes	yes	cutting (mainly longitudinal, partly oblique)	medium-hard?	wood?	no	2
21	projectile	NA	yes	yes?	projectile?	NA	NA	yes?	1
22	-	-	-	yes	sawing/cutting	medium-hard/hard	observations limited; wood?	no?	1.3
23	cutting	bone	no	yes	sawing/cutting (80-20)	hard	bone	no?	2
24	-	-	-	no	-	-	-	no	2
25	scraping	dry hide	yes	yes	scraping	soft	hide	yes	3

Table A2. Blind test interpretations in the low magnification part of the test and the observations on which they were based.

Low magnification								
ID	**Action**	**Argument action**	**Wm relative hardness**	**WM relative argument**	**Worked material**	**Worked material argument**	**Hafted**	**Hafted argument**
1	NA (unused?)	tentative ED only in concave (protected) parts of the edge (distribution seems unlikely for use-wear)	NA (unused?)	NA	?	NA	yes	possibly hafted, distribution of edge damage matches better with hafting than use (but no definite use-wear)
2	percussion	invasive abruptly terminating ventral edge damage	hard/ medium-hard	invasive abruptly terminating ventral edge damage	?	NA	yes	bifacial ED and crushing on ventral proximal left edge
3	-	only production-related features, fragile edge part that could not have easily survived use/ prehension still intact	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
4	grooving	dominantly dorsal ED and crushing; perforating also possible but grooving seems more probable	medium-hard	abruptly terminated but partly relatively invasive edge damage, crushing	?	NA	no	lack of evidence
5	planing/ scraping	ventral cone-initiated ED and crushing	hard/ medium-hard	ventral cone-initiated ED and crushing	?	NA	no	lack of evidence
6	projectile	ventral invasive ED and fissuration on the cutting edge	contact with hard material?	intensity of ED	?	NA	yes	projectile use implies; bending-initiated ED (counterpressure) on one lateral edge
7	scraping/ planing	ventral cone-initiated ED (part step/fissure-terminated) (but very localised, pattern strange)	hard/ medium-hard	ventral cone-initiated ED (part step/fissure-terminated) (but very localised, pattern strange)	?	NA	yes?	possible (limited) ED on lateral edge
8	scraping/ planing	cone-initiated abruptly terminating dorsal removals, ventral abrasion/edge rounding	medium-hard, abrasive	cone-initiated abruptly terminating dorsal removals, ventral abrasion/edge rounding	?	NA	no	lack of evidence; use-wear at both ends
9	drilling / perforating (60-40)	ED and abrasion on both dorsal and ventral aspects	hard/ medium-hard	relatively small and mixed ED, abrasion obscures initiations	?	NA	yes	clearly patterned ED and abrasion on proximal lateral edges
10	scraping	dominantly dorsal ED and crushing	hard	crushing and abruptly terminating ED (edge partly undercut)	?	NA	yes	lateral crushing that looks patterned but difficult to tell apart from retouch

11	possibly used	small bending-initiated snaps that can be production-related; possible ER but may be just a trick of light on the edge	soft?	small bending-initiated removals, ER (uncertain)	?	NA	no	lack of evidence
12	-	crushing probably related to retouch; distal edge has sharp protrusions that would not survive use	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
13	scraping; sawing?	edge damage with varying orientations	medium-hard	edge strong, would expect less damage from soft material	?	NA	no	lack of evidence
14	projectile	snap break associated with spin-offs; large lateral obliquely oriented step-terminating removal; possible counterpres-sure removal in basal part (the last could be production)	NA	NA	NA	NA	yes	projectile use implies; possible counterpres-sure removal
15	grooving	possible ED but no initiations; bit edge slightly rounded; uncertain, features can be production-rela-ted	hard/ medium-hard	possible abruptly terminating ED, ER	?	NA	no	lack of evidence
16	projectile/ knife (50-50)	isolated scars at distal end	soft	limited bending-initiated edge damage on thin edges	?	NA	yes?	possible ED in one location in the proximal part
17	grooving; scraping	dorsal abruptly terminated ED and heavy ventral ER/abrasion; dorsal scarring and ventral abrasion	hard	abruptly terminated ED, abrasion	?	NA	no	lack of evidence, use of multiple edges
18	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
19	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
20	projectile/ cutting (55-45)	bifacial bending-initiated lateral ED; snap with spin-offs	soft	NA	?	NA	yes?	a cone-initiated proximal scar on one lateral edge and a large bending-initiated with a proximal-distal direction on the opposite edge
21	projectile?	a single distal bending-initiated removal, noncharacteristic break; uncertain	NA	NA	NA	NA	yes?	projectile use implies
22	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
23	possibly used	small breaks at distal end, partly obliquely oriented edge damage on right lateral edge, limited ED on proximal left edge	no interpretation	NA	?	NA	yes?	proximal edge damage
24	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
25	scraping	heavy distal ER with transverse striations	dry hide	heavy striated ER	dry hide	heavy striated ER	yes	patterned ED on lateral edges

Table A3. Blind test interpretations in the high magnification part of the test and the observations on which they were based.

High magnification								
ID	**Action**	**Argument action**	**Wm relative hardness**	**WM relative argument**	**Worked material**	**Worked material argument**	**Haf-ted**	**Hafted argument**
1	-	microwear limited (occasional longitudinal discontinuous and irregular striations and slightly abraded small ridges)	NA (unused)	NA (unused)	NA (unused)	NA (unused)	yes	limited microwear on one lateral edge (occasional longitudinal discontinuous and irregular striations and slightly abraded small ridges)
2	percussion	incipient cracks, linear features with a transverse orientation	medium-hard	wood identification	(dry) wood	irregular and discontinuous striations (the latter not as dominant as from scraping or sawing)	yes	perpendicular and longitudinal striations (both surface and subsurface) associated with the lateral proximal ED, abrasion of low ridges, cracks oriented perpendicularly to the edge
3	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
4	-	microwear very limited (small number of discontinuous and irregular striations)	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
5	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
6	no change in interpreta-tion	no relevant microwear associated with the ED	NA	NA	NA	NA	see low magnifi-cation	see low magnification
7	scraping/ planing	ventral ED, abrasion, linear features	hard/ medium-hard	ED, incipient cracks, abrasion	wood?	discontinuous and irregular striations, sleeks	no	lack of evidence
8	scraping/ planing	abrasion, surface cracks, linear features	hard	heavy wear including surface cracks	would say (dry) antler, cannot exclude bone; wear in proximal part more mineral-looking	irregular striations, abundant sleeks, some broad plastic deformations	no	lack of evidence, use-wear at both extremities
9	perforating/ drilling (50-50)	transverse and oblique linear features	medium-hard	wood identification	wood?	discontinuous striations	no interpre-tation	microwear indistinguishable from production wear
10	scraping	low magnification evidence	hard	ventral surface recrystallised, further interpretations not possible	no further interpretation	ventral surface recrystallised, further interpretations not possible	no interpre-tation	NA
11	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
12	-	only production-related features (some resemble use-wear)	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
13	shaving (planing), intermittent longitudinal use?	ED, abrasion, linear features parallel, oblique and perpendicular to the edge	medium-hard/ hard	ED, abrasion	antler or bone?	dominantly irregular striations	no	lack of evidence
14	-	no microwear apart from microscopic ED on very fragile part of an edge	NA	NA	NA	NA	no	lack of evidence
15	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
16	cutting	striations parallel to the edge	soft	low magnification evidence	meat/(relatively) fresh hide	low magnification evidence, discontinuous and irregular striations	yes?	ridge abrasion and striations with varying orientations in the proximal part

17	grooving	striations oblique across the tip	hard	features limited to the outermost tip	bone/dry antler	deep surface cracking of the edge matches with bone but plastic deformations better with antler; possible retouch striations mixed with use-wear at the tip	no	lack of evidence
18	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
19	-	only production-related features	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
20	cutting (mainly longitudinal, partly oblique)	parallel (short) and oblique (long) striations	medium-hard	wood identification	wood?	dominantly regular striations, possible to exclude soft plants	no	lack of evidence
21	-	no conclusive microwear	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
22	sawing/ cutting	ED, abrasion, rare parallel striations (observations very limited due to extensive recrystallization planes)	medium-hard/ hard	ED, abrasion	wood? not enough observations	mix of regular and irregular striations (observations very limited due to extensive recrystallization planes)	no?	ambiguous wear on the non-active edge
23	sawing/ cutting (80-20)	ED, ridge abrasion, striations	hard	ED, wear on ridges	bone	bone saw from the reference sample is the closest match for the observed wear pattern	no?	no microwear linked with ED observed under low magnification
24	-	no microwear	NA (unused)	NA (unused)	NA (unused)	NA (unused)	no	lack of evidence
25	scraping	linear features perpendicular to the edge	soft	ER, lack of ED	hide	ER, irregular striations, sleeks (sleeks not as frequent as on reference scraper used on dry tanned hide)	yes	striations associated with ED