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Prehistory of the Nile Basin and the Sahara.
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Digital Data and Holocene Lithic Industries in the Sudanese Nile Valley: a Case Study

Although I only met him once, Fred Wendorf has a basic impact on everything I know about archaeology. During my undergraduate years in Miskolc, Hungary, it seemed impossible to gain data about Palaeolithic Egypt until I found a Wendorf, Schild and others article in the Science journal (Wendorf *et al.* 1976). Their names guided me from publication to publication deep into the Northeast African prehistory. Fred Wendorf is and will be an unwavering foundation of our discipline. With this essay I thank him for all the inspiration and knowledge he gave to me.

Introduction

The prehistoric remains from the fourth catarct area of the Nile stand in a vacuum. The uneasy taphonomic situations and the transit location between conventional research areas make these remains difficult to assess in the prevailing chronological and cultural schemes. Grasping the knapped lithics in these frames of reference posits a real challenge, because these artefacts are underrepresented in the discourse about Holocene prehistory of the Sudanese Nile Valley. The Merowe Dam salvage era offers an opportunity to have a fresh look at the role of lithic industries, and the ways how lithic data can be managed. In the case of the

Merowe Dam Archaeological Salvage Project (MDASP), it is hard to escape from the comparsion with the UNESCO High Dam salvage expedition. Both enterprises were realized by international cooperation, conducted at a less known territory in archaeological terms and produced an astonishing amount of new data. One huge difference for the MDASP is its standing on the shoulders of giants. The past fifty years witnessed the elaboration of a Northeast African prehistory with a distinct scientific community.

This remarkable scholarly background is now further strengthened by novel ways of communication, i.e. through "The Internet". Thoughtful management, sharing and co-creating of digital content already play an important role in scientific practice, and eventually, in the production of scientific knowledge. Through digital media, archaeologists are increasingly and inevitably engaged in a cooperative system of stakeholders, which affects many existing norms of disciplinary behaviour. One of the grand challenges for archaeology is not just the use of software or the Web, but to understand their effects on the very core of its method, and to create a cyberinfrastructure for its own.

In my opinion, knapped lithics are a good match for digital care. Current methods in lithic analysis can be extremely data-consuming, in order to take reasonable statements about the archaeological record. For adequate conclusions and cooperation, great quantity and good quality data are essential, hence lithic experts are on the verge of a consensus about the standards of data creation. The logic of digital data processing favours these types of standards, besides, the capacity of digital storage and transfer seems endless. In order to broaden the role of lithics from cultural markers to a versatile record of past human behavior in the fourth cataract area, I hypothesize a need for detailed and structured data about them that can be reused along diverse theoretical considerations. This need can be fulfilled by digital data publication, as one alternative among many others. Through a case study I present the manifold requirements of an effective publication which facilitates data for further research.

1. Lithic artefacts in the Holocene prehistory of the Middle Nile Valley

Lithics are not pivotal players in the discourse about Holocene prehistory of the Sudanese Nile Valley. The regional cultural frames are built upon the relationship between absolute dates and ceramic material (e.g. Dittrich 2015; Garcea and Hildebrand 2009; Gatto 2002a; 2002b; 2006; Honegger 2014; Jesse 2002; Sadig 2010; Salvatori 2012; Salvatori and Usai 2007; Usai 2014). In many cases, lithics only complement these relationships, by typical retouched tools or technology derived morpho-types, as cultural markers. There are indications about the use of lithic tools as projectiles and insets, but so far we know little about debitage products that testify the lion's share of variability in a lithic assemblage (Becker and Wendorf 1993; Caneva and Zarattini 1983; Honegger 2009; Kobusiewicz 1996). We do not have a detailed understanding about the economic and social aspects of lithic production. The recent years saw an explicit need for these informations, accompanied by publications with a more technological orientation and analytical accent (e.g. Dittrich 2011; Dittrich *et al.* 2007; Garcea 2003; Jakob 2010; Kabaciński 2003; Kobusiewicz 2011; Osypiński 2010; 2011; Usai 2005; 2006; 2008).

The present imbalanced assessment of lithic artefacts arose from a host of factors. The first phase of research concentrated on the cultural-chronological outline of the area which was approached through the pioneer ceramic studies of Arkell, Myers and Reisner. Ceramics are recognized as a highly informative record of the past, with a design that changes faster than lithics (Garcea and Hildebrand 2009; Salvatori 2012). The vast distribution of wavy line ceramics over North Africa, the early appearance of ceramic technology and domestication in the Sahara directed the focus of research on questions about interregional contacts. The lithic implements of the Sudanese Nile Valley had got less attention in that discourse (Dittrich 2013; Usai 2006; 2014). Moreover, many publications about the Holocene prehistory of Sudan continued to display the exploratory phase of scientific research, because many areas were just discovered from an archaeological point of view. These publications were and are not intended to unravel lithic technological organization, their aim is to report proceedings. Lastly, the special taphonomic and stratigraphic situations warrant caution about the integrity of lithic assemblages (Dittrich 2015; Salvatori *et al.* 2011; Usai 2014; Wengrow *et al.* 2014). There are many variables to consider before we can recognize the temporal resolution of the preserved remains of a site/layer/concentration.

Lithics constitute the most durable and one of the most numerous artefact category from prehistoric times well until the Meroitic era. Our understanding about lithics today rest on a modest segment of the total variability that can be recorded. This segment approached by heterogenous classification schemas that forged in a gradual discovery of prehistoric Sudan. Complex technological analyses offer a more comprehensive understanding of local lithic traditions, site formation and intersite relations, with a more systematic, high resolution approach to lithic variability (Andrefsky 2009; Barton *et al.* 2004; Hiscock and Tabrett 2010; Holdaway, Wandsnider 2006; Lycett 2015; Scerri *et al.* 2015). To achieve this aim, there is a need for substantial, standards-aligned datasets to share.

2. Digital archaeology and data publication

The prime mover behind the knowledge economy and society today is communication, which is accelerating at an unprecedented pace with the help of Web 2.0 and 3.0 (Boulton 2012; Cerroni 2007). The only 12-years-old Web 2.0 is not a new technological instrument but a novel attitude to digital communication. Instead of a one-sided dissemination tool (Web 1.0), the Internet can be used as an instrument for sharing, discussing and co-creation of contents (Dunn 2011; Limp 2011; O'Reilly 2005; Oikarinen and Karasti 2014). In our everyday world this means social media, blogs, comments, wikis and piles of cat videos. In the scientific method, this is the way of knowledge production.

Knowledge is a preformative act, as it is only embodied in practice (Boast and Biehl 2011). For this reason, generation of knowledge is possible only through engagement with other agents – other people and things, and this engagement must involve data sharing between people. In the field of lithic studies, François Bordes basically transformed our knowledge about the past, only through a transformed practice of lithic data presentation (i.e. with his typology). In 2016, we are facing such substantial changes. The almost infinite possibility to collect, arrange and communicate scientific data evokes René Descartes' bedrock call of science:

„I am calling the best minds to progress further than me, each one according to his bent and ability, in the necessary experiments, and [they] would communicate to the public whatever they learned, so that one man might begin where another left off; and thus, in the combined lifetimes and labours of many, much more progress would be made by all together than anyone could make by himself." (Descartes 1993; translated to English by the author).

The Web 2.0 communication provoked a rapid and pervasive change in the expectations, methods and publication habits of the scholarly community (Austin *et al.* 2015; Boulton 2012; Emanuel 2015; Jamali *et al.* 2009; Kansa 2011; Larivière *et al.* 2015; Morgan end Eve 2012; Oikarinen and Karasti 2014; Richardson 2013; Stodden *et al.* 2013; Wallis *et al.* 2013). E-publishing is gaining ground in opposition to printed media, and this trend is more pronounced in the younger age cohorts of academics. In practical terms the next generation of scholars will acquire scientific information almost exclusively online. Social media also have a growing impact; beside popular channels as Facebook or Twitter, there are specific professional applications (Academia, ResearchGate, Mendeley, Figshare, OrcID etc; Lupton 2014; Perry and Beale 2015). The scientific community is in the online state of a „constant conference". Researchers, institutions, publishing companies and other stakeholders begin to perceive science as a cooperative system with an emphasis on effective communication through digital technologies (Destro Bisol *et al.* 2014). This system of knowledge production is also interlinked with policies and funding. In the EU, it is part of the Digital Agenda for Europe, one of the flagship initiavtives of the Europe 2020 strategy (European Commission 2012).

A grand challenge for archaeology in 2016 is not to accept or avoid these facts but to build a *cyberinfrastructure* in accordance with the special needs and possibilities characterising this field of inquiry (Borgman 2015; Dallas 2015; Hole 2012; Huggett 2015; Kintigh *et al*. 2014). Archaeologists use digital techniques for a long time in their research, from GIS to virtual reconstructions. The majority of archaeological data are also born and stored in digital form, but these data are almost never made public. Apart from skill-related, legal and organizational issues, this practice seems to contradict the scientific method *per se* (Austin *et al*. 2015; Destro Bisol *et al*. 2014). In ideal case, researchers publish their theories together with the data on which theories are built. This allows other scientists to replicate research in order to test associated theories, and to re-use data in novel ways. Data sharing thus is an essential part of the process.

The amount and complexity of archaeological, hence lithic data are growing continuously. Data publication was largely restricted in the printed academic discourse, but it is possible to share in its entirety through digital means. Paraphrasing Angela Close from 1989, this possibility does not take away our problems with data but highlights and rearranges them (Close 1989). We have to redefine what the (published) archaeological data mean; how can we structure and manage them from a professional point of view; what are our technical choices for representation and sharing; lastly, how can we resolve the attribution, curation and preservation of digital data.

2.1. Data in archaeology

There is not a clear-cut definition for archaeological data, nor some supreme court to decide. Pragmatically data are structured information not economical to subdivide in the given structure (Atici *et al*. 2012; Borgman 2015; Van Pool and Leonard 2011). Archaeological narrative represents almost inseparable unity of data and interpretation. From the very moment of their discovery, physical residues of the past are selected, arranged and interpreted by multiple parties. Hence, archaeological data is contextual, contingent and patchy (Dallas 2015). If we accept the scientific method in archaeology, we would give the same epistemological credit for the first and the *n*-th narrative about the past. The main reason for our discredit is that the *n*-th researcher is more distant from the „raw data", because she/he has to work with the results of former published interpretations. This create a confusing data diversity, but scientific method, for the sake of the Descartian benefits, promotes data integrity. Paradoxically, multifaceted interpretation is secured only if data have some distance from their creators' dispositions. This very delicate act of data isolation, basically, standardization is typically a task for expert communities (Atici *et al.* 2012; Costa *et al.* 2013; Dallas 2015; Kansa *et al.* 2014; Limp 2011). This problem is well known in areas where communication is intense. Experts of Wavy Line ceramics reached great progress in integrating methods and terminology, creating baseline standards of study (Garcea and Caputo 2004; Gatto 2002a; 2002b; 2006; Jesse 2002; Mohammed-Ali and Khabir 2003; Salvatori and Usai 2007). The standards are constructed on the material reality of the sherds, reflect the specific archaeological agenda but not comitted to one theoretical position. The trait of „tightly packed zigzag" can be used for a variety of purposes. This consensus on standards is the most important element of archaeological data.

2.2. Data publication

Informal data sharing is typically a one-to-one action embedded in personal conversation (emails). Digital data sharing as publication enhances this practice in order to distribute consistent, standards-aligned datasets for reuse by a wider audience. *Data publication* conforms to disciplinary standards, formal requirements of academic discourse and technical requirements of online dissemination (Kansa *et al.*2014; Kratz and Strasser 2014). Creating such datasets requires extra efforts with some necessary steps presented on Fig. 1.

The dataset is accompanied by documentation that helps other researchers from the same field to use the data. It consists of contextual informations and higher-level theories about the project; data ontology or creation methods as middle-level theory; practical description of variables as low-level theoremes. Currently there are three basic forms of documentation: attached file; separate publication in a data journal (e.g. Journal of Open Archaeology Data); or in a more familiar reverse oreder, where documentation is the published article and dataset is the supplement. Digital repositories attach machine-readable metadata to the

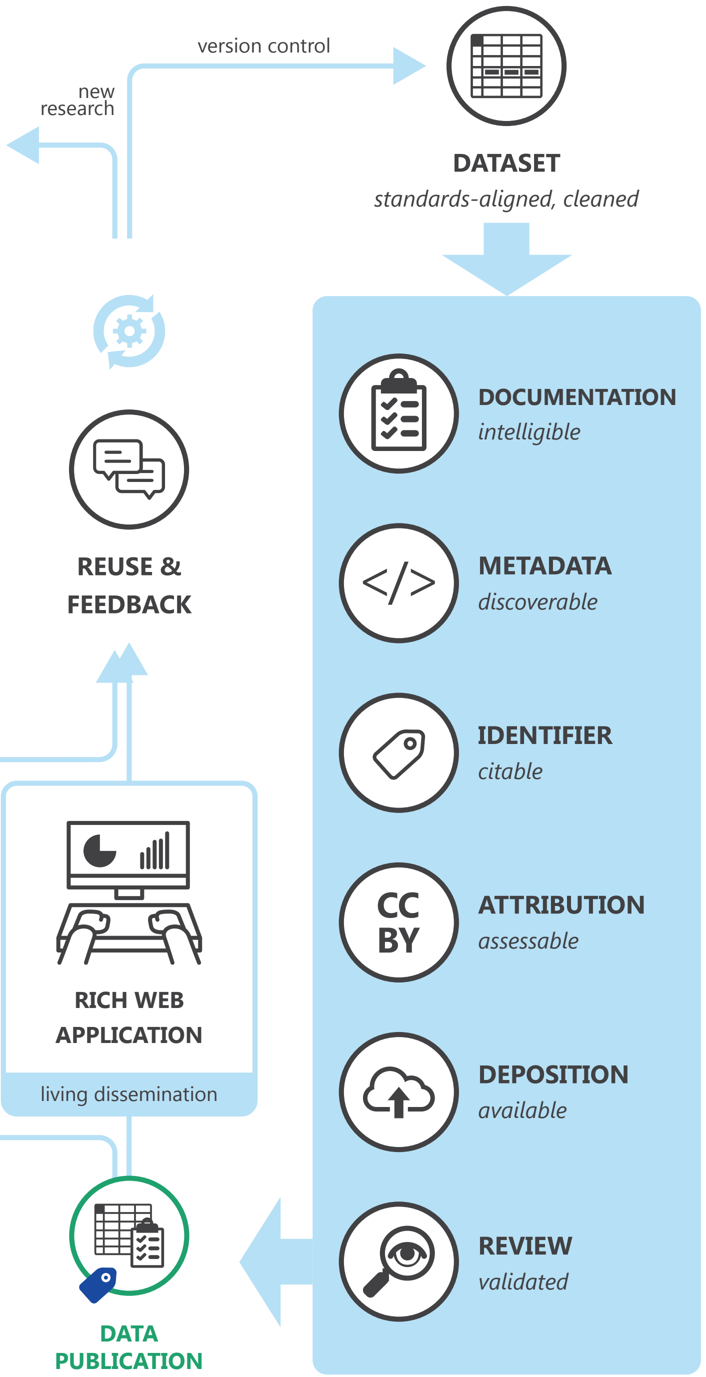

Fig. 1. Main steps of digital data publication

hosted content to make them discoverable by search engines. In most of the cases, these metadata can be manipulated by humans, for example, through tagging. One of the most important feature is citation, which can be secured online by Digital Object Identifiers (DOI-s), in order to implement publication in the academic discourse (doi.org). Online data dissemination and archiving are provided by non-profit, for-profit organizations and public institutions as well. Copyright options can be set by the provider or by the uploader. In the case of datasets an open license is advised which allows to use and manipulate the data. Today we can encounter two distinct ways of dissemination (Costa *et al.* 2013). (1) Static datasets released as stable resources, the files can be manipulated after downloading. This method is comparable to the paper based academic publication scheme with a big difference in storage capacity. Living datasets (2) offer interactive, so-called rich web applications to manipulate, visualize and expand the original content (Limp 2011).

Scientific and instrumental conditions of data publication have a distinct relationship. People use data not read them, thus instruments of use affect recognition, methods of data creation, eventually, interpretation. Archaeological observation usually involves phenomena, not a sole phenomenon. Therefore, analysis basically means organization and classification irrespective of the subject and theory of a given project. Digital instruments have been proven helpful exactly in this kind of work. They made a great contribution to the „scientific boom" in archaeological practice and the materiality turn in archaeological theory we are witnessing today (Killick 2015; Kristiansen 2014).

Print-based academic discourse requires highly filtered and abstract data presentation in order to save space for narratives at all. Online data publication does not supersede this requirement, but creates a problem that is exactly the opposite of scantiness: there is too much space, petabytes of information appear more of an obstacle than help. Web 2.0. takes advantage on quantity and offer personal filtering and abstraction tools. One single database can be repurposed many ways, and many separate databases can be aggregated as one to extract new informations. This degree of control over other people's data is unprecedented, giving the opportunity for multiple interpretation on the same sources. All these advances rely on interoperability, an agreed modularization of observations on archaeological phenomena. Methods of lithic studies evolved in this direction during the past decades: standardization of taxonomy, decoupling observations from the level of lithic tool to attributes, and statistical representation of data.

3. Outline of lithic data management history

Knapped stone tools are part of the whole human story, it is the main source of information concerning the million-years long preceramic era. Data about stone tools therefore have to comply a wide diverse set of theoretical systems, nevertheless, physical qualities of rocks and the act of knapping constrain the range of observable phenomena tight. Lithic data management, or systematics, became more comprehensive, more modular and more versatile to overcome these constraints throughout the years. The modern era of lithic research history begin with the typological work of François Bordes (Bordes 1979). During the sixty years since his *Typologie du paléolithique*… a wide array of methods formed and exist beside each other today. The monothetic, essentialist, teleologic, structuralist etc models apply *a priori* discrete categories for classification. Polythetic, constructionist, evolutionist, analytic etc. models have a bottom up approach. The observed variation serves criteria for pattern recognition (Read 2007; Tostevin 2011; Van Pool and Leonard 2011; Wylie 2002).

The Bordian method originally was a genuine solution for a communication problem. Instead of single artefacts as lead fossils, Bordes recognized the importance of comparsion between distributional patterns in lithic assemblages. This approach demanded huge datasets that was impractical to publish in print, therefore some kind of data shrinking was needed. This need was fulfilled by the concept of type, basic statistics and standardized forms of data presentation: cumulative diagrams, bar graphs, and consistent artefact drawings.

The essentialist view of type postulated a concept of a finished tool in prehistoric minds that can be detected by the skillful prehistorian. Although Bordes never defined the term, his writing made clear that type was a heuristic cherry picking of different morphological and technological traits: „One has to see a great number of implements, classify them, see them again several times, before one acquires a »typological eye«" (Miller and Bordes 1972).

Classic typologies, among them Tixier's work from 1963, defined the analytical units of pattern recognition in typical tools (Tixier 1963). Lithic variability beyond secondary modfied typical tools almost never reached the public, i.e. scientific publication. Soon the scholarly community perceived data *per se* as typical tools and Bordian indices, because these were the primary structured informations appeared in the printed media. This dilemma was addressed by Steward and Seltzer more than 75 years ago: constructing typology in the reality is a conclusive act of intensive research, but other scholars usually begin their research according to an existing typology (Steward and Setzler 1938).

The lively discourse referenced as the Binford–Bordes debate lead the American Reduction Sequence (RS) approach and processual archaeology in general, into the mainstream of lithic studies (e.g. Binford 1973; Bisson 2000; Bordes and Sonneville-Bordes 1970; Rolland and Dibble 1990; Tostevin 2011). The debate centered on the meaning of lithic variability, emphasizing that production and use are dynamic processes, during that form and functions of lithic implements change. Classic types are snapshots of change created by irresolute boundaries along a complex morphological-tehnological continuum. From a processual point of view typology draws a static picture about stone tools, compressing the long history of preparation and use into one sole timestamp (cf. Bailey 2007: 207). Some types in Bordes' schema in fact represented different states of the same process which shook the credit planted in the concept of type as an intentional, finished tool. Technological research, experimental archaeology and later traceology made clear that between use and design there is a complex set of relations (Andrefsky 2009; Hiscock and Tabrett 2010; Holdaway and Douglass 2012).

This functional argument opened up a rupture concerning the aims of stone tool research. Classic culture-historical interpretation of the past was supplanted by research programs that asked for realities of living, subsistence, and social relations of past communities. The RS approach, the French technological school, not least the Schild and Wendorf dynamic technological system compiled a different methodology, when they centered their research on technology and assemblage formation (e.g. Bar-Yosef and Van Peer 2009; Carr and Bradbury 2011; Soressi and Geneste 2011; Lycett and Chauhan 2010; Schild and Wendorf 1977; Tostevin 2011). The scope of analysis included whole assemblages irrespective the degree of modification on a piece. Consequently, the basic unit of research scaled up from artefacts to characteristic traits (*témoins*) or attributes. This resolution shift enabled polythetic classification. After Wittgenstein's game analogy, a stone implement takes only one physical form but according to its attributes can be part of different aggregates simultaneously: microlith by its size, flake by dimensions, sidescraper by location of retouch and grave offering by its context of deposition (Fig. 2). This broad and layered scope of data management followed by new representation techniques. An unambiguous taxonomy and meticulous rules of drawing set foot with the spread of the *chaîne opératoire* concept (Inizan *et al.* 1999). RS approaches adopted quantitative statistical methods and visualization to handle aggregate stone tool data (e.g. Lycett 2015; Magnani 2014; Scerri *et al.* 2015; Van Pool and Leonard 2011).

Current relativism in archaeological theory put emphasis on probability instead of objective facts about the past (e.g. Skibo and Schiffer 2008; Wylie 2002).

The growing amount of research data are impenetrable for the human eye, hence the articulation and confidence of interpretations are crucial today. Heuristic typologies can direct our attention towards relevant trends but the confidence of such interpretations can not be judged. Statistical analytic tools have the means to provide us with tested, statistically significant phenomena and this significance is alluring for the archaeologist. By the 2010s, lithic data management reaching a general consensus along technological organization, attributes (including morphometric data) and quantitative analyses. This approach is in concert with the criteria of digital data sharing as outlined above.

4. Case study: HSAP 057 data publication

HSAP 057 was a surface site at the fourth cataract area of the Nile, explored by the Hungarian Sudan Archaeological Project in 2007 (Király 2008). Its discovery and parameters are characteristic in the area, its lithic assemblage has been chosen as a case study of digital data publication. With this case I intend to present data documentation, the process of publication and the possibilities of curation after publication.

The site was discovered during an extensive survey in January 2007. The present author conducted a systematic collection and test excavation between february 17-24, 2007 (Király 2012). Its spatial coverage was well delineated on the flat plateau of a small gneiss-granite djebel, a common situation in the vicinity (Osypiński 2014). Less than half of the 300 m^2 plateau was free from human sized cliffs. On this free area all the findings here were piece plotted on drawings and the surface was photo-documented by 1 m^2 squares. Because of logistical difficulties only 627 pieces, approximately one fifth of the plotted lithics were collected for further study. Ceramic material consists of 102 sherds that were collected all, other types of artefacts were absent.

Ceramic material have a similarity with Late Mesolithic of the Middle Nile Valley (nomenclature *sensu* Salvatori and Usai 2007): predominantly mineral temper; only decorated sherds; covering and banded decoration, mostly tightly packed zigzag applied by serrated implements, with a few dotted wavy line sherds; lack of incised decoration. Lithics can conform more described industries from the Nubian Middle Neolithic and the Middle Nile Valley Late Mesolithic (nomenclature *sensu* Salvatori and Usai 2007): substantial quartz debitage but few „tools"; many backed implements, mostly lunates on flakes and double backed perforators; cores with one striking platform or sliced cores; dominance of flakes. Overall the site has a late mesolithic-early neolithic character, placing the occupations in the Middle Holocene chronozone, possibly the second half of the 6th millenium, 5500-5000 BC.[1] Study of the lithic material is underway by the author.

4.1. Research questions (high-level theory)

1. What patterns of lithic technological organization can be observed? One of the main question of my study is what human behaviors can be detected in the lithic variability at HSAP057. I am interested mostly in raw material use relative to reduction methods and the criteria of blank selection for further modification.
2. How coherent is the assemblage in spatial and temporal terms? HSAP 057 was a palimpsest of past human activities. Material patterning on the surface was shaped by anthropogenic, geomorphological and other taphonomic processes over millenia. The main question is that what time interval is represented at the assemblage/site level of aggregation.
3. How can I achieve a versatile and reusable database? Working at the fourth cataract region made me clear that the „sites" are arbitrary units in the lihtic-littered landscape, imposed by different research agendas of different working groups. This patchy process of discovery is natural and necessary although the distribution of past human activity is continuous and contingent (Barton *et al*. 2004). Surface distribution of artifacts in arid areas are result of exceedingly complex cultural and natural processes that can not be fully comprehend on site-level. Moreover, lithic economy typically unfold as a multilocal history. Interpretation of one chipped stone assemblage is more efficient if the researcher has the opportunity to navigate across artifact, site and region scales. In order to achieve this, comparable datasets are needed without interfering the particular standards set by individual research agendas.

4.2. Lithic artefact as data (middle-level theory)

I applied a socio-ecological and behavioral archaeological approach to link research questions with artefacts (e.g. Barton *et* al. 2004; Skibo and Schiffer 2008). According to Skibo and Schiffer, human life consists of innumerable interactions with other people and millions of artifacts. Archaeological artefact *is* behavior –

[1] In Király 2012: 175 the date estimation was published as „second half of the 5th millenium BC" because the error of the author.

interaction and its impression in the physical world, the only way that past behavior is accessible to us. Archaeological artefacts parttaking countless interactions since their production, with humans, natural phenomena and other objects as well. This history of an artefact called *behavioral chain*.

Knapping as interaction leaves traces (*témoins*) in the matter. One gesture usually execute one notable detachment with a negative scar on the surface of the block. Series of detachments form a layered topography of negative scars and other stigmata, which can be read as a knapping method. As knapping advances, this topography begin to spread over on all the pieces that is detached from the original block of stone. Use and taphonomic processes cause further stigmata, even thousands of years later than the first detachments. From an epistemological point of view, lithics are aggregates of traces with distinct ontologies. If the aim of lithic analysis is to infer past human behavior, basic unit of measurement has to be the *témoin*, which consists of an attribute (*sensu* Clarke 1968) and its location: on the artefact, at the site, in the region.

The topography of attributes is a valuable asset for the archaeologist because human behavior can be modularized to single interactions, the traces of interactions can be arranged in a relative temporal sequence, and the sequence is detectable over many artefacts. Lithic attributes thus have distinct spatio-temporal

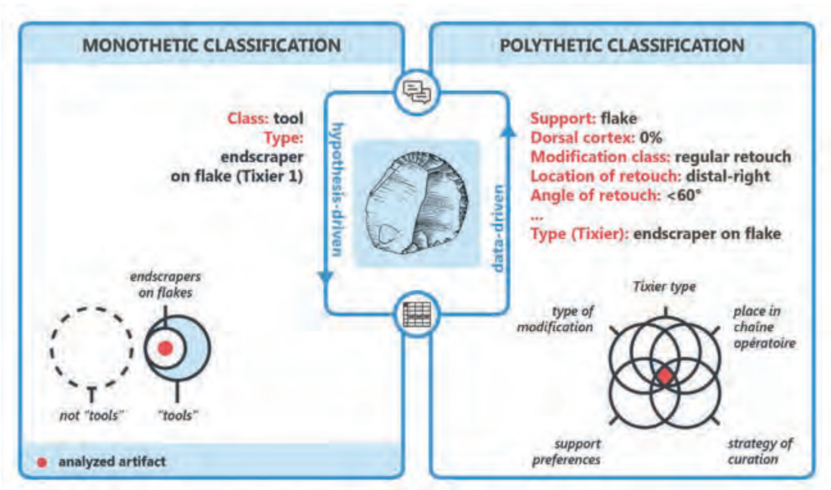

Fig. 2. Monothetic and polythetic classification systems, theory and data driven research models, and their complementary relationship, exemplified by a hypothetical lithic artefact

scales of interpretation with different qualities: extent of an artefact, concentration of artefacts, sites, regions. One single negative scar with certain characteristics can be interpreted as a detachment with a soft hammer; distinct pattern of negatives on a piece can be indicative for a Levallois method; abundant occurence of primary flakes in an assemblage can point on-site decortication; absence of primary flakes from nearby sites suggests that the first site is a local workshop area. Raw material, morphometric and technological data can captured on every single item irrespective of its stratigraphic position or the size of the sample. With the attribute system, these data from mixed surface assemblages can be handled together with data from more secure archaeological contexts.

4.3. Data ontology (low-level theory)

Data collection was determined by three criteria. I surveyed the stone tool research literature for the range of possible analyses, that I compared against the research questions and the character of the assemblage itself. Unit of data capture was the attribute which represent a higher resolution than the units commonly found in published reports about holocene prehistory of the Middle Nile Valley. This resolution was needed because of the technological character of my research and the diverse terminology observed in the reports. In the database, instead of „micropoinçons" there are pieces with dorsal cortex; having converging distal and proximal ends; left and right sides bear secondary modification in their entire length; type of modification is backing. Based on the attributes every user can assemble groups of artefacts according to her/his classification system. The attributes designate technological and morphological traits according to Inizan *et al*. (1999). This publication, beside its analytical strengths offers a multilingual nomenclature.

The database presently contains 131 different attributes (variables), data capture on the 627 pieces required approximately 180 hours (Fig. 3). According to the third research question above, emphasis was placed on versatility. At the present state of inquiry we do not know exactly what attributes are significant in the understanding of lithic assemblages from the fourth cataract region. I registered much more variables than usually needed, to test their significance, and to faciliate tests along different research questions as mine.

Variables along nominal and ordinal scales are attributes that can not be quantified by macroscopic observation, or their quantification would be inefficient. Examples are severity of platform edge damage, intensity of ventral ripples on flakes. The independent grouping variables are nominal too, like debitage catego-

RAW MATERIAL OBSERVABLE DATA

Petrology; nodule form; cortex color; cortex texture; color; texture; patterns, bioclasts, inclusions; brightness; translucence; heat modification; secondary cortex; polish; roundedness

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POSITIVES (CORES, CORE FRAGMENTS AND CHUNKS)
METRIC AND OBSERVABLE DATA

Knapping method; knapping technology; length, width and thickness by maximum dimension; number of non-cortical striking platforms; number of debitage surfaces; number of flake scars; number of flake scars on debitage surfaces

CORES STRIKING PLATFORMS

Length, width, circumference; type of striking platform; angle between striking platform and debitage surface

CORES DEBITAGE SURFACES

Length, width, circumference; degree of damage, weathering, cracks, scaled area; scar count; scar pattern; number of attached striking platforms; number of scars with non-feather termination; dimensions of biggest and last negative

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NEGATIVES (DETACHED PIECES) OBSERVABLE DATA

Debitage class; breakage class; break type; form; form of cross-section; position of dorsal cortex; dorsal scar count; dorsal scar pattern; propagation; termination; point of force; location and number of bulbs; type of bulb; presence of cone of percussion; accentuated ripples; type of talon; talon damage; damage on the ventral proximal and dorsal proximal area

NEGATIVES (DETACHED PIECES) METRIC DATA

Length, width and thickness by maximum dimension, by debitage axis, by morphological axis; outline length; Mass; width and thickness at proximal, mesial and distal sections; bulb length; bulb thickness; talon width; talon maximum depth and depth at the middle; theoretical talon depth; exterior and interior angle

NEGATIVES (DETACHED PIECES) ZONAL-LOCATIONAL DATA

Dorsal cortex coverage; non-modified edge length and steepness; type, location and steepness of edge alteration (non-retouch); type, location and steepness of edge modification (retouch, backing etc.)

NEGATIVES (DETACHED PIECES) BACKED IMPLEMENTS

Type of support; shape of proximal and distal ends; side of backing; direction of backing; shape of backed and non-backed edge; shape of piece in lateral view

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Fig. 3. Selection of attributes recorded on the Mid-Holocene lithic assemblage from HSAP 057, fourth cataract area, Sudan. Source: Király 2016

ry, talon type and different raw material characteristics. Interval scale variables are the metric data that I recorded along all the main orientations in use.

4.4. Process of data publication

Data publication followed the static dissemination model. I pursued criteria for intelligent openness which means that data must be: discoverable, accessible, intelligible, assessable and re-useable (Boulton 2012). During preparation I corrected the inconsistencies with the OpenRefine software (openrefine.org). The cleaned set converted to a Microsoft Access file, with an attached documentation file. The two files together constitute the database for publication. Assessment has been secured with a Creative Commons Attribution 4.0 international license (creativecommons.org). I chose the Figshare repository for archiving, identification and dissemination (figshare.com). After uploading, metadata was created about the content. The uploaded data was reviewed by the editors, and the repository provided a persistent identifier (DOI) for the sake of citation (Király 2016).

4.5. Data curation and version control

The deposited data file is not manageable online, it has to be downloaded to work with it. The author can replace the file without modifying the metadata. Figshare ensures version control, previous versions are stored under separate DOIs. Users can comment the dataset or request the author for modification. This repository offers a free-of-charge membership plan for private individuals.

5. Summary and future prospects

Lithic analysis is an exceptionally data-consuming endeavor, because understanding the production and use of stone tools requires to survey whole assemblages. This magnitude of data cannot be represented in the print-based academic discourse. Apart from compact statistical visualization techniques, researchers increasingly use digital dissemination tools, that do not impose volume restrictions. Data sharing can result standards-aligned, aggregate datasets, wich improves the ability to reproduce distinct conclusions and generate new knowledge. Digital communication is zealously promoted by different stakeholders around the scientific enterprise. Online data publication can comply with the formal standards of academic publication. Several workflows are available, according to preferences and institutional protocols imposed on the author. With the case study I presented a method which is free of charge and does not demand special IT skills.

Stone tools attest great potential in the understanding of Holocene prehistory along the Middle Nile Valley. Particularly interesting problem is the development of lithic technological organization relative to subsistence practices and changing ceramic traditions. Intensive fieldwork during the past decades provided a massive amount of new informations. However, published data about lithics are often preliminary and difficult to compare due to their terminological diversity.

Standards-aligned digital data publication and attribute based studies of knapped stone artefacts repesent a viable option to improve discussion about lithics in the Holocene Middle Nile Valley. The HSAP 057 database certainly will need revisions and additions. Data about retouched implements are insufficient, there are too many nominal variables, more efficient tools will enhance the data resolution and so on. Digital communication of data creates an opportunity to address these issues, prompting a discourse on the methodological foundations of our research.

Addendum

Since the submission of the manuscript a new study was released in this topic with similar methodological approach and conclusions (Marwick 2017).

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