Chapter 2
Macro and Micro Evidences from the Past: The State of the Art of Archeological Use-Wear Studies

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2.1 Introduction

Since very early, functional interpretations on prehistoric tools revealed large interest and investment, becoming an emergent method in the archaeological research. In fact, the first reference to functional interpretations on archeological lithic tools was made during the late nineteenth century and beginning of the twentieth by research of John Evans (1897), John Spurrell and Morse Pfeiffer (1912), Cecil Curvew (1930), and Denis Peyrony (Peyrony 1949), mostly focusing on the analysis of macro-wear traces and fractures identified in the surface of lithic prehistoric tools.

Following these initial efforts, during the 1930s, Sergei Semenov research focused on the observation of physical alterations on the active areas of lithic and bone tools made and used by prehistoric human populations. Starting with the pioneering work of Semenov, (Semenov, S. 1957) resulting in his Ph.D. dissertation "Pervobitnoya Tekhnika" (i.e., prehistoric technology), new methods were introduced in functional studies. Based on experimental observations, use-wear analysis became an important proxy to identify and classify wear traces that allow functional interpretations. From a theoretical

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J. M. Marreiros et al. (eds.), *Use-Wear and Residue Analysis in Archaeology,* Manuals in Archaeological Method, Theory and Technique 10, DOI 10.1007/978-3-319-08257-8_2

point of view, Semenov's work follows the Marxist perspective that characterized the Russian archeology during the twentieth century (Trigger 1984, 2006). According to this theoretical agenda, the technological characterization of archeological artifacts was seen as a fundamental proxy to understand the economic and social organization of the past populations. This techno-functional approach shows no distinction between the history of tool production and the human record, from which the main goal was to understand the origin and function of the first tools used by humans, allowing the reconstruction of human technological evolution (Childe 1936, 1942; Clemente et al. 2002; Klejn 1982; Longo et al. 2005; Phillips 1988).

Semenov's research, first published in Russian, was translated and presented to the Western Europe during the 1960s (Semenov 1964). The introduction of Semenov's methods in the Western world is associated with the emergence of the New Archeology (e.g., Binford 1962). Following this idea, the New Archeology agenda, emergent from the American anthropological school, placed emphasis on the use of a tool as a result of a specific task made by humans (Schiffer 1975), resulting from an environmental and cultural stimulation (Hayden and Kamminga 1979; Shiffer 1976). Thus, according to this interdisciplinary approach, the archeologist is seen as a social scientist, whose main concern is to infer about human technological, economic, and social behavior and organization reflected on the *function* and *use* of tools. Therefore, use-wear analysis was seen as one of the keys to interpret the archeological record as a clear indicator of human behavior (Sterud 1978), and an essential proxy for the reconstruction of social and cultural human behavior and organizatiomn (Redman 1973).

During the initial phase, use-wear studies were developed from Semenov's work and characterized mainly by methodological questions, with three main concerns:

1. The studies were carried out on different raw materials and activities, testing distinct variables used on experimental replications, blind tests and ethnographic data (e.g., Bamforth 1986; Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980; Shea 1988)
2. The use of low power magnifications, mainly focused on macro traces (i.e., edge damage) and fractures resulting from tool use kinematics (Brink 1978; Broadbent 1979; Kamminga 1982; Nilsen and Dittemore 1974; Hester and Heizer 1973; Hester and Shafer 1975; Rosenfelid 1971; Sonnenfeld 1962), although some studies start introducing micro approaches (Hayden 1979)
3. The review of the terminology of the discipline and its methods. Since Semenov's work, use-wear studies have developed new analytic methods, improving the accuracy in the identification and record of use-wear traces on archeological tools and functional interpretations.

In this scenario during the last decades, use-wear disciplines were characterized by the development of numerous methodological agendas, mainly focusing on experimental studies (Anderson 1999; Buc 2011; Fischer et al. 1984; Hodgskiss 2010; Odell and Cowan 1986; Pétillon et al. 2011; Shea et al. 2001), blind tests (Álvarez et al. 2011; Evans and Donahue 2005; Odell and Odell-Vereecken 1980; Wadley and Lombard 2007), identification and quantification (e.g., Grace et al. 1985; Gonzalez-Urquijo and Ibáñez-Estevez 2003; Vardi et al. 2010; Stevens et al. 2010) of all different kinds of use-wear traces and residue remains on different materials such as lithics, bone, shell and ceramic, among others (e.g., Hardy 1998; Langejans 2010; Lombard 2005; Lombard and Wadley 2009; Wadley et al. 2004). Such multi-approach of use-wear and residue analysis led to the development of specific and complementary techniques in order to improve a clear and solid background to the interpretation of technology, resource exploitation and settlement patterns from different chronological and geographical contexts that characterized human prehistoric behavior.

2.2 Functional Studies vs. Typology and the Beginning of the Use-Wear Studies in Western Europe

Experimental and ethnographic data allow the use of analogy between the observed artifacts and archeological tools. The French ethnographic approach, led by Leroi-Gourhan (1964), had a significant contribution to lithic studies. Lithic tools, such as endscrapers, sidescrapers and burins were categorized due to their morphological similitude with observed tools, as indirect evidence (e.g., Vila 2002). In this debate, the relation between typology and functionality was early explored, during the construction of the so-called descriptive lithic typology, whose classification is based on the technological and morphological attributes, from which functional interpretations were made, assuming that only the retouched pieces were used as tools (Sonneville-Bordes 1954; Sonneville-Bordes and Perrot 1953, 1954, 1955, 1956).

As mentioned above, during the first decades, functional interpretation of lithic tools was marked by an exciting discussion and criticism to Semenov's work. François Bordes and Semenov themselves played one of the main debates focusing on the methodological aspects of how to analyze functionality and the evolution and reconstruction of human technology from lithic assemblages (Bordes 1969; Bordes and Sonneville-Bordes 1970; Semenov 1970).

Refusing the classical typological classification, Semenov's perspective was that the functional attribution based in a simple analytical description with no direct evidences of use was erroneous (Semenov 1970). On the other hand, according to Bordes, the so-called functional types should not be only based on use-wear analysis. However, Semenov argued that "[…] typology assumes an important role in archeology […], however, Paleolithic studies should not be limited by typological classification. Researchers show enquiry about function and use of human old stone tools. Thus, Paleolithic studies need a paleoethnographic and paleotechnological reconstruction of the past human societies" (Semenov 1970, p. 123). Therefore, according to Semenov, functional studies, combined with typological categories, allow a broad and complete interpretation of the lithic technology, reflecting prehistoric human socio-economic patterns.

From a functional perspective, the definition of lithic tool refers to a lithic artifact that was used to modify other material, independently from the raw material, morphology and presence or absence of retouch, and, therefore, according to

Semenov's perspective, this can only be directly tested using use-wear analysis. Due to these debates, during the last decade functional studies have focused on this dichotomy between retouched tools and functional interpretations: (1) the presence of retouched is not diagnostic to tool use, since tools without retouch show wear traces, (2) the used edge is not always the tool active area but the handle edge, (3) several tools had multi-functions, showing different active areas associated with different uses. This approach focusing on several topics on lithic technological studies led to a new interpretation on different lithic morph-types and technological strategies (e.g., Bicho and Gibaja 2006; Gassin 1996; Gibaja and Palomo 2004; Ibáñez and González 1996; Igreja 2005; Moss 1983; Plisson 1985).

2.3 The Definition

Use-wear and residue analysis refers to the study of wear traces on the edges and/or surfaces of objects caused by use (e.g., Fullagar and Matherson 2013; Odell 2004). Although with some initial skepticism, use-wear studies revealed to be one of the most important disciplines to interpret site and artifacts function in the archeological research (Grace 1996; Stafford and Stafford 1983). As mentioned above, the initial phase of use-wear research was marked by several methodological and theoretical debates including the methods, terminology, and its definition. In fact, the terms traceology, *functional analysis* or *use-wear and residue analysis*, commonly used today, were adopted only in the last decades. Associated with the emergence of the Marxist agenda, the term *traceology* or *traceological analysis* (e.g., Levitt 1979), praises the concept of *wear traces* and characterizes the *mechanical* character responsible for the formation and modification of tool edges and surfaces, as main indicator of the tools' function (Semenov 1964). Thus, during the 1970s of the twentieth century the terms *use-wear analysis* and *functional analysis* were introduced and globally embraced during the "Conference on lithic use-wear analysis" held in Vancouver (1977).

Since the 1990s the use-wear research has brought in new methods characterized by new technological techniques, microscopic systems and software, and include the investigation of different materials such as residues (e.g., Christensen et al. 1992; Fullagar 1993; Thomas 1993). In this scenario, parallel to the technological novelties, different types of archeological contexts, chronologies, and raw materials were analyzed, such as lithic (e.g., chert, quartzite, quartz, obsidian), organic (e.g., bone, ivory, antler and shells), ceramic, and metallic tools (e.g., Anderson-Gerfaud 1980, 1981, 1983; Barton and White 1993; Bertrand 1999; d'Errico and Giacobini 1985; d'Errico 1993; Évora 2007; Donahue 1988; González and Ibáñez 1994; González and Ibáñez 1993; Lemorini et al. 2005; Lammers-Keijsers 2008; Moss 1983; Plisson 1985; Sidéra and Legrand 2006; Semenov 1964, 1981; Unger-Hamilton 1988; Villa and d'Errico 2001).

Recently, this multidisciplinary approach in use-wear studies was expressed during the International conference on use-wear analysis 2012 held in Faro, Portugal.

The meeting was marked by contributions from all different use-wear topics, such as theory and methodology, archeological artifacts, and residues analysis (Marreiros et al. in press). As a consequence of this approach the Association of Archeological Wear and Residue Analysts (AWRANA) was established. Aiming to bring together specialists in archeological research who deal with the analysis of artifacts to study function and modification, the association extends to all aspects of wear, modifications, and residue in different artifact materials (Fullagar and Matherson 2013).

2.4 Methods and Techniques

As mentioned above after the introduction of Semenov's contribution, the first use-wear studies were mainly characterized by low power magnifications simply replying Semenov's methodology using a stereomicroscopy (low-power approach, 5× to 60×, generically <100×). These observations focused mainly on attributes such as edge angle and profile, edge damage, and diagnostic fractures (Brodbent and Knutsson 1979, 1981; Kamminga 1982). According to the classification and distribution of these attributes on artifact edges and surface, the observations using low-power method revealed a huge difficulty to identify in detail some traces, since this approach makes possible only the preliminary identification of the nature and hardness of the worked materials and type of movement (Grace 1996; Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980). This procedure led to a strong criticism on Semenov's methods, and many authors considered the methodology inappropriate to clearly identify diagnostic wear traces associated with a specific worked material. Today we know that these assumptions were likely related to: (1) the use of reduced focus microscopes and (2) the absence of an experimental program. After all, according to Semenov observations, functional studies should identify different types of diagnostic stigmas using both low and high magnifications using an experimental background reference (Semenov 1964).

The high-power approach was introduced by Lawrence Keeley (1980) that initially used a reflected light microscope (10× to 400×). According to Keeley, the high-power method, allows, not only to distinguish the degree of hardness of the worked material, but at the same time identify and classify different types of material (e.g., hide, wood, bone, antler, etc.; Keeley and Newcomer 1977). In the 1970s, the publication of "*Technique and methodology in microwear studies: a critical review*" (Keeley 1974), shows that use-wear analysis requires a quantification method of the diversity development and distribution of micro-wear traces, of which one of the most important is the polish formation (Vaughan 1985).

According to this new methodological protocol, the high degree of observation on high magnification almost eclipsed the low power approach, claiming that diagnostic polishes rendered macro observations of surface and edge fractures. However, the polish formation was not clear and its analysis shows some difficulties associated with: (1) distinct materials producing distinct polishes and (2) how to quantify those distinctive polishes.

Nevertheless, the debate between low and high power microscopy continued over the last decades, mainly considering the advantages and limitations of both approaches. As a result of this debate, during the Uppsala conference in 1989 (Graslund et al. 1990), several papers focused on the low and high magnification, consensually showed that both methods were complementary and not alternative for clear functional interpretations (Odell 2001; Olausson 1993). These two approaches and their proposes were categorized: (1) macroscopic observation (low magnifications), using a stereoscopic microscope, allows the identification of macro-wear traces (e.g., edge damage and diagnostic impact fractures) and detect the area that should be analyzed using microscopic observations (high magnifications); and (2) microscopic method, that allows a detailed observation, identification, and record of micro-wear traces in the tool edges and surfaces, not visible using only macroscopic approach (e.g., striations and polish formation).

In sum, the combination of both approaches marked the beginning of a new integrated methodology, although the debate on standardized criteria and quantification methods for all different micro-wear traces is still today one of the main methodological debates in use-wear studies. Therefore, during the last decades the effort has been to develop standardized criteria (i.e., methods and terminology) for an objective use-wear analysis. This became even more relevant during the 1980 and 1990s, since one of the main goals of use-wear studies was to identify and quantify different wear traces associated with all possible different processes (i.e., use, fractures and postdepositional; Grace 1996) and raw materials (e.g., different types of lithic rocks: chert, quartz, quartzite, and obsidian; Yamada 1986). These studies show that the configuration of distinct categories of wear traces, such as formation, distribution, extension, and morphology, were influenced by a large range of variables (Akoshima 1987), for which the experimental tests became the main reference for testing hypotheses (e.g., Anderson-Gerfaud 1988; Josht 2006; Odell 2001).

Initially, the polish formation was described based on simple visual characterization. However, this method had several problems, since the identification of different polishes were subjective and not clearly quantified (Mansur 1983; Vaughan 1985).

One of the main debated topics during the last decades within use-wear studies is to create standardized criteria of quantification for wear traces. At the same time Yamada (1986) and Bradley and Clayton (1987), using the macroscopic analysis of chert microtopography argued that different raw material compositions influence the wear-traces formation. Akoshima (1987) argued that wear-traces analysis should record and measure shape and distribution of different macro- and micro-traces (number, shape, distribution, extension, and termination). Experimental tests and the creation of quantification methods must play an important role in use-wear studies. According to this idea the creation of a recording method built a quantifying basis for functional interpretation, grounded on recording differences during the formation of wear traces, material hardiness, and movement.

Thus, during the last decades use-wear studies focused on developing several quantification methods and specific software, from which the main goal was to identify the origin, classification, and agents responsible for the polish formation process on the micro-topography of tool surface. Following these questions, the meetings “Technical aspect of micro-wear studies on stone tools” (Ungrath et al. 1986) and “Le geste retrouve” (Anderson et al. 1993) marked the impulse on the interpretation and quantification of polish formation. This debate was followed by several projects such as the “Fast expert system” and “Image processing software” (Grace 1996; Grace et al. 1985; van den Dries 1994), interferometry (Dumont 1982), image analysis (Grace et al. 1987; Vila and Gallart 1993; González-Urquijo and Ibáñez-Estevez 2003) or atomic force microscopy (Kimball et al. 1995), and recently scanning electron microscopy (SEM; Debert & Sherriff 2007; Mansur 1983) and lase scanning confocal microscope (LSCM; Evans and Donahue 2008; Evans and Macdonald 2011).

At this moment, the methods used in use-wear and residue analysis follow four main observation techniques: optical microscope, that includes (1) macroscopic (low power) and (2) microscopic (high power) magnifications, (3) scanning electron microscope (SEM), and (4) laser scanning confocal microscope (LSCM).

2.4.1 Optical Microscope

As mentioned above, the most common technique used on use-wear and residue analysis is the light-sensitive optical microscope method, including macroscopic (low power) and microscopic (high power) magnifications. Low power use-wear analysis is usually referred as stereomicroscope analysis using magnifications between 4–10×. In this apparatus, the artifact is illuminated by reflective light that could be placed in different angles, enabling shadow effect. In this procedure, all edges and surfaces of the artifact are systematically analyzed, in order to analyze and record small fractures and features, as well as to select the areas for microscope observation (e.g., Kamminga 1982; Odell and Odell-Vereecken 1980, 1981, 2004; Tringham et al. 1974). On the other hand, the high power technique consists the use of a metallurgical microscope at higher magnification with incident light perpendicular (90°) to the material surface. In order to distinguish, classify, and record different wear traces, such as polish, the high power magnification (50–400×) is the most successful technique. As mentioned above, the combination of both magnifications allow a more complete analysis, and during the last decades researches have used both techniques in order to improve methodological approaches (e.g., Grace 1996; Clemente and Gibaja 1998; van Gijn 1998; Rots 2002).

2.4.2 Scanning Electron Microscope (SEM)

The SEM uses a stream of electrons controlled by magnetic or electric fields instead of light illumination projection. This lightning method allows SEM to produce an image at higher magnification, resolution, and depth of field than a traditional metallographic microscope (Del Bene 1979; d’Errico and Moucadel-Espinet 1986;

Hay 1977). However, the use of the SEM technique when applied to archeological analysis has several limitations, mainly regarding to (1) price, since it is an expensive technique, whether buying or renting SEM apparatus, (2) sampling, the SEM analysis is limited to the object volume, and (3) time, due to the necessary time required for sample preparation, when using acetate peels, and analysis. Thus, SEM technique, even being very efficient, is most of the times limited to specific questions and small sample sizes.

2.4.3 Laser Scanning Confocal Microscope

The laser scanning confocal microscope technique consists on an image formed by the conjugation of images of reflected light from distinct focal planes. In other words, this technique creates an image multifocus image in real time. LSCM allows observations ranging between 25–800× magnification (e.g., Debert and Sherriff 2007; Derndarsky and Ocklind 2001; Evans and Donahue 2008; Mansur 1983; Shanks et al. 2001; Scott et al. 2005, 2006). The LSCM florescent technique developed for biomedical research during the 1980s, have been used in the archeological research to illustrate and model (topography) the texture of the analyzed object surface, allowing to a more detailed wear quantification. Contrary to the SEM technique, the LSCM, although expensive, is similar to the traditional metallurgical microscope, with no limitations regarding to sample size and time of use (Evans and Donahue 2008).

2.5 Methods

As previously shown, during the last decades use-wear and residue analysis have developed different and complementary methodological approaches and techniques to a more detailed and complete analysis of all type of wear traces. This section consists on a brief description of wear traces commonly recognized on lithic tools. Traditionally use-wear analysis is organized in two main categories: macroscopic, including edge damage and diagnostic impact fractures, and microscopic traces, referring to striations, polish, hafting traces, and residue remains.

2.5.1 Macroanalysis

2.5.1.1 Fractures

As mentioned above, macro wear analysis focuses on the identification and classification of fractures. The origin and formation of fractures is the results of edge retouched or edge damage resultant from a use of a tool in a specific task. Attributes such as distribution, quantity, and classification are assumed as reflex of various sources responsible for their origin and formation: raw material (e.g., chert, quartzite, quartz), hardness, resistance, and nature of the worked material (e.g., bone, antler, wood), edge angle of the tool, angle of tool to the material, period of time of use, and direction and/or movement of use (e.g., scraping or cutting; Adams 1989; Broadbent 1979, 1981; Grace 1996; Hayden 1979; Hubercome 1992; Kamming 1982; Odell 1981, 2001; Odell-Vereecken 1980; Risch 1995; Semenov 1964; Tringham 1975).

Experimental tests and macro observation show that nature and formation processes of such fractures might be related to various natures and variables. Such complexity and unpredictability indicate that different macro traces were not clearly diagnostic of a specific material and/or use. Nevertheless, experimental work has shown that specific uses and/movements are responsible for a specific origin and distribution of fractures in tools. As an example, regarding to lithic tools, longitudinal movements (e.g., cutting) result in macro and micro fractures in the ventral and dorsal surface of the tool. From transversal movements (e.g., scrapping), macro and micro fractures are concentrated in the surface of contact between the tool and the worked material, and the formation of these stigmas occur normally in the opposite surface to this contact. The distribution is perpendicular to the used edge and show low variability regarding to shape and extension than the cutting movement (e.g., Odell and Odell-Vereecken 1980; Trigham et al. 1974). Also, circular or semicircular movements (drilling or incision), produce fractures in all the edges of the contact surfaces.

2.5.1.2 Classification

The classification of edge damage commonly used in use-wear studies is organized according to the morphology, distribution, position, and termination of the small fractures along the edges (Anderson-Gerfaud 1981; Akoshima 1987; Grace 1989; Gutiérrez 1990; González and Ibáñez 1994; Hayden 1979; Kamminga 1982; Keeley 1980; Odell 1975; Odell and Odell-Vereecken 1980; Tringham et al. 1974; Unger-Hamilton 1988). Morphology is organized by semicircular, circular (half-moon), triangular, quadrangular, trapezoidal, and irregular forms. The continuity or discontinuity between the micro fractures characterized the distribution of the edge damage, while the position refers to the formation of small fractures, which is typed as isolated, aligned, or superimposed. The termination categories indicate the distal end morphology of the micro fractures, described as regular, reflected, stepped, and oblique (90°).

Experimental tests have shown that such morphologies are likely related to type of movement and the resistance/hardiness of the worked material. Thus, for example, it is generally accepted that working soft material (butchering or fresh vegetal material) creates semicircular shapes, and hard materials triangular and trapezoidal (bone or antler). Although some researchers argue that the duration of the work, rather than the worked material, led to the formation of triangular or trapezoidal shapes (Akoshima 1987). Experimental studies and functional analysis, macro and micro wear, allow the identification of diagnostic impact fractures associated with projectile activities (Bergmann and Newcomer 1983; Bradley 1982; Bradley and Frison 1987; Frison and Bradley 1980; Fischer et al. 1984; Geneste and Plisson 1986, 1990, 1993; Lombard 2005; Lombard et al. 2004; Odell and Cowan 1986; O'Farrell 1996, 2004; Shea et al. 2002; Villa and Lenoir 2006). These fractures are categorized in two main groups: (1) macro impact marks, diagnostic fractures, and striations, and (2) micro hafting and prehension traces, polish and organic residues (i.e., resin or mastic).

2.5.2 Microanalysis

2.5.2.1 Striations

Striations consist linear grooves present in the tool surface resulting from the abrasive contact between the tool and the worked material or abrasive materials on one or both surfaces (Semenov 1964, 1981). The distribution and intensity (depth) of the striations were classified in different categories: (1) dark background, as an observed thin dark line, (2) smooth background, characterized by a bright line, and (3) grooves, that consists on a series of parallel grooves and perpendiculars to orientation of the striation (Keeley 1980; Mansur 1983). This classification has been seen as a reflex of different shapes and resistance of the tool and/or worked material. Following this idea, d'Errico (1985) suggests three different types of striations: (1) protuberant, (2) *comet-like*, and (3) stretch.

Vaughan in "*Use-wear analysis of flaked stone tools*" (1985) suggests a third type of classification: deep, superficial, and direction indicator. Deep striations are continuous grooves in the tool surface; superficial grooves are characterized by a succession of punctual linear striations present in a small area that have not deep penetrated in the surface; the direction indicator striations clearly indicates a direction of a certain movement. Although, the data from striation analysis do not present enough data, mainly because striation might be caused by postdepositional disturbance, and the interpretation of tool functional rarely are exclusively based on the striation analysis.

2.5.2.2 Polish Description and Formation

The origin and formation of polish has been one of the most complex and debated topics in the methodological agenda of use-wear studies. From early on, the paper "Technique and methodology in microwear studies: a critical review" from Keeley (1974) states that the main focus of the use-wear studies was the quantification of the development of wear polish formation.

It was commonly assumed among researchers, that distinctive polishes are associated with specific worked materials, and hence the classification and quantification of the polish formation became one of the fundamental questions to be addressed in functional analysis (e.g., Dumont 1982). However, according to some authors the definition and origin of the polish formation had never been precise and objective, and huge criticism was expressed by Grace et al. (1985, 1987). In fact, the formation and distribution of polish is influenced by several variables, some of them not related to its use, including different postdepositional processes such as water, temperature, and other abrasive agents might influence the formation of micro-wear traces and polish (van Gijn 1990; Moss 1983; Vaughan 1985). On the other hand, polish reflects tool's natural characteristics, such as surface micro topography and hardness, and/or raw material texture (Bradley and Clayton 1987; Grace et al. 1993; Keeley 1978, 1980). Other important variable that influences the development of micro-wear traces is the duration and pressure of each action, according to Grace the polish made by the same material but that took different durations and pressure may show significant differences (Grace et al. 1993).

Following that critical view, many researchers developed a matrix analysis based on the different polish characteristics and classifications that were identified during its formation stages (Hubercome 1997; Vaughan 1985). However these attempts were confused and offered many details and low objectivity, making such characterization more difficult.

Types such as smooth-pitted polish, terraced-bumpy polish, stuccolike or gently undulating glow and pit-depression valleys, were not that accurate, and therefore some researchers argued that this typology introduced by Keeley needed to be reviewed and refreshed.

In fact those researchers argued that the analysis of polish is associated with the analyst experience of archeological and experimental materials. Distinguish polish from different materials and movements are easier than make a complete description. Thus, it is important that all researchers have a comparative reference assemblage, experimental materials, and a photographic collection. New technologies, such as image editing software and GIS software started playing an important role to quantify and describe micro-wear traces, making possible the comparison of data from different sources. One of these specific polishes results from the hafting of a tool with a handle. Prehensile wear or hafting traces is still a debated topic in use wear studies (Collin and Jardon-Giner 1993; Keeley 1982; Moss 1983). Many points of this debate are related with all the variables within this process: handle material, used tool and type of adhesive materials, resin, and other organic materials. According to Grace (1993), some of those supposed hafting traces are the result of the tool production process and therefore misclassified. Frequently, hafting is recognized by indirect evidences, such as tool morphometry, functionality, other wear traces, and mainly its distribution on the tool surface. The hafting process is associated with different types of wear traces: polish, striations, edge rounding, and micro striations. However such observation and identification is difficult since much of these traces may be attributed to other factors including technological process, trampling, and postdepositional processes.

This debate was expressed during the meeting "*Technical aspect of microwear studies on stone tools*" in 1985 (Owen and Unrath 1986), with the introduction of methodological approaches as the silica-gel theory, deposition model and abrasive theory, as proxy to impulse the research on the polish formation process (Anderson-Gerfaud 1980; Grace 1990; Kamminga 1979; Meeks et al. 1982; Levi-Sala 1993; Witthoft 1967; Yamada 1993; Yamada and Sawada 1993). The main aim was to determine the origin and formation of distinctive polishes and its association with different various materials. Using image-editing software, Grace (1996; van der Dries 1994) created the "Fast expert system" that could identify and use 33 variables during the polish formation and therefore identify the material worked and its movement.

Thus, it is clearly important that the analysis should focus on all available data, through the different analyzing methods, and not be based only on one single type of wear trace.

2.5.2.3 Hafting Traces

From the early Semenov's work, those archeologists mentioned that morphology and wear traces indicate that many lithic tools were possibly hafted (Keeley 1982; Odell and Odell-Vereecken 1980, 1981, 1994; Owen and Unrath 1989; Semenov 1964; Stordeur 1987), however, hafting and prehension were never intensely explored, and researchers focused on the thought to be working edge. The main argument was that, even if hafting produce wear traces, the contact would be minimal and traces associated with this movement would be not clearly diagnostic to a reliable interpretation, easily confused to any type of minimal result of use of postdeposition modification. Recently, thanks to the experimental works of Rots (2003, 2010), new data has been acquainted, that realized systematically and relying both on microscopic evidences and residues analysis, as well including ethnographic sources.

2.5.2.4 Residue Analysis

During the first phase of use-wear studies, the residue analysis was a separated approach from functional interpretations (Grace 1996). While use-wear analysis concerns the use of the tool, residue studies consists the identification of organic or inorganic residues present on the artifact (Fullagar 1993; Fullagar and Matherson 2013; Haslam 2006). The preservation of such organic results from: (1) heating processes caused by the intense contact and friction between the tool and the worked material; (2) water in the worked material; (3) high percentage of silica in chert tools; (4) the acidity and abrasive particles in some organic materials (Hardy and Garufi 1998; Hardy 2004; Levi-Sala 1986; Lombard 2008; Loy 1983, 1993; Thomas 1993; Fullagar 1998; Shanks et al. 2001). The identification of residues, under favorable conditions of preservation is possible with the analysis of embedded remains in micro fractures, cracks, and micro-striations, or stuck (adherent) to the surface (Haslam 2006; Langejans 2010; Longo et al. 2005; Wedley et al. 2004; Wedley and Lombard 2007). Thus, it focuses mainly on blood and muscular tissue (Gernaey et al. 2001; Hohberg et al. 2009; Tuross et al. 1996), amid (Barton 2007; Lu 2003, 2006), lipids and fat acids (Evershed et al. 2001), animal (bone, scales, collagen or hair) remains (Jans et al. 2004), plant remains and microfossils (phytoliths, pollens, etc.), and pigments (Blanchette 2000).

From the methodological perspective the residue analysis is organized in three techniques: (1) optical incident light macro, (2) microscopic observation, and (3) the observed residue remain is removed for detailed analysis. The identification of the residue remain is made using polarized light microscopy and analysis, depending on the type of remain, may include different techniques, such as a simple biochemical or a spectroscopic analysis.

In residue analysis there are many problems regarding postdepositional contamination from surrounding sediments, organic remains not related to the use of the artifact, and excavation or postexcavation handling of the artifact (Evans and Donahue 2005; Grace 1989, 1996). Furthermore, residue analysis has been used as a complementary method to use-wear studies and functional interpretations in order to interpret the function of archeological tools. Its potential replies properly in the integration and confirmation of macro- and micro-wear data, with the possibility of further specifying the type—or included the species—of the worked material. However, functional interpretations based exclusively on residue observation should be avoided, as extremely dangerous and still unreliable.

2.6 Postdepositional, Collecting, and Sampling Artifacts

One of the main issues of use-wear analysis is the preservation and alterations of wear traces in archeological tools resulting from the postdepositional processes during the formation of the archeological record. From early on, John Evans and George Escol Sellers recognized that several natural processes could produce fractures on lithics tools similar to those generate by human handling (Baesemann 1986; Kamisnka et al. 1993; Levi-Sala 1986, 1993; Mazzucco et al. 2013; Geneste and Plisson 1986; Plisson and Mauger 1988). From this assumption, during the first decades of the development of use-wear studies, several studies show the existence of similarities in wear traces from natural postdepositional processes and human use (Keeley and Newcomer 1977). Factors such as postdepositional alterations and trampling among others might cause significant alterations on tools edge and/or surface such as edge damage, fractures and surface polish, and striations.

During the last decades, experimental tests have tried to replicate postdeposition processes (soil deposition, movement and transport, erosion and trampling) and identification and classification of associated wear traces (e.g., Burroni et al. 2002; Evans and Donahue 2005; Levi-Sala 1986). From these essays, even for similar to use wear traces (macro observation), the stigma resulting from the action of these processes show a random distribution, resulting on isolated and disperse marks (micro observations), that may modify or destroy the use wear evidences (Vaughan 1985).

Resulting from postdepositional processes, the *colored* or *gloss patina*, consists in the deposition of various minerals present in the surrounding soil, water and/or rocks, resulting in the oxidation and corrosion of the tools surface (Anderson-Gerfaud 1980). Other type of postdepositional alteration is the so-called *luster* or *miscellaneous luster* (Gijn 1990). Caused by various natural and mechanical post-depositional processes, this process consists of luminous and lustrous effect distributed in all directions and all over the tool surface (Longo et al. 2001).

Likewise, one of the most important issues in use-wear analysis is the state of preservation of the archeological materials. Besides all the postdepositional processes during the archeological site formation, the recovery (e.g., contact with metal trowels, *metal polish*), cleaning (abrasive cleaning materials or acids), storage (frequent contact between materials), and analysis of archeological assemblages (e.g., metal caliper) may cause surface and edge alterations and therefore interfere with the use wear analysis.

Thus, the use of correct methods and conditions (including the appropriate equipment) after recovering the archeological materials is fundamental to preserve all data available. As a result, during the past years many researchers have held to this methodological process in use-wear studies as follows:

1. Wash and rub the archeological materials must be done with the use of soap and water with hands avoiding any abrasive material.
2. When necessary, due to the presence of concretion or soil remains, the tools should be emerged in a solution of water and hydrochloric acid (5–10 %) for not more than 1 or 2 min, or emerged only in water using an ultrasonic cleaner. Finally, during the macro and microscopic analysis, in order to remove wear grease from handling, the artifact surface is cleaned using cotton imbued with petroleum.

2.7 Final Remarks

This chapter focuses on the historical background of the theory and methodological background of functional studies. Since Semenov's systematic research, use-wear and residue studies had focus on the observation, identification, and interpretation of different evidences of use in archeological tools in order to understand human technological and socio-cultural behavior.

One of the main statements in use-wear and residue analysis is that different variables (i.e., raw materials, worked material, movement) are responsible for different kinds of relict macro- and micro-wear traces, requiring occasionally specific analyzing methods.

Although as discussed above, functional studies are complex, wear traces undoubtedly associated with numerous variables, requiring a constant methodological and technological improvement. This has been clear from the last decades of research, during which functional analysis have focused on different research topics. Therefore, during the last decades, functional analysis was marked by the development of theory, method, and techniques in order to infer prehistoric tools functionality. This methodological agenda effort to improve systematic criteria to clear identify, classify, and interpret all different wear traces, while the development of specific techniques, such as several macro and microscopic approaches (e.g., SEM and LSCM) focuses on specific question related to specific variables.

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http://www.springer.com/978-3-319-08256-1

Use-Wear and Residue Analysis in Archaeology
Marreiros, J.M.; Gibaja Bao, J.F.; Ferreira Bicho, N. (Eds.)
2015, XI, 223 p. 64 illus., 49 illus. in color., Hardcover
ISBN: 978-3-319-08256-1