**TRAIL**

**An Experimental Trace and Residue Reference Library for the functional analysis of stone tools in Liège**

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We present the experimental reference library for wear traces and residues on stone tools that has been created at **TraceoLab**, University of Liège, Belgium. This collection has been named **TRAIL** ***(“Traces In Liège”)*** and intends to provide a route (a trail) towards improved understanding of archaeological wear traces and residues. Through that means, it aims to contribute to an improved understanding of prehistoric stone tools, technologies, site function and past human behaviour. TRAIL has been gradually build up since the creation of TraceoLab in 2012. Since only part of the collection has been integrated in publications up to now (references included below), we include general details here on how the reference library is composed. **This document serves as a basis to understand the composition of TRAIL and to gain insight in which publications of TraceoLab members contain what parts of the TRAIL reference library. This document will be gradually expanded upon as experiments proceed.**

The initial core of TRAIL is formed by the experimental reference collection of Veerle Rots that she created during her previous research, including her PhD research (2002a; see also Rots 2010a). This part of the collection consists of about 1400 pieces. Since 2012, efforts have been invested in the development of this collection within the framework of archaeological investigations and largely thanks to the involvement of Christian Lepers, an experienced primitive technologist, in the group TraceoLab. As a result, the TraceoLab reference collection currently (i.e., April 2021) consist of about 5800 stone tools, each of which is part of a particular experiment focused on one broader topic. The combination of these multiple experiments provides a reliable reference framework to identify and interpret functional evidence on archaeological stone tools. Different parts of the collection have been published, generally within the context of the research in which they were performed, and these publications are referred to below.

In addition, the collection also contains several blind tests, focused on wear traces and residues on both flint and quartz tools, on grinding stones and on particular topics such as projectiles. Part of these blind tests have been published (e.g., Hayes et al. 2017; Rots et al 2006, 2016; Taipale et al. In press). For some tests, individual results have been incorporated in Master (Tydgadt 2019a, Genevois 2019) and PhD theses (Taipale 2020, Coppe 2020).

# Nature of the experiments

The large majority of experiments performed at TraceoLab are performed by humans in controlled settings. While the control of variables is often supposed to be restricted to machine-based experiments only, this is not really the case. While machine-based experiments permit to test a single variable at the same time in an artificial environment, human-based experiments also permit to test a single variable, though with some variation induced by the fact that a human being is performing the experiment. The latter is considered more reliable for comparative trace production as it is closer to prehistoric conditions. The advantage of machine-based experiments lies elsewhere, for instance, in the detailed understanding of trace formation, but it does not permit a direct comparison with archaeological wear traces or residues. Machine-based experiments are thus by definition methodological in nature, while experiments performed by humans can be oriented on methodological or thematic issues (i.e. archaeological case study, hypothesis testing). An ideal reference library includes examples of both types of experiments, in agreement with the topics addressed by the researchers using the reference library.

# Production of the experimental stone tools

## Raw material

The main raw material used for the TraceoLab experiments is flint that is directly collected from the Harmignies quarry (area of Mons) in Belgium. This material has easy access from Liège university. It is a fine- to medium-grained flint with some inclusions.

Other raw materials are procured mainly in the vicinity of archaeological sites under investigation (e.g., France, Germany, South Africa, Ethiopia). As a result, the collection also includes pieces in chert, radiolarite, quartz, dolerite, quartzite.

## Knapping

All stone tools from the initial collection of Veerle Rots have been produced by three knappers mainly: Louis Pirnay (Ϯ), Philippe Pirson and Claude Bawin. All three are experienced knappers, with the late Louis Pirnay being the most experienced one at the time (1998-2011).

Since 2012, nearly all stone tools from the TraceoLab reference collection are manufactured by Christian Lepers who has about 25 years of experience in stone knapping. He only uses hammer materials compatible with prehistoric conditions, being various stone, bone, antler and hardwood hammers, next to compressors. He is experienced in different reduction techniques as well as in shaping.

# General experimental protocols used at TraceoLab

In most cases, TraceoLab experiments are performed outside, unless the topic of the experiment does not require it. All data with regard to their production, possible retouch and their use are registered in detail on registration sheets. All pieces are systematically photographed before and after the experiment. Pictures, and if relevant videos, are taken at different moments during the experiment.

Christian Lepers is the main user of experimental tools and has as such acquired a lot of experience. Indeed, he has been using stone tools on a nearly daily basis for close to 10 years now. This permits to overcome problems that could be caused by inexperience in using stone tools. Other researchers also participate in the experiments and the tool user is systematically recorded on the registration sheets.

For projectile experiments, an artificial target is frequently used, the details of which have been described earlier (see Coppe and Rots 2017). The artificial target is standardly composed of a nearly complete animal skeleton encased in ballistic gelatin. Ballistic gelatin has been used since a long time as a proxy for animal bodies in prehistoric ballistic experiments, following their successful use in military experiments. The bloc of ballistic gelatin containing a real skeleton is subsequently covered with a fresh or rehydrated animal skin. Skeletons are refitted into anatomical position using plastic wire; no metal is used to avoid potential friction wear on the stone points during the experiment. The gelatin (Type A, 240–260 bloom) is mixed with an amount of 10% of weight in water at 45 °C and the bloc is cooled in a cold chamber at 4 °C during 48 h. To the basic recipe, two drops of essential cinnamon oil are added per 4 l to increase the transparency of the mixture, which constitutes one of the important advantages of using gelatin for projectile experimentation as fractures within the target are perfectly visible.

The artificial target we created had the intention to be as similar as possible to a real animal, thereby mimicking the variation in type of contact and contact material of an animal target. In our opinion, such a target is required when examining fracture patterns in detail because it offers the possibility that a point may slide against a rib instead of only touching it head-on (cf. bone plate), which is similar to real hunting situations. The choice is guided by the objective to try and obtain the most reliable data attainable in an artificial context on the variation in fracture types and on fracture frequencies.

# Main themes of the experiments

## Production

This experimental set covers a range of hammers and production techniques in view of understanding wear and residue formation. Results are mostly published (Rots 2010b, 2012). It currently contains about 650 pieces. In addition, various retouch techniques have been incorporated.

## Tool use

A first part of the tool use experiments concerns repetitive, systematic experiments focusing on use-wear formation with use durations varying between 1 minute and 3 hours, for each of the main worked materials, in both dry and fresh state, and for each of the main use motions (about 650 pieces). This collection is mainly used for training purposes and integrates the following activities:

* Woodworking: dry and fresh, hardwood and softwood; motions: scraping, shaving, cutting, adzing, grooving, perforating
* Hide working: dry and fresh; motions: scraping, shaving, cutting, perforating
* Bone working: dry and fresh; motions: shaving, scraping, cutting, grooving, perforating
* Antler working: dry and fresh; motions: scraping, shaving, cutting, grooving, perforating
* Butchering

Other activities are also represented in the collection, like processing various mineral materials, fish, ivory, shell, plants, etc.

A second part of the tool use experiments focused on raw materials other than flint, such as quartz, dolerite, hornfels, obsidian form an important part of the collection (about 550 pieces). These experiments were performed within the framework of several studies, mostly regarding African archaeological sites (de la Peña et al. 2018; Taipale and Rots 2019; Rots et al. 2017; Rots et al. In prep.).

In a third part of tool use experiments of TRAIL, more elaborate attention was devoted to certain use-related topics. Hide working is part of the standard worked materials represented in the collection, but a specific large-scale experiment has been organised to focus on different hafting techniques, raw materials and hide working stages (about 120 pieces specifically for this experiment). Projectiles also form an important part of the reference collection as it is one of the key research topics of TraceoLab. A range of experiments has been performed, focusing on different projectile morphologies, raw materials and propulsion modes (about 1000 pieces). These experiments were part of broader archaeological studies (de la Peña et al. 2018; Rots 2016; Rots et al. 2017; Taipale and Rots 2019; Tomasso et al. 2015; Tomasso et al. 2018), but a large-scale methodological study was also performed within the framework of a PhD research (Coppe & Rots 2017, Coppe et al. 2019, Coppe 2020) and is currently being continued upon (Tydgadt In prep.). Closer attention was also devoted to strike-a-lights (about 30 pieces). The latter experiments focused on different techniques of fire making in the context of the interpretation of archaeological traces. Results are mostly published (Taipale et al. 2020; Tydgadt 2019b; Rots 2011, 2012, 2015; Sorenson & Rots 2015). Various other experiments have been performed but are not further detailed here (about 500 pieces).

## Prehension and Hafting

A large set of the collection focusses on prehension and hafting traces (about 500 pieces). It mainly relies on the work performed by Veerle Rots in her PhD research (Rots 2002; 2010a). A range of hafting materials and hafting techniques is represented:

* Haft type: juxtaposed, male, male split
* Various handle materials: wood, bone, antler; next to wrappings (animal and vegetal material)
* Fixing mechanisms: bindings in plant or animal material, glue

All pieces were used for durations from a few seconds up to several hours. Results have been broadly published: Rots 2002b, 2003, 2004, 2008, 2010a; Rots et al. 2001; Rots and Vermeersch 2004.

Additional hafting-related experiments have been performed in the framework of the PhD research of Noora Taipale (2020) and Sonja Tomasso (2021). Also bifacial pieces and their hafting form another important element in on-going research and their numbers are increasing in the reference collection. Specific experiments with regard to the hafting of projectiles have been performed and are still on-going. Also glue hafting has been examined more closely (Cnuts et al. 2018; Rots et al. 2020; Tydgadt and Rots In prep.).

## Residues

Most of the experiments on residues performed up to now have been part of the PhD research of Dries Cnuts mainly and focused on both methodological issues (e.g., Cnuts and Rots 2017, Cnuts et al. 2018a, 2018b, Cnuts 2021) and archaeological case studies (Douze et al. 2020; Tomasso et al. 2020). In addition, a series is included that specifically focuses on exploring the potential of the scanning electron microscope (SEM-EDS) in residue analysis (Hayes and Rots 2018, Hayes et al. 2019). The collection currently contains about 350 stone tools specifically devoted to residues. A residue library of organic and mineral materials is also available (about 500 pieces).

## Transport

Within the framework of hafting research, it was examined whether traces from human transport in a bag could possibly be confused with hafting traces. To do so, different transport situations have been compared. The reference set consists of about 80 pieces. Results are included in Rots (2010a).

## Trampling

Different trampling experiments have been performed (about 100 pieces), one focusing on fracture formation on flint tools (not published, but partially included in Rots 2002a, 2010), and another one focusing on notch formation on quartz (de la Peña et al. 2018).

## Excavation

The impact of several excavation protocols, including sieving, has been tested (about 150 pieces). Results are published (Cnuts et al. 2021).

## Friction & Storage

The experiment intended to evaluate the impact of stone-on-stone friction due to transport of tools in bigger bags or due to storage of stone tools on large mixed platforms (about 150 pieces). Results are largely published (Rots 2010).

## Fire

A large-scale fire experiment has been performed to evaluate the influence of heat from an adjacent or overlying fireplace on adhesive preservation on stone tools. In addition, smaller follow-up experiments have been performed bringing the total number of pieces to about 180. Results are published (Cnuts et al 2018a, 2018b).

## Taphonomy

Taphonomic experiments have been performed within the specific context of residue research and these are partially published (Cnuts & Rots 2017).

Taphonomic experiments have mainly been performed within the framework of the (on-going) PhD research of Marine Michel. It concerns human-made, natural and machine-based experiments. This collection currently consists of about 470 pieces. Parts of this collection have been published (e.g., Michel et al. 2019).

# Conclusion

The above-mentioned composition of TRAIL, the TraceoLab experimental reference library for traces and residues, is considered to permit reliable identifications and interpretations of archaeological wear traces and residues. In spite of its elaborate size and varied composition, such a library is never complete and it systematically needs to be expanded upon as research continues. Indeed, nearly each archaeological case study requires an accompanying experimental program, the size of which depends on the issues at stakes. An archaeological study may thus require follow-up experiments, experiments with local raw materials in order to guarantee comparability between the traces and patterning, or experiments aimed at testing specific hypotheses. In addition, more methodologically oriented studies may also require experiments, the extent of which is often more important than for other studies. The current composition of TRAIL is already elaborate and it thus consist an indispensable tool for reliable use-wear and residue analyses. All members of TraceoLab have free access to this collection, but also external researchers can request access for particular research projects.

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