What Materials Can Teach About Learning. an assessment of cumulative culture among the Hominins of Dmanisi (Lower Palaeolithic, 1.8mya, Oldowan, Democratic Republic of Georgia).
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What Materials Can Teach About Learning.

an assessment of cumulative culture among the Hominins of Dmanisi (1.8mya, Lower Palaeolithic, Oldowan, Democratic Republic of Georgia).

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Thesis BA3 – 1083VBTHEY

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Chapter 1: Introduction

The ability to create and utilize tools is not just limited to human species, rather a number of closely and non-closely related species have been observed to possess similar abilities (Shaw, 2021; Völter and Call, 2014; Schick *et al.*, 1999). That being said, *Homo sapiens* appear to accumulate technological developments at a larger scale, in order to increasingly exploit their environment. Extensive research has been conducted into this "cumulative culture"; however, whether its evolutionary origins leans more toward learned social behaviours or individual cognitive ability remains contested (Caldwell *et al*., 2012; Osiurak and Raynaud, 2020; Read, 2020). A common thread in this research has been, and still is, is the subject of cognition, while currently prevailing ideas within academic research are also highly influenced by evolutionary thinking. One source for insights into the cognitive evolution within the human lineage is the archaeological record (Coolidge and Wynn, 2016; Renfrew *et al.,* 1993).

1.1 Summary of previous research

The two paradigms, regarding the origin of cumulative culture, can be summarized in the follow way. On the one hand, there are those who argue the most essential component of cumulative culture is social interactions and the scale at which they take place. This allows humans to create traditions, upon which they can reliably innovate through technological reasoning. However, learning from others is critical in this process (Boyd *et al.*, 2011; Hill *et al.*, 2014). On the other hand, there are those who emphasize developments in the individual's ability to innovate as having been the primary driver for cumulative culture. According to them, the difference between humans and other animals arises from the increased cognitive potential for innovative behaviours. Social behaviours merely establish traditions, which retain innovations within a population (Gruber *et al.*, 2015; Iriki and Taoka, 2012).

This distinction is best explained by an analogy based on a ratchet mechanism (figure 1.1) (Tennie *et al*., 2009). The spinning of the gear can be seen as new advantageous behaviours generated by an individual, as it enhances the ability to exploit the environment. While the function of the gear and pawl can be compared to social behaviours, as it allows for the transmission, and thus the retention of advantageous traits within a population. Over time this mechanism allows for substantial increases in the complexity of technological behaviour.

In order to better understand the relationship of these two aspects of cumulative culture, an analysis of the appearance and disappearance of different lithic behaviours can provide a valuable line of evidence. Through the archaeological record, the retention of social traditions and the appearance technical developments can be brought to light, and in turn, might place both traits in its evolutionary context.

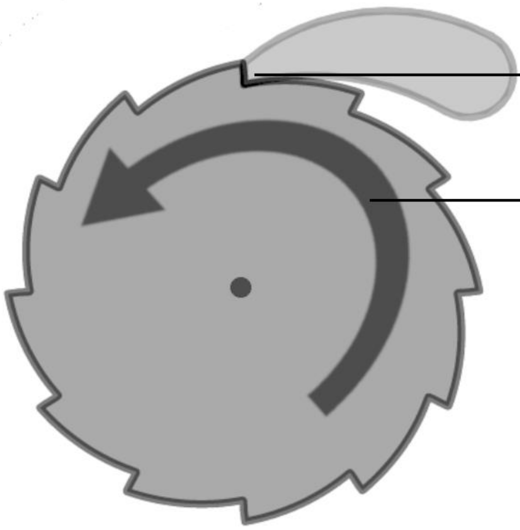

Figure 1.1: Visualization of the ratchet mechanism underlying cumulative culture (By G.J. Kuijt).

Previous research conducted by D. Stout *et al.* (2019), offers a bottom-up model based on identifying aspects of cumulative culture within the archaeological record. This model was applied to three Oldowan sites in Gona, Ethiopia (EG-10, EG-12, and OGS-7). The aim was to empirically differentiate behaviour copying, an ability that facilitates the social aspect of ratcheting, from evidence for other social transmission methods. The model concluded that behaviour copying of knapping behaviour was already present in the Oldowan tradition by 2,6 mya in East Africa. However, no evidence for the large-scale accumulation of cultural traits was discovered. Therefore, the conclusion suggests that cultural ratcheting was yet to be fully developed. This suggests that the focus on the origins of cumulative culture should not be dedicated solely to social learning mechanisms. According to Stout *et al.* (2019), behaviour copying served as an evolutionary prerequisite to further adaptations increasing technological innovation. Technical reasoning is one of the primary drivers for a species ability for technological innovations and the identification of wide-reaching trends, within the Oldowan, may shed light into the evolutionary trajectory of this trait.

The aim of this thesis is to further the process of identifying the relation between social and individual cognitive ability during the emergence of cumulative culture in human evolution. This is achieved through applying the model developed by Stout *et al.* (2019) to another Oldowan site, thus increasing the analysed spatial-temporal record. More specifically, the Oldowan lithic assemblage excavated at Dmanisi, Georgia. The much-discussed site of Dmanisi was chosen because it has played a critical role in human evolution, as it contains some of the earliest evidence for hominins outside of Africa (Ferring *et al.,* 2011). This means, that there is an existing body of previous research that can be drawn from. The main focus for this lithic analysis will thus be centred around behaviour copying with regard to temporally differing sequences, and subsequently the results will be reviewed and placed in the established discussion regarding cumulative culture.

1.2 Research question:

Several notions need to be addressed in order answer the research question: what evidence for cumulative culture is present in the Oldowan assemblage at Dmanisi, Georgia (¬1,8mya) and how does it relate to Gona, Ethiopia (¬2,5 mya)? Firstly, the concept of cumulative culture will have to be described in detail. Moreover, theories regarding its development and the importance of the research must be highlighted. Secondly, a methodology for discovering evidence of cumulative culture in the archaeological record must be established. Thirdly, existing knowledge on the cognitive capacities of the Dmanisi Hominin and the evidence for cumulative culture at Gona will have to be be gathered from previous research. Finally, the broader framework of evolutionary patterns related to cumulative culture must be explored in order to contextualize the results of this thesis.

1.3 Structure of the thesis

The aim of this chapter was to introduce the topic and importance of this thesis, while the research questions serve as the foundation for the following chapters. Chapter two will concern the background of the assemblage, such as find context and excavated materials. Chapter three will consist of a description of the model offered up by Stout *et al.* (2019) and how it will be employed on the Dmanisi assemblage, in order to gain insight into the research question. This will serve as a basis for the results, which are described in chapter four. Here, the raw data of the lithic analysis will be presented, and general trends will be highlighted. Chapter five discusses whether trends in behaviour copying can be inferred from the lithic analysis, interpretations regarding cumulative culture, limitations of this study and the wider implications of those findings. lastly, the final chapter will summarize the conclusions to the research questions and suggests lines of future research for investigating the presence of cumulative culture at Dmanisi.

Chapter 2: Background – The Lower Palaeolithic site of Dmanisi, Democratic Republic of Georgia

Despite dating roughly 0.8 million years after Gona, the site of Dmanisi contains a similar technocomplex, which first appeared in Africa. Investigating the possible social or individual cognitive differences between the two sites, will shed light into the discussion about the origin of cumulative culture. Chapter 2 serves to provide a background for later inferences regarding the cognitive abilities of the Dmanisi Hominins. Firstly, the aim is to provide contextualizing information regarding the excavations at Dmanisi. This includes geographic location, dating and stratigraphy. Subsequently, previous research into the excavated material regarding the paleoenvironment, *Homo* occupation and the corresponding technocomplexes will be summarized.

The knowledge of the first *Homo* dispersal out of Africa has tremendously benefitted from the discoveries made at Dmanisi. Mainly because of the discovery of the oldest (to date) hominid fossils found outside Africa. This suggests one avenue of *Homo* dispersal out of Africa through the middle east. That being said, there remains discussion surrounding the timing of this migration, especially with regard to the hominid occupation at Dmanisi (Agusti and Lordkipanidze, 2011; Ferring *et al.*, 2011).

2.1 Context of the excavation

2.1.1 Topography

The site of Dmanisi is located in the Democratic Republic of Georgia (figure 2.1), approximately 85 km southwest of the capital Tbilisi. It lies raised approximately 80 metres above the present-day waterline, in between the junction of the Mashavera and Pinezauri rivers, which likely run the same course as they did during hominid occupation (Crislip, 2013). Dmanisi served as a defensive structure during medieval times due to its elevated position. For this reason, archaeological excavation had already been taking place before the discovery of the Palaeolithic remains. However, once late Pliocene to early Pleistocene faunal remains were discovered, new research into the site opened up. Upon the initial discovered of intact hominid remains, Dmanisi was marked as a key site in the field of human evolution (Gabunia *et al.*, 2000).

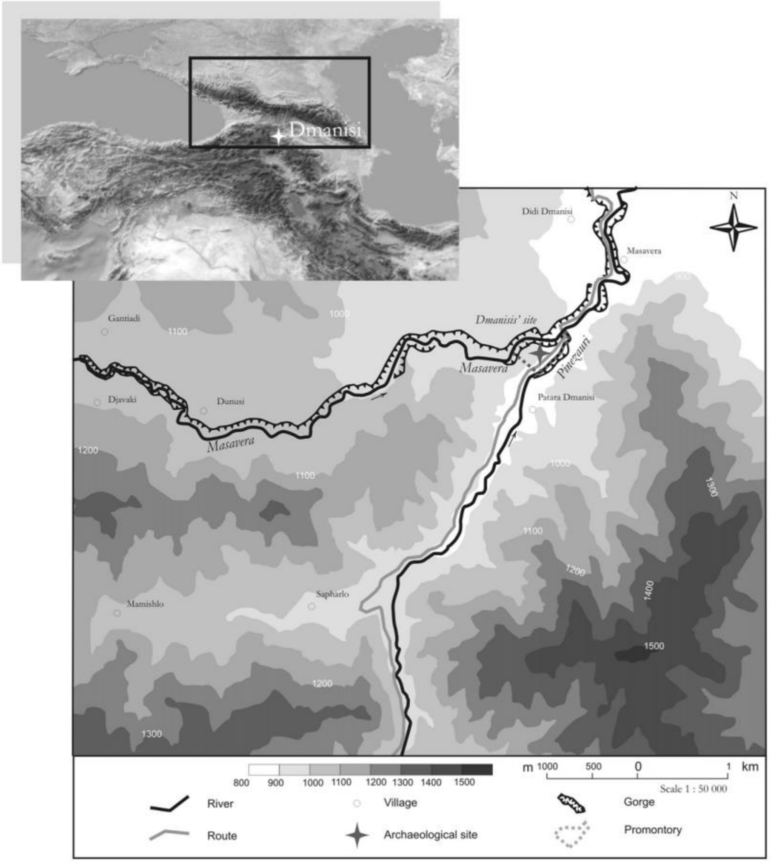

Figure 2.1: Geographical context of the archaeological site of Dmanisi, Georgia (Mgaladze *et al.*, 2011).

2.1.2 Excavation

The excavated area is largely situated within the medieval ruins (figure 2.2). From archaeological work done in the 1980 in the cellar of one of the medieval structures; it became appeared that the medieval ruins were located on top of deposits of Palaeolithic material. Subsequently, excavations more focused on this Palaeolithic period began in 1991 and continued until 1999, the largest trenches (block 1 and 2) were established during this period. The assemblage of early *Homo* fossils was yielded from these two blocks. Furthermore, this excavation also started investigations into unit M5, which is located approximately 75 metres outside of the ruins, and has unearthed lithic artifacts dated earlier than the *Homo* fossils (Ferring *et al.*, 2011). From 2000 to 2008, more excavations took place most notably expansions to Block 2 and M5. Crislip (2013) has done extensive research on the formation processes of the Palaeolithic strata. He concluded that weathering processes did not affect the bone material disproportionally in certain strata over others. Thus, the abundance of bone material accurately reflects the depositional patterning of the past.

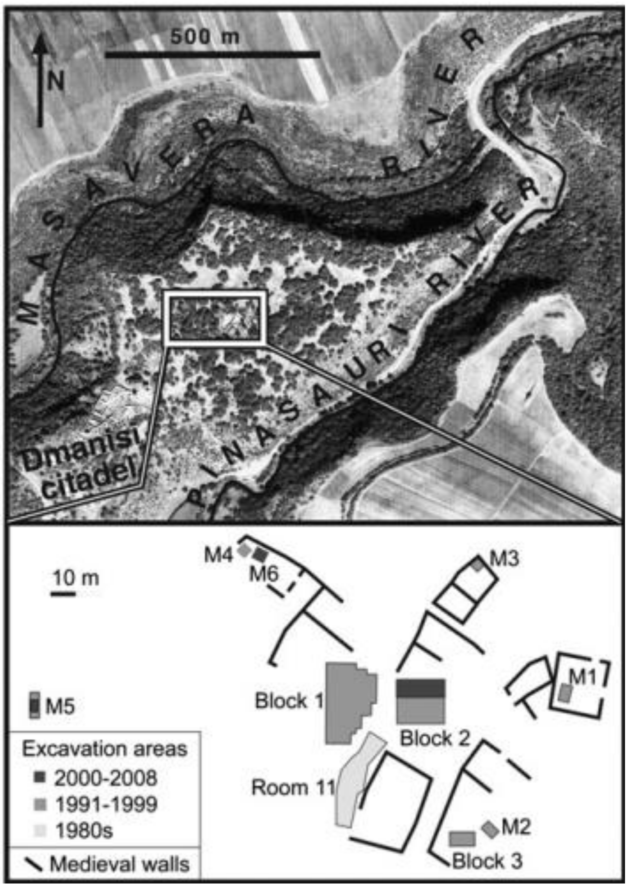

Figure 2.2: The relative locations of the excavation areas at Dmanisi, including periods of excavations (Mgaladze *et al.*, 2011).

2.1.3 Dating, stratigraphy, and geology

The stratigraphy is complicated by the presence of subsurface formations referred to as pipes and gullies. In essence, they originate from hydraulic processes (piping), the result of which are underground tunnel-like structures (pipes). At times these structures collapse leading to complex disruptions in the stratigraphy. Redeposited roof sediments (Gullies) dating to later periods are found at the same depth as the sediment in which the pipes formed. A Majority of excavated bone material was recovered from these formations. The volcanic sediments, found at Dmanisi, were aeolian in origins and buried the archaeological material relatively quickly after deposition, adding to the excellent preservation conditions. Moreover, other site formation processes provide evidence for discontinuous human occupation at the site (figure 2.3) (Crislip, 2013).

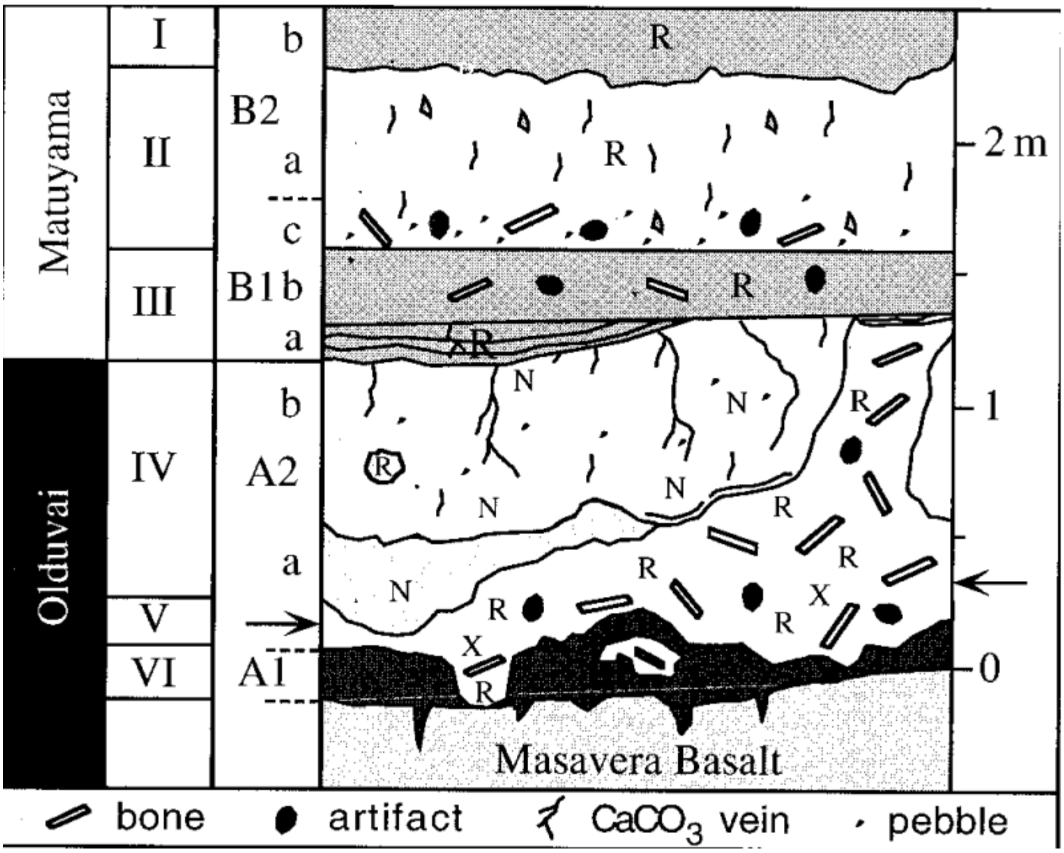

Figure 2.3: Representation of the eastern wall from block 1. The stratigraphical sequences do not accurately correspond to the current prevailing interpretations and have since been revised. However, the centre most column represents the levels, which are used for lithic analysis (Gabunia *et al.*, 2000).

The original stratigraphy of the site (level VI to I see figure 2.3), used in many of the publishing's before 2007, did not take into account gullies present at the site (figure 2.4). For this reason, the stratigraphy was revised to levels A1, A2, A4, B1, B1z, B1x, B1y, B2, B3, B4 (Lordkipanidze *et al.*, 2007); with an upper boundary of 1.825 ± 0.021 mya and a lower boundary of 1.765 ± 0.021 mya (Messager *et al.*, 2011). The largest division that can be made within the sequence is based on a palaeomagnetic shift during the transition from the Oldovai to the Matuyama, which took place 1.778 ± 0.003 mya (Horng *et al.*, 2002). The sedimentary layers deposited before the polarity reversal are labelled "A" and the layers deposited afterwards are labelled "B" (Calvo-Rathert *et al.*, 2008; Ferring *et al.*, 2011).

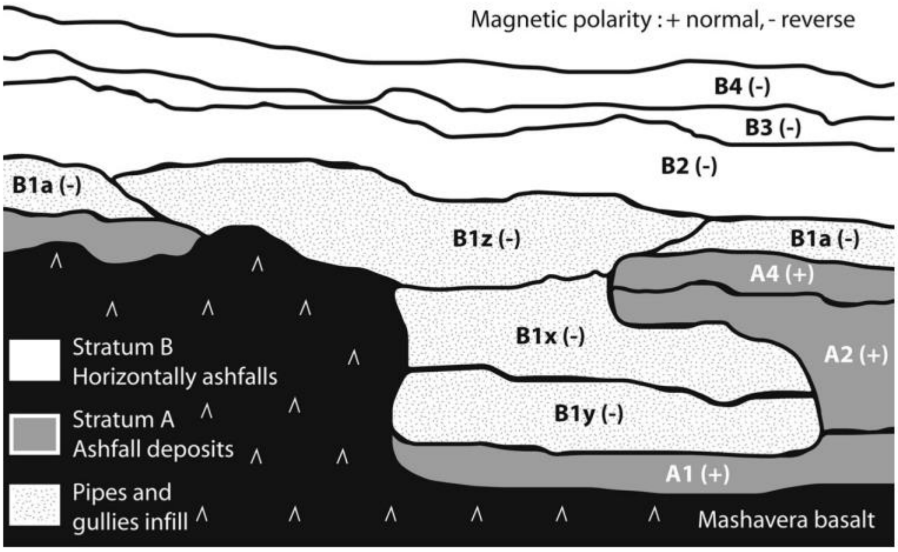

Figure 2.4: The stratigraphical sequence of block 2, this interpretation is currently most widely accepted (Mgaladze *et al.,* 2011).

2.2 Discoveries from Dmanisi

2.2.1 Paleoenvironment

The aforementioned conditions did not solely allow for the preservation of anthropogenic materials, but the site also offers insights regarding the palaeoenvironment during *Homo* occupation. The zooarchaeological fossils have proven especially useful for this. The majority of the site's carnivore assemblage is composed of a highly diverse presence of members of the Felidae family. Mustelidae's remain represent the second most numerous taxa, closely followed by both medium- and large sized Canidae. The least numerous families, in the composition of the carnivore guild, are Ursidae and Hyaenidae. The latter with remarkably only one species present (Bartolini-Lucenti *et al.,* 2022B). Furthermore, Bovidae and Cervidae are the most numerous members of the order Artiodactyla, while Equidae and Rhinocerotidae are the only Perissodactyla's present (Bartolini-Lucenti *et al.,* 2022A).

Several implications can be drawn from the zooarchaeological assemblage. Firstly, spatial analysis of bone material supports the significant role carnivores played in bone accumulation at the site in block 2 strata B1, whereas hominin activity plays a much smaller part (Coil *et al.*, 2020). Secondly, besides evidence for the presence of an active carnivore guild at Dmanisi, it is also one of the most diverse early Pleistocene assemblages related to human evolution. Remarkably little African species are represented in the record, somewhat more present are Asian species. However, the greatest similarities correspond with the carnivore guild found in Europe, mainly during the period dating shortly after Dmanisi occupation by *Homo* (Bartolini-Lucenti *et al.,* 2022B). Thirdly, further research beyond the carnivore guild conducted by Bartonlini-Lucenti *et al.* (2022B) analyses the composition of the large mammal fauna. Their conclusion reaches a similar result as the previous study, with a high resemblance of species present in successive European sites. To explain this, they consider a broad migratory pattern from east to west among Eurasian species, with *Homo* possibly taking advantage of this corridor, through the Levant, during their first migration out of Africa.

Furthermore, the large mammalian faunal record also serves as a proxy for vegetative and climatic conditions. This is suggestive of a landscape populated by wooded savannah and grassland species, together with a temperate climate and a decrease in precipitation compared to present times (Bartolini-Lucenti *et al.,* 2022B). Moreover, a period of relatively high aridity, occurring during the time of *Homo* occupation, is identified (Bartolini-Lucenti *et al.,* 2022A). This conclusion is further supported by geologic analysis and multiproxy palaeobotanical research. More specifically, analysis of the phytolith and carpo-remains, which were discovered during excavation, and pollen material, which were extracted from block 2, M5 and a nearby area. (Crislip, 2013; Messager *et al.*, 2010).

2.2.2 Hominin fossils

The *Homo* remains found at Dmanisi make up one of the most remarkable fossil assemblages of the Early Pleistocene. Not only are there numerous postcranial bones present within the assemblage, but incredibly well preserved cranial remains belonging to five individuals, 4 of which with corresponding mandibles, mark Dmanisi as a key site in the taxonomy of early *Homo*. Skull 1 (d2280) and skull 2 (d2282 (mandible D211)) were excavated in block 1 in strata B1. Skull 3 (D2700 (mandible d2735)) was excavated in in block 2, strata B1x. Skull 4 (D3444 (mandible D3900)) and skull 5 (D4500 (mandible (D2600)) were excavated in block 2 strata B1y. All skulls were deposited between 1.765 ± 0.021 mya and 1.778 ± 0.003 mya (Bermúdez del Castro *et al.* 2014; Margvelashvili *et al.*, 2022).

Moreover, there is significant variety between these skulls. Several of these variations show that males as well as females were present and that they range from subadult to mature specimen (Rightmire *et al.,* 2017). However, despite the accountable differences in morphology, other variations have been subject to ongoing debate regarding the taxonomic classification of certain specimen. The majority of hypotheses are centre around “skull 5”

(D4500), which has the smallest braincase (546 cm^3) and a unique mandible morphology (figure 2.5).

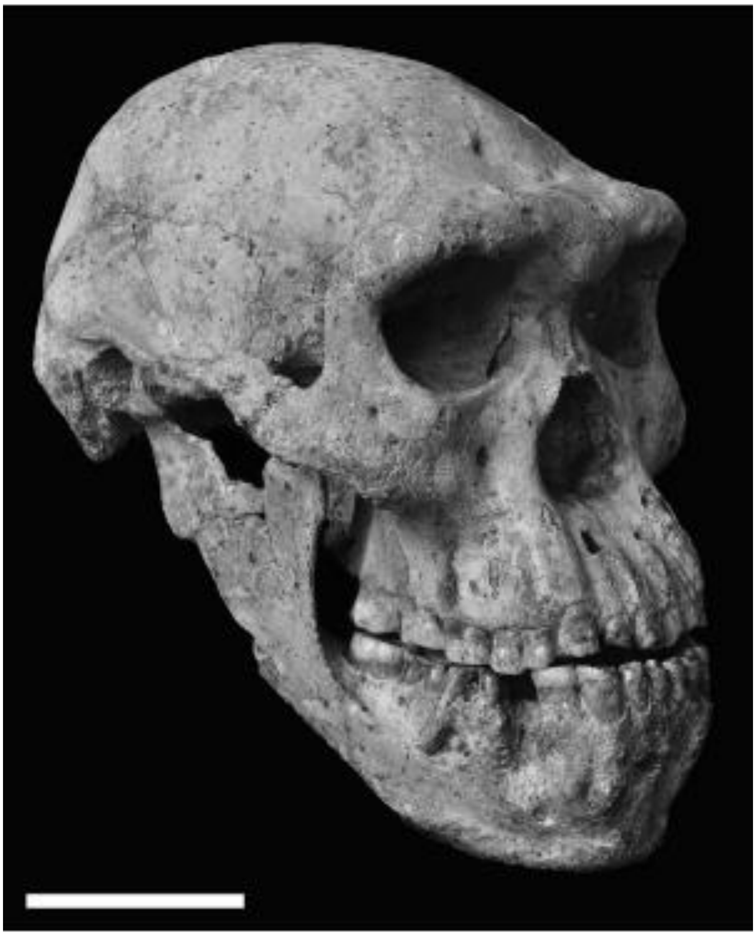

Figure 2.5: Skull 5 (D4500 and corresponding mandible D2600) is subject to much debate due its unique mandible morphology, which is rather robust compared to the other specimens. Additionally, the endocranial volume of 543 cm^3 is the lowest in the fossil assemblage. Discovered in block 2 strata B1y. The scale bar represents 5 cm (Rightmire *et al.*, 2017).

Endocranial analysis of the 5 *Homo* skulls, indicates that the brain morphology of the Dmanisi hominins was similar to that of early *Homo*. The relatively archaic frontal lobe organisation suggests that complex traits such as social behaviour, tool making or usage, and language abilities were limited in these individuals. Indicating that the evolution of such cognitive abilities continued after the initial dispersal out of Africa (Ponce de León *et al.*, 2021).

Cranium d3444, and primarily corresponding mandible d3900 (figure 2.6) suggests the individual survived for a longer period of time without functioning teeth. This implies that the individual either ate solely soft foods such as plants along with bone marrow and/or the presence of strong social scaffolding. Both behaviours go beyond that observed in other extant primates, which allowed the individual to survive for considerably longer (Lordkipanidze *et al.*, 2006). Further evidence on skull 2 is suggestive of head injuries possibly pointing to social behaviour manifested in interpersonal violence (Margvelashvili *et al.*, 2022).

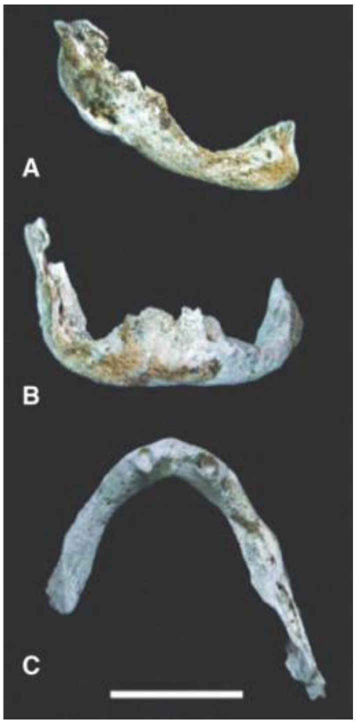

Figure 2.6: The mandible (D2390) of skull 4 (D3444) displays features that suggest the individual survived for a longer period of time without teeth. Discovered in block 2 strata B1y. A: Right lateral view, B: Frontal view, C: Occlusal view. The Scale bar represents 5 cm (Lordkipanidze *et al.*, 2006).

The scapula D4166 and humeri d2680, D2715 and D4507 are more similar in morphology to great apes and *Australopithecus*, than to modern humans. The femur D4167, the patella D3418 and the tibia D3901 show features seen in early *Homo* species. While the clavicles D4161, D4162 and D2724 are more similar to those found in modern humans. Additionally, analysis of the metatarsals also concludes on a more derived morphology, closer to modern humans. All post cranial material was deposited between 1.765 ± 0.021 mya and 1.778 ± 0.003 mya. In general, the limbs are more akin to *Australopithecus* and *H. habilis* than to the more derived features seen in *H. (erectus) ergaster* (Lordkipanidze *et al.*, 2007).

The morphology of upper and especially lower limbs is well suited to a terrestrial lifestyle. This is evident in their adaptations for long range walking and energy conservation during running. These developments are suggestive of the emergence of a partial carnivore subsistence strategy, be that either hunting or scavenging (Pontzer *et al.*, 2010).

Additionally, evidence for the dietary patterns can be determined from the dental morphology. Tooth wear analysis suggests a versatile diet, one not too different from that of *H. erectus* found across Asia. Main sources of subsistence were: fibrous plants and fruits, high starch plants, underground storage organs and abundant meat (Margvelashvili *et al.*, 2016; Martín-Francés *et al.*, 2014; Martinón-Torres *et al.*, 2008; Pontzer *et al.*, 2011).

Overall, the morphology of the hominin remains display a mosaic of features attributable to early *Homo* species such as *H. habilis* and more derived features related to the African (sub)species of *H. ergaster (*or *H. erectus ergaster)* (Gabunia *et al.*, 2000; Lordkipanidze *et al.*, 2007; Martinón-Torres *et al.*, 2008).

In case all the skull specimens are attributed to an identical palaeodeme (population), it warrants the classification of a single species at the site. Furthermore, this might require a major rethinking of how early *Homo* species are taxonomized based on shared morphologies (Skinner *et al.,* 2006). However, if the differences are enough to distinguish skull 5 and its mandible from the others found at Dmanisi, it requires the creation of a new (sub)species (Rightmire *et al.,* 2006).

Those in support of the single palaeodeme hypothesis, attribute the site's morphological differences to high phenotypical diversity within populations (Lordkipanidze *et al.*, 2013; Rightmire *et al.,* 2017). This might imply a single lineage of early *Homo* evolving over a multitude of continents, rather than an entirely African origin (Dennell and Roebroeks, 2005; Lordkipanidze *et al.*, 2006; Lordkipanidze *et al.*, 2007; Lordkipanidze *et al.*, 2013; Martinón-Torres *et al.*, 2008; Ponzer *et al.*, 2009;). Furthermore, relatively strong sexual dimorphism compared to extant primates and *Homo sapiens*, might be another explanation for these differences (Rightmire *et al.*, 2019; Skinner *et al.,* 2006). Lastly, relating to mandible D2600, dental pathologies might have resulted in the most noteworthy dissimilarities in morphology found at Dmanisi (Margevelashvili *et al.*, 2013; Rightmire *et al.* 2008).

On the other hand, Bermúdez del Castro *et al.* (2014) classify the skull 5 specimen as a new intermediate, species: *H. georgicus*. The basis for this argument is founded on uncertainty regarding the complicated stratigraphy at Dmanisi. Moreover, aforementioned evidence regarding morphological variations remains disputed (Martín-Francés *et al.*, 2014; Rightmire *et al.* 2008; Wallace *et al.*, 2008).

2.2.3 Technology

The excavations at Dmanisi have resulted in the collection of an extensive lithic assemblage associated with the previously described hominin occupation. This material has, similarly to the hominin fossil assemblage, been subject to rigorous investigation. De Lumley *et al.* (2005), Baena *et al.* (2010), and Mgeladze *et al.* (2011) provide the most in-depth interpretation of the material. Over 8000 individual lithics artifacts in total were analysed, around 40% of which showed clear anthropogenic modification.

The lithic artefact assemblage is largely derived from block 1 and 2, which totals an area of 100-150 m², and is categorized based on the old stratigraphical interpretation. The levels which contain noteworthy anthropogenic materials are in decreasing order of richness level II, level IV, and level III. The magnetic polarity of the sediments in level II and III suggests the material was deposited after 1.778 ± 0.003 mya. Dating level IV is more complicated as the level is disturbed by a gully formation, which contained the majority of lithics artifacts. Meaning, the redeposited assemblage of level IV likely also contains a material largely dating after 1.778 ± 0.003 mya, however with an uncertain relation to the previous two levels (Mgeladze *et al.*, 2011).

The material has been assigned to the mode 1 techno complex, more specifically the Oldowan industry, which was first developed 2.6 mya (Semaw, 2000). Characteristic of the industry was a relatively simple unifacial or bifacial core-flake reduction strategy making use of a hammerstone to strike a blank on either the cortical surface, a natural fracture, or a flake scar. Cores were exploited relatively weakly, and the results were sharp cores, relatively few flakes, and much debitage. However, within the Oldowan a variety of technological distinctions that can be made, such as reduction strategy or raw material preferences. This variation is attributable to a number of factors, such as: environmental circumstances, cognitive or motor constraints and behaviour copying (Roche *et al.*, 1999).

Doronichev and Golovanova (2010) proposes the Oldowan can be divided in two phases. The first phase lasted from 2.6 mya to 1.7 mya, characterize red by a reliance on choppers and unipolar core reduction. By 1.7 mya another Oldowan phase became commonplace, associated with the emergence of *Homo erectus*. It features an increase in multi-directional core (multipolar or discoid-like) reduction and retouched small flakes. However, Semaw *et al.* (2009) considers the Oldowan to have lasted from 2.6 mya to 1.6/1.5 mya, in a more uniform fashion. It originated in east Africa and was likely developed and spread by early *Homo* species such as *Homo habilis* or *Homo rudolfensis*. The industry is characterized by a wide array of core reduction strategies. Occasionally more complex strategies show up, such as retouched flakes; however, no lasting temporal trends can be identified.

The oldest lithic material, excavated from level IV, is comparable to Oldowan industries that first appeared about 2,5 mya in the eastern Africa. It is characterized by a core-flake assemblage, notably lacking the presence of small, retouched tools. In contrast, lithic material deposited in level II contains 20, both intentionally and unintentionally, retouched tools (figure 2.7). Further differences in level II (figure 2.10) and level IV (figure 2.11) are related to the methods in core reduction, such as in knapping gestures. The knapping gestures of level II are more curved in trajectort and faster compared to the knapping gestures of level IV (figure 2.8). Level IV cores are predominantly reduced with one striking directionality, while level II also features multipolar striking directionality besides unipolar reduction. Both unifacial and bifacial reduction strategies are present in the assemblage. (Baena *et al.*, 2010; de Lumley *et al.*, 2005).

Raw materials were largely made up of volcanic stones and were gathered from sources in the proximal environment (figure 2.9). Petrographic analysis determined the most frequent raw material variant: 35,9% consists of several types of basalt, 31,3% consists of tuff materials. Other types of rock present at the site are limestone, sandstone, quartzite, and quartz (Mgeladze *et al.*, 2010). The majority of lithics were rolled cobbles, obtained from the two nearby rivers. Furthermore, angular fragments are also present in the assemblage, these include types of tuff, from upper Cretaceous formations, and porous basalt, derived from lava flow (Mgeladze *et al.*, 2011).

Analysis into the function of the lithic industry at Dmanisi reveals a wide-ranging possible uses for the products. Impact marks on whole cobbles suggests they were used as anvils; similar traces were found on fractured cobbles as well. Fractured cobbles may have also functioned in the disarticulation of animal remains. Micro retouches on sharp edges of core and flakes indicate they may have been used for the cutting of meat, hides or wood.

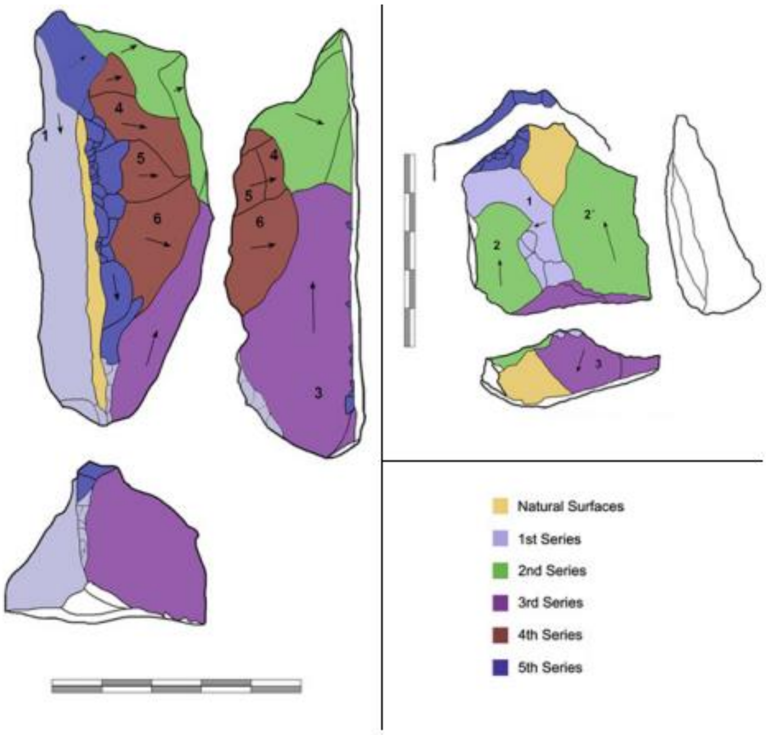

Figure 2.7: Schematic representations of the reduction sequence on two cores from level II. Both containing evidence of intentional retouch on one face (Baena *et al.*, 2010).

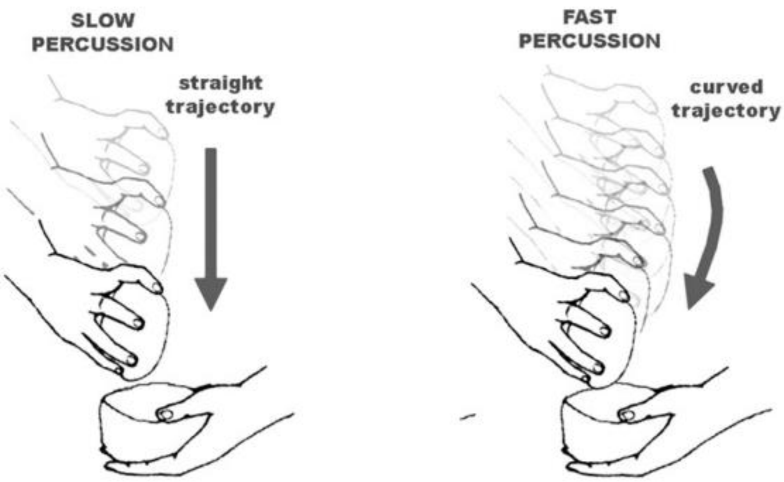

Figure 2.8: Visualization of the different knapping gestures present at Dmanisi. The left method is related to level IV, while the right method is related to level II (Baena *et al.*, 2010).

Flakes were the primarily exploited for animal processing, while cores may have functioned as digging tools or hammerstones (de Lumley *et al.*, 2005). The small number of retouched flakes that appear in the upper layers are interpreted to be scrapers. Additionally, a significant number of unmodified cobbles and angular fragments (manuports) of lower quality were transported to the site without further use. The reason for this behaviour is currently only explained by the preparation of stone caches for future visits, made possible by the abundance of material in the local area (Mgeladze *et al.*, 2011).

Figure 2.9: A selection of raw material variants collected from the local environment of Dmanisi (Mgeladze *et al.*, 2011).

Dmanisi shares key features with other Oldowan sites, with regard to lithic behaviours. The Oldowan is first emerges in East African sites, appears to migrate into Asia and is then observed in younger European sites. This dispersal is not associated with a specific type of hominin and thus the technology was likely to be shared by different species (Mgeladze *et al.*, 2011). Furthermore, the presence of discoid-like reduction strategies and possibly retouched tools in level II might suggest the independent development of this technique or a cultural exchange event with Africa during the occupation of Dmanisi (Doronichev and Golovanova, 2010).

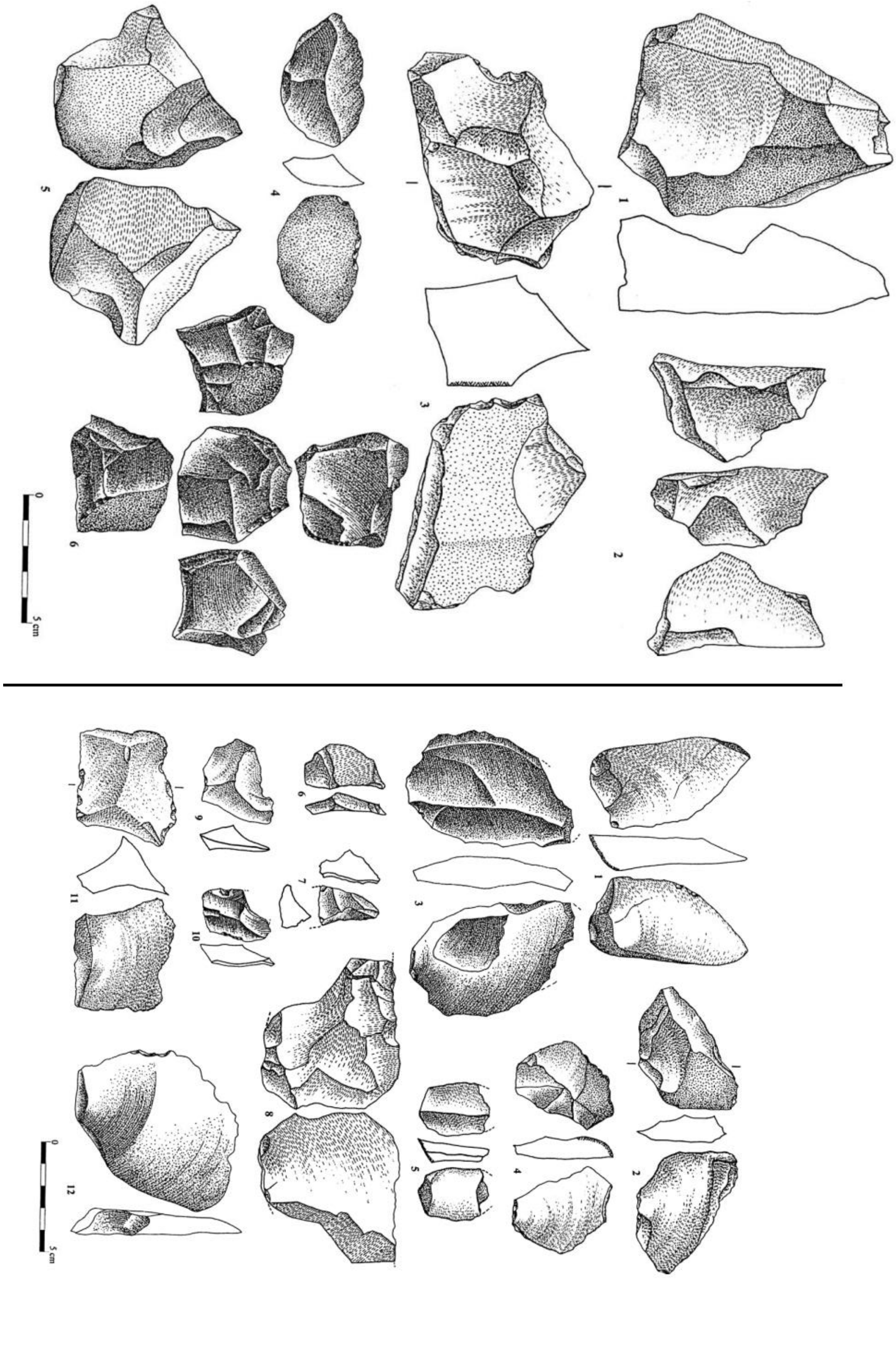

Figure 2.10: Schematic representation of a selection of cores (left panel) and flakes (right panel) excavated in level II (de Lumley *et al.*, 2005).

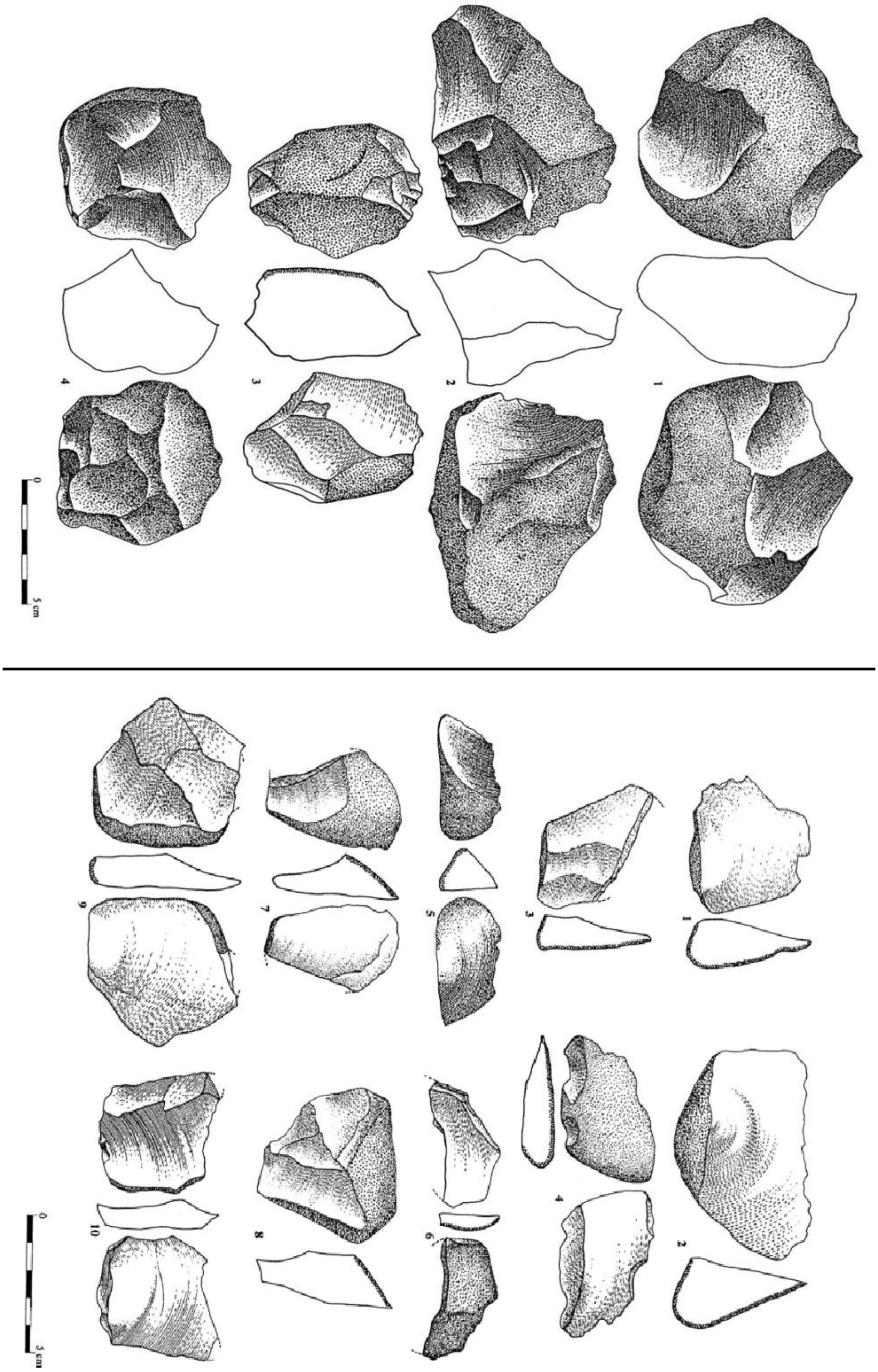

Figure 2.11: Schematic representation of a selection of cores (left panel) and flakes (right panel) excavated in level IV (de Lumley *et al.*, 2005).

Chapter 3: Approach and Methods – Comparative lithic analysis

3.1 Framework for the analysis

In order to recognize the emergence of a ratchet mechanism in the evolutionary history of the genus *Homo*, it is important to consider the complexity of modern human skill learning. Implicate in this notion is the development of numerous individual traits, rather than one singular evolutionary event (Stout and Hecht, 2017). Stout *et al.* (2019) constructed a stepwise framework (figure 3.1) to partially disentangle this pattern of graduality, offering evidence for specific aspects that enable ratcheting with regard to the developments in tool construction behaviour. This model will be deployed temporal trends within the Oldowan assemblage from Dmanisi, with the aim to infer the presence of early-stage cumulative culture.

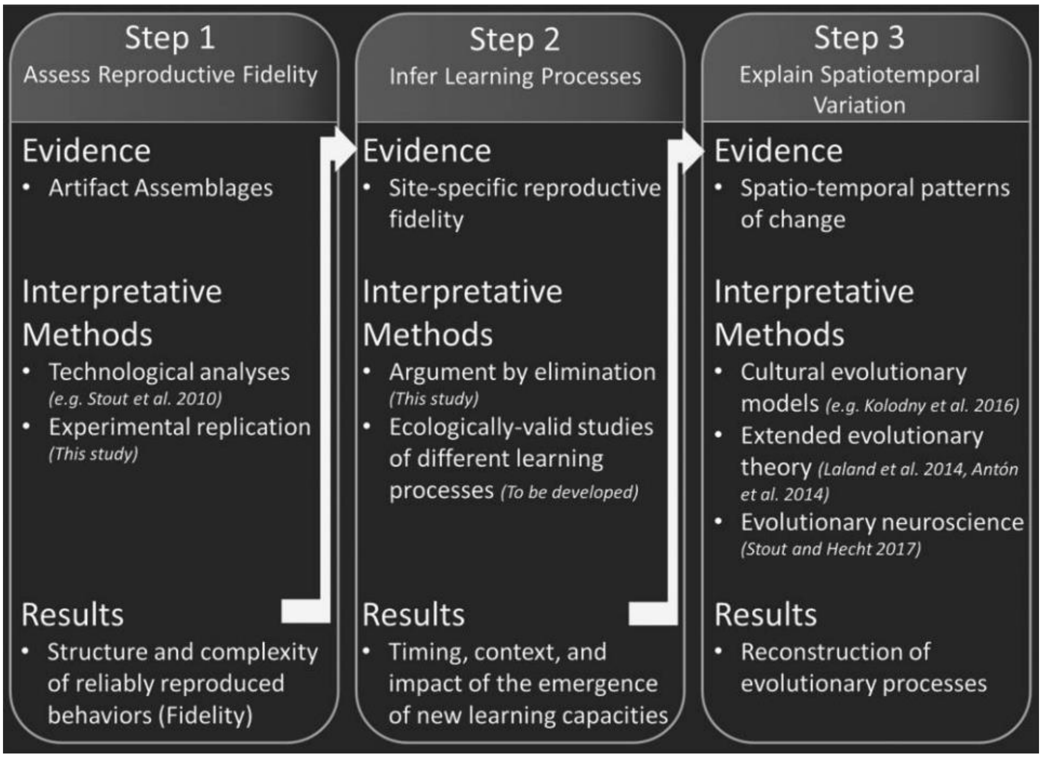

Figure 3.1: The stepwise approach for identifying behaviour copying at archaeological sites. The model will be applied to level II and level IV of Dmanisi (Stout *et al*., 2019).

The initial strategy is to assess evidence for patterns resembling behavioural copying. Behavioural copying is a distinct but broad form of social learning, that must be able to facilitate the improvement of previous technology. It implies an active skill that is practiced through both social influences and individual motivation. Behaviour copying can be described as a teaching process that creates strong traditions within a population, it can be expressed in imitation (step-by-step reproduction) or emulation (end-state copying). The degree of accuracy in behaviour copying (level of fidelity) enables the process of ratcheting, as high fidelity results in the retention aspect (social), while low fidelity can possibly result it technological improvement (individual). Fidelity is for this reason imperative to the presence of behavioural copying, but as will be seen later, does not constitute behaviour copying. Lithic material from archaeological excavations alone can solely offer insights into the level of fidelity. Moreover, Lycett and von Cramon-Taubadel (2015) regard lithic analysis based on morphological similarities as an insufficient proxy for the presence of fidelity since different reduction methods can result in indistinguishable morphological results. In order to account for this, the morphological features of the analysed artifacts must be indicative of differing reduction strategies.

In order to find evidence for behaviour copying the analysis must adhere to three principles: reduction strategies, raw materials selection and reproduction (Lycett and von Cramon-Taubadel, 2015). Following this line of reasoning, the first step of this analysis will focus on the first two of the three factors, namely reduction strategies and raw materials, in order to identify two equally viable but differing lithic reduction strategies. Preferably, the methods of establishing viability (also referred to as utility or functionality in Stout *et al.* (2019)) are grounded in an experimental approach based raw materials reflecting the local environmental conditions. Observing increases in viability over the temporal dimension between reduction strategies results in the impossibility of finding evidence for behaviour copying. That is because, the increase is equally likely to be cause by individual invention without knowledge of the previous reduction strategy. In essence, the difference between evidence for fidelity and behaviour copying is that in the latter a certain degree of over-imitation (imitation despite favourable alternatives) may take place (Burdett *et al.*, 2018). The transmitted behaviour is not necessarily more viable that other possibilities, however the population still continues to practice the behaviour because it is established in a similar manner as an actively maintained tradition. Thus, in order to determine the presence of behaviour copying in the archaeological record, the two transmitted behaviours cannot display an increase of viability over time, as that does not prove the existence of two differing traditions being actively transmitted in similar environmental circumstances.

Furthermore, the last of the three principles, reproduction, will be inferred once consistent fidelity in lithic behaviours is reliably established within the assemblage. Inductive reasoning will be applied to the observed developments in the lithic assemblage, in order to exclude alternative processes leading to differences or similarities found in the results. A number of other factors may explain apparent fidelity in lithic assemblages (Roche *et al.*, 1999). For example, anatomical differences between populations of tool makers may oblige one population into a specific reduction strategy, while another favours a reduction strategy solely through social reproduction.

Firstly, the primary taxonomical differences that must be examined are psychological and physiological in nature (Schick *et al.*, 1999; Toth and Schick, 2009; Völter and Call, 2014). In order to rule out differences related to the analysed assemblages, comparison of the upper and lower limb morphology along with cranial capacity will be performed. Secondly, environmental constraints, such as variability in the availability and morphology of raw materials or shifting subsistence strategies, may constrict the possible technological solutions and result in the appearance, but not confirmation, of fidelity in the archaeological record (Reeves *et al.*, 2021; Roche *et al.*, 1999; Semaw, 2000).

When alternative explanations are excluded, the resulting conclusions will be assessed for evidence of either the absence or presence of behaviour copying. In case the results suggest a temporal development towards equal or decreased viability of the identified lithic behaviours, it is suggestive of behaviour copying. If no such trend is identified, no certainty of the presence of either individual reinvention or behaviour copying can be established. Subsequently, the result will be placed into existing multidisciplinary frameworks. Although still largely premature, in this stage an attempt is made to explain broad reaching patterns of technological developments during the Lower Palaeolithic.

Stout *et al.* (2019) applies this framework to the Oldowan materials found at three sites near Gona, Ethiopia. Locations EG-7, OG-10 and OG-12 were used as spatiotemporal categories all dating to approximately 2.6 mya. The primary focus of the experimental approach was to understand relation between differences in unifacial and bifacial knapping methods and technological flake-categories based on the presence of cortex on striking platforms and dorsal surfaces. Raw material availability was considered for the development of an experimental variable for viability. Through rigorous statistical analysis, the conclusion was drawn that behaviour copying was present in the Oldowan approximately 2.6 mya, as both reduction strategies had a similar viability value. However, no evidence for increased cultural ratcheting was discovered.

3.2 Material analysis

The site of Dmanisi can be split up in two temporal categories, both were likely deposited after the paleomagnetic shift about 1.78 mya (Calvo-Rathert *et al.*, 2008; Ferring *et al.*, 2011). The two distinct occupational periods are dated relatively shortly after each other, at least within a 100,000-year timeframe (Crislip, 2013; Messager *et al.*, 2011). Here, level II (N = 3612), which dates to after the paleomagnetic switch, will be the youngest temporal category for assessing the presence of detailed behavioural copying at the site. Level IV (N = 370) has an earlier yet boarder time range and will be the oldest temporal category. However, due to this reinterpretation primarily in block 2, the distinct temporal category cannot be fully guaranteed with regard to the material from level IV (Lordkipanidze *et al.*, 2007). The materials investigated were excavated from 1991 to 1999, for this reason analysis of lithic materials has not yet fully caught up with the new stratigraphical units (de Lumley *et al.*, 2005). That being said, the redeposited material in level IV dated to before the paleomagnetic shift, is unlikely to have been deposited synchronic to level II (Crislip, 2013; Bermúdez De Castro, 2014). level IV will still be considered a separate assemblage from level II, nevertheless level IV may consist of material from a much broader temporal range. De Lumley *et al*. (2005) offers the only available source for the detailed analysis of interlevel differences in lithic behaviour at Dmanisi and will thus provide all data used in this analysis.

Types: Quantitative representation of classifiable lithic material may be suggestive of variation in the reduction strategy. In total 3982 individual lithic artifacts were analysed (N,level II = 3612 and N,level IV = 370). All lithics were assigned to one of ten artifact types, based on morphological characteristics. Materials classified as blocks were assigned to the "whole pebble" artifact type, while chopper cores were assigned to the "cores" artifact type.

Classification: To simplify the quantitative comparison of material related to Oldowan knapping methods, artifact types will be subdivided into two categories. Artifacts related to the Oldowan reduction technique and artifacts unrelated to the Oldowan reduction technique. See table 3.1 for the division of all artifact types into these categories.

Oldowan related artifact types	Non-Oldowan related artifact types
Hammerstones	Whole pebbles
choppers	Broken pebbles
Cores (including chopper cores)	Pebbles with isolated removals
Flakes	
Small flakes	
Non-cortical debris	
Cortical debris	

Table 3.1: The two classificatory categories for the artifact types found in level II and level IV (Table by G.J. Kuijt).

Size: Variation in the average length of whole pebbles, broken pebble and cores will also be taken into consideration to strengthen the argument for a difference in reduction strategy.

Raw material: The difference or similarities in reduction sequence seen in both layers may be related to biases in raw material. Due to a limited dataset only the raw material selection for whole pebbles and broken pebbles can be analysed for this comparative approach. Differences and similarities will for thus solely be applicable to non-Oldowan related artifact types.

Knapped value: Analysis for viability is based on experimental values gathered by continuous experimental methods, performed by a joined Spanish-Georgian team since 2003**.** This experimental evidence is gathered from lithics derived from the proximal environment of the site, in a similar manner as the creators of the archaeological artifacts (Baena *et al.*, 2010). Different raw material types are assigned a knapped value and a use value (figure 3.2). Raw material types are categorized based on their suitability for either knapping behaviour, with a knapped value above 4,0 (type A), or general usefulness, with a knapped value below 4,0 (type B) (table 2). This data will serve to validate the similarities in viability (utility) of knapping strategies.

Type A raw materials (>4)	Type B raw materials (<4)
Fine tuff	Coarse tuff
Flint	Basalt
	Other volcanic rocks
	Metamorphic rocks
	Quartz
	Flint
	Limestone

Table 3.2: The two classificatory categories for raw material types found at Dmanisi, based on ongoing knapping experiments from a joined Spanish-Georgian team that started in 2003 (Table by G.J. Kuijt, data derived from (Baena *et al.*, 2010)).

	KNAPPED VALUE			USE VALUE				AVERAGE VALUE
	HOM.	TOUGHNESS	TOTAL	HOM.	TOUGHNESS	HARDNESS	TOTAL	
MICRITIC LIMESTONE	2	3	2,5	5	3	2	3,3	2,9
YELLOW TUFF	5	5	5	4	3	3	3,3	4,15
GREEN TUFF	4	5	4,5	5	4	4	4,3	4,4
FINE GR. BASALT & ANDESITE	4	3	3,5	3	3	4	3,3	3,4
MIDDLE GR. BASALT & DIABASE	1	1	1	1	3	4	2,3	1,65
SANDSTONE / TUFF SANSTONE	2	2	2	2	4	2	2,6	2,3
QUARTZ	2	2	2	2	5	2	3	2,5
CHERT	5	5	5	5	5	4	4,6	4,8

Figure 3.2: The experimental results of raw materials from the local environment of Dmanisi, Displaying both the suitability for knapping and general use. Together with four examples of lithic artifacts originating from the alluvial deposits. The data was gathered by a joint Spanish-Georgian team that started ongoing experiments in 2003 (Baena *et al.*, 2010).

The raw material type fine tuff, assigned to yellow tuff, and green tuff in the experimental model (figure 3.2), while chert corresponds to flint. Primarily because, fine tuff was generally preferred for knapping, additionally, green and yellow tuff are included amongst this category. Other raw materials, which do not directly appear in the experimental model, such as other volcanic rocks and metamorphic rocks, will be considered as having a knapped value below 4,0. Moreover, knapping related artifact types across the entire site are rarely made from this material (11,1% of cores and 5,1% of flakes) (de Lumley *et al.*, 2005; Mgeladze *et al.*, 2011).

Reduction method: Additionally, analysing of certain qualitative features may also be suggestive of a difference in reduction strategy. This comparison will rely on variation in reduction methods, similarly to Stout *et al.* (2019). Cores will be subdivided into three distinct categories. Firstly, cores where reduction is evident on a single face, unifacial knapping. Secondly, cores where reduction has taken place on two or more faces, bifacial/multifacial knapping. Lastly, cores where neither of the two categories is applicable.

Flake type: Furthermore, the presence of cortex on the platform and dorsal side of flakes will also be taken into account. There are seven categories based on which the flakes are subdivided (Toth, 1985). Type I: +/+ (cortex on both the platform as well as the dorsal side); Type II: +/partial (cortex on the platform as well as partially on the dorsal side); Type III: +/- (cortex on the platform and an absence of cortex on the dorsal side); Type IV: -/+ (an absence of cortex on the platform and a presence of cortex on the dorsal side); Type V: -/partial (an absence of cortex on the platform and cortex partially on the dorsal side); Type VI: -/- (an absence of cortex on the platform as well as on the dorsal side); and indeterminable flakes.

The experimental model by Stout *et al.* (2019), which was designed for the site of Gona, predicts that type I, type II (primarily) and type III will be more prevalent when unifacial knapping is dominant. On the other hand, when bifacial/multifacial knapping is dominant type IV, type V (primarily) and type VI will be more prevalent. If this trend is found to also apply to level II and IV, the model from Stout *et al* (2019) may be suggestive of broader trend within the Oldowan.

Chapter 4: Results –Analysis of the Lithic Assemblages from Dmanisi

4.1 Differences and similarities

Types: The analysed assemblage consists of 3982 total artifacts, originating from level II and level IV. The majority of artifacts originate from the temporally younger level II and totals N = 3612, whereas the older level IV totals N = 370. The most common type of artifact are lithics without anthropogenic evidence, this includes whole pebbles and broken pebbles. They made up 52,7% of level II and 67,4% of level IV. Flakes made up the most common type of artifact with anthropogenic evidence, level II and level IV consisting of 16,7% and 12,0% flakes respectively. This was followed up in level II by non-cortical debris and cortical debris (11,1% and 11,2% respectively), while in level IV choppers and cores were next most represented after flakes (7,6% and 4,6% respectively) (Table 4.1).

Table 4.1: The frequency of different artifact types in level II and level IV (Table by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Types of artifacts per layer	Oldowan related material (artifact classifications)	N,Level II	%,Level II	%,Level II of artifact classification	N,Level IV	%,Level IV	%,Level IV of artifact classification
Whole pebbles	No	1203	33,3%	61,9%	161	44,0%	64,4%
Broken pebbles	No	701	19,4%	36,1%	86	23,4%	34,4%
Pebbles with isolated removals	No	38	1,1%	2,0%	3	0,8%	1,2%
Hammerstones	Yes	9	0,2%	0,5%	3	0,8%	2,5%
Choppers	Yes	146	4,0%	8,7%	28	7,6%	23,3%
Cores (including chopper cores)	Yes	72	2,0%	4,3%	20	4,6%	16,7%
Flakes	Yes	603	16,7%	36,1%	44	12,0%	36,7%
Small flakes	Yes	35	1,0%	2,1%	1	0,3%	0,8%
Non-cortical debris	Yes	400	11,1%	24,0%	13	3,5%	10,8%
Cortical debris	Yes	405	11,2%	24,3%	11	3,0%	9,2%
Total		**3612**	**100,0%**	-	**370**	**100,0%**	-

Classification: To elaborate further, artifact types were classified in accordance with their relation to the Oldowan industry. Overall, level II had a relatively higher presence of Oldowan related material with 46,2%; against the 31,8% of level IV. The relative number of flakes in the Oldowan related material classification was quite similar (level II = 36,1% and level IV = 36,7%); while more variation can be seen in the relative number of cores in this specific classification, it is much lower in level II (4,3%) compared to level IV (16,7%). A similar pattern can be observed in the relative number of choppers in the Oldowan related materials (level II = 8,7% and level IV = 23,3%). The reverse holds true for non-cortical and cortical debris, as 24% and 24,3% respectively make up the Oldowan related assemblage in level II, whereas in level IV this is 10,8 and 9,2% respectively. Differences in the presence of hammerstones, pebbles with isolated removals and small flakes will be seen as insignificant.

Size: Table 4.2 allows for a comparison regarding the dimensions of whole pebbles, broken pebbles, and cores. Across all three types of artifacts level IV had a greater average length. The largest difference is found in Oldowan related materials, namely cores, where level II was on average 14,3 mm smaller in length than level IV.

Table 4.2: The average length of whole pebbles, broken pebbles, and cores in level II and level IV. In mm (Table by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Average length (mm)	**Level II**	**Level IV**	**Difference**
Whole pebble	74,0	80,0	6,0
Broken pebble	71,0	80,0	9,0
Cores	70,0	84,3	14,3

Raw materials: The results drawn from the raw material analysis are composed of data from whole pebbles (level II = 1202 and level IV = 159) and broken pebbles (level II = 689 and level IV = 86) and will thus solely apply to non-Oldowan related lithic procurement (table 4.3). The relative percentages of both fine tuff (level II = 27,3% and level IV = 35,2%) and basalt (level II = 22,5% and level IV = 39,3%) are increased in the temporally younger level II, compared to level IV. On the other hand, the relative percentages of coarse tuff (level II = 30,1% and level IV = 8,9%), and other volcanic rocks to a lesser extend (level II = 12,9% and level IV = 7,7%), are decreased in level II, compared to level IV. Furthermore, the sum of the remaining raw materials vary 1,7 percentage points and individual differences among raw materials are considered to be insignificant (table 4.4).

Table 4.3: Frequency of raw materials of the artifact types whole pebbles and broken pebbles, in level II and level IV. Type A materials have a knapped value greater than 4, while type B materials have a knapped value lower than 4 (Table by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Raw material and type	**N,level II Whole pebbles**	**%,level II Whole pebbles**	**N,level IV Whole pebbles**	**%,level IV Whole pebbles**	**N,level II Broken pebbles**	**%,level II Broken pebbles**	**N,level IV Broken pebbles**	**%,level IV Broken pebbles**
Fine tuff (A)	313	26,0%	50	31,1%	207	29,5%	37	43,0%
Coarse tuff (B)	397	33,0%	17	10,6%	176	25,1%	5	5,8%
Basalt (B)	257	21,4%	73	45,3%	172	24,5%	24	27,9%
Other volcanic rocks (B)	158	13,1%	11	6,8%	87	12,4%	8	9,3%
Metam-orphic rocks (B)	59	4,9%	5	3,1%	33	4,7%	10	11,6%
Quartz (B)	15	1,2%	2	1,2%	13	1,9%	2	2,3%
Flint (A)	2	0,2%	1	0,6%	1	0,1%	0	0,0%
Limest-one (B)	1	0,1%	0	0,0%	0	0,0%	0	0,0%
Indeter-minable	1	0,1%	2	1,2%	12	1,7%	0	0,0%
Totals	**1203**	**100,0%**	**161**	**100,0%**	**701**	**100,0%**	**86**	**100,0%**

Table 4.4: Combined frequency of raw materials, regarding the artifact types whole pebbles and broken pebbles, in level II and level IV. Type A materials have a knapped value greater than 4, while type B materials have a knapped value lower than 4 (Table by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Raw material and type	N,level II Total	%,level II Total	N,level IV Total	%,level IV Total
Fine tuff (A)	520	27,3%	87	35,2%
Coarse tuff (B)	573	30,1%	22	8,9%
Basalt (B)	429	22,5%	97	39,3%
Other volcanic rocks (B)	245	12,9%	19	7,7%
Metamorphic rocks (B)	92	4,8%	15	6,1%
Quartz (B)	28	1,5%	4	1,6%
Flint (A)	3	0,2%	1	0,4%
Limestone (B)	1	0,1%	0	0,0%
Indeterminable	13	0,7%	2	0,8%
Totals	**1904**	**100,0%**	**247**	**100,0%**

Knapped value: Furthermore, from table 4.4 the conclusion can be drawn that non-Oldowan related material in level II had a higher presence of type B raw materials, which are generally better suited for general use (type A = 27,2% and type B = 71,8%). The same holds true for level IV; however, among non-Oldowan related material, there is an increase of type A raw materials, which are generally better suited for knapping (type A = 35,6% and type B = 64,4%).

Reduction method: Level II and level IV have a relatively comparable presence regarding the three reduction method variants. Due to the high percentage of indeterminable cores (level II = 19,4% and level IV = 22,2%), both levels will be treated as displaying similar trends regarding reduction methods. Unifacial knapping being employed in approximately 40% of cores, while bifacial/multifacial knapping is being employed in approximately 38% of cores (table 4.5). It will be assumed that the total of 18 cores analysed for reduction method in level IV, is in line with the total of 20 cores present in the assemblage at large. This difference may be explained by the refitting of multiple fragments of cores, but no further elaboration is given.

Table 4.5: The frequency of reduction method in level II and level IV (Table by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Reduction method	N,level II	%,level II	N,level IV	%,level IV
Unifacial	31	43,1%	7	38,9%
Bifacial/Multifacial	27	37,5%	7	38,9%
Indeterminable	14	19,4%	4	22,2%
Total	**72**	**100,0%**	**18**	**100,0%**

Flake types: All seven flake types are represented in both levels to a similar degree (table 4.6). In level II 23,4% of flakes are associated with unifacial knapping being the dominant reduction method, which consists for 13,5% of type II. Compared to level IV where 24,4% of flakes suggest a reduction method where unifacial knapping is dominant, with 15,6% consisting of type II. A slightly larger, but insignificant, difference between the levels is found with regard to flake types associated with a bifacial/multifacial dominated reduction method (level II: total = 42,8%, type V = 18,0%; level IV: total = 51,1%, type V = 20,0%). A substantial portion of the flakes (level II = 33,9% and level IV = 24,4%) cannot be assigned into either of the six initial types, leaving conclusions drawn regarding interlevel trends with a degree of uncertainty.

Table 4.6: The frequency of flake types in level II and level IV. Type I: +/+ (cortex on both the platform as well as the dorsal side); Type II: +/partial (cortex on the platform as well as partially on the dorsal side); Type III: +/- (cortex on the platform and an absence of cortex on the dorsal side); Type IV: -/+ (an absence of cortex on the platform and a presence of cortex on the dorsal side); Type V: -/partial (an absence of cortex on the platform and cortex partially on the dorsal side); Type VI: -/- (an absence of cortex on the platform as well as on the dorsal side); and indeterminable flakes (Table by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Flake type	N,level II	%,level II	N,level IV	%,level IV
Type I	37	5,8%	2	4,4%
Type II	86	13,5%	7	15,6%
Type III	26	4,1%	2	4,4%
Type IV	27	4,2%	2	4,4%
Type V	115	18,0%	9	20,0%
Type VI	131	20,5%	12	26,7%
Indeterminable	216	33,9%	11	24,4%
Total	**638**	**100,0%**	**45**	**100,0%**

4.2 Interlevel trends

Types and classification: The comparison of differences related to the quantitative representation of artifact types in both level II and IV, suggests developments related to reduction strategy. Firstly, there is a temporal increase in Oldowan related artifacts, which may be related to an increase in knapping behaviour. Both whole pebbles and broken pebbles are present in greater quantity within level IV, while Oldowan related materials are significantly more present in level II (Figure 4.1). Secondly, figure 4.2 represents the relative frequency of artifact types, within the category Oldowan related materials, in both level. The relative frequency of cores and chopper cores is significantly higher in level IV among this category; however, the relative frequency of flakes is remarkably similar. Moreover, the relative presence of non-cortical debris and cortical debris is significantly higher in level II.

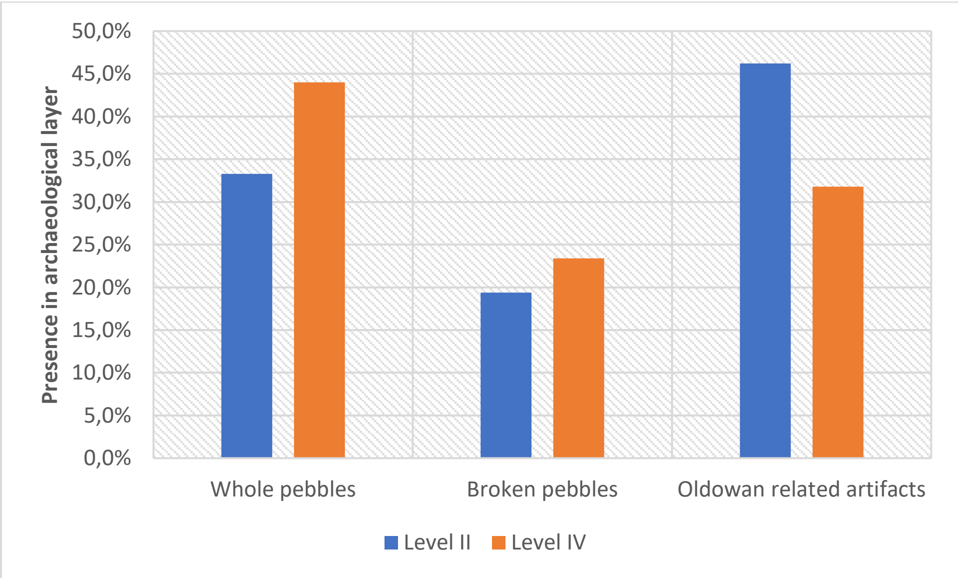

Figure 4.1: The relative frequency of whole pebbles, broken pebbles, and Oldowan related materials in level II and level IV (Figure by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

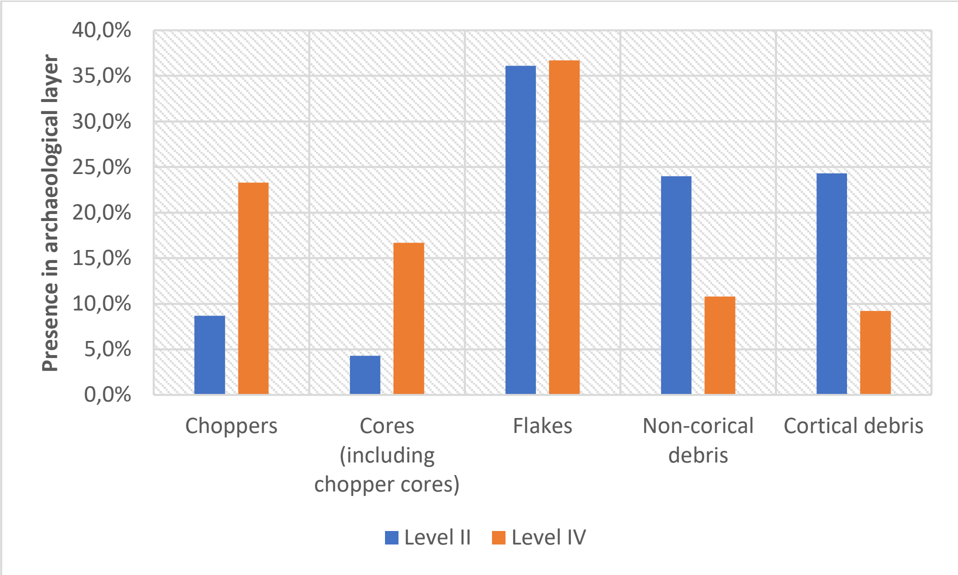

Figure 4.2: The relative frequency of Oldowan related artifact types in level II and level IV (Figure by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

These interlevel differences may be suggestive of an increase in the exploitation of singular cores for the procurement of flakes in level II. The relatively high presence of cores and choppers in level IV are suggestive of a lesser reliance on flake production and an increased reliance in cores and choppers. The increased frequency in debris in level II, being another indication of a greater reliance on knapping. The majority of flakes are classified as large flakes, no significant difference in the presence of small flakes was found.

Size: The average size of cores, whole pebbles and broken pebbles further strengthens the notion of increased core exploitation in level II. Cores are on average smaller in level II, which is indicative of higher exploitation (figure 4.3). Moreover, the average size of whole and broken pebbles is on smaller as well, decreasing the likelihood of selection for larger cores as this may include data from manuports.

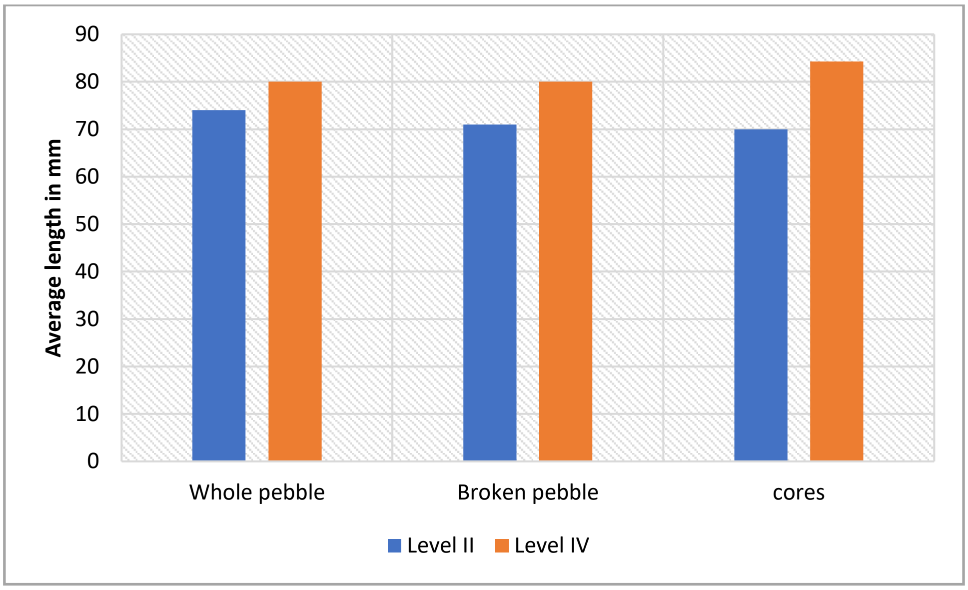

Figure 4.3: Size comparison of whole pebbles, broken pebbles, and cores in level II and level IV, in mm (Figure by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Raw material and knapped value: From the results regarding raw material selection, evidence can be found for variation in resource procurement with regard to knapped value between both sides. There is a minor decrease in the relative frequency of type A materials among non-Oldowan related artifacts in level IV, this difference amounts to 8,4 percentage points. With the aid of the established experimental data a temporal development towards the selection of material more viable for the reduction strategy in level II can be inferred.

Reduction method and flake type: Figure 4.4 shows no significant variation in preference for a unifacial or bifacial/multifacial reduction method in the respective levels. Comparable conclusions can be drawn from the cortical remains on flakes, as these ratios are remarkably similar in both levels (figure 4.5). Moreover, there is no evidence that the Gona experimental model is predictive of any unifacial or bifacial/multifacial trends at Dmanisi. The most common flake type in both layers (besides indeterminable flakes) is type VI, whilst the most frequent flake type, according to the model, would be either type II or type V. Moreover, the ratio of flake types associated with unifacial knapping to flake types associated with bifacial/multifacial knapping is not in line with the ratio unifacial cores to bifacial/multifacial cores in either level.

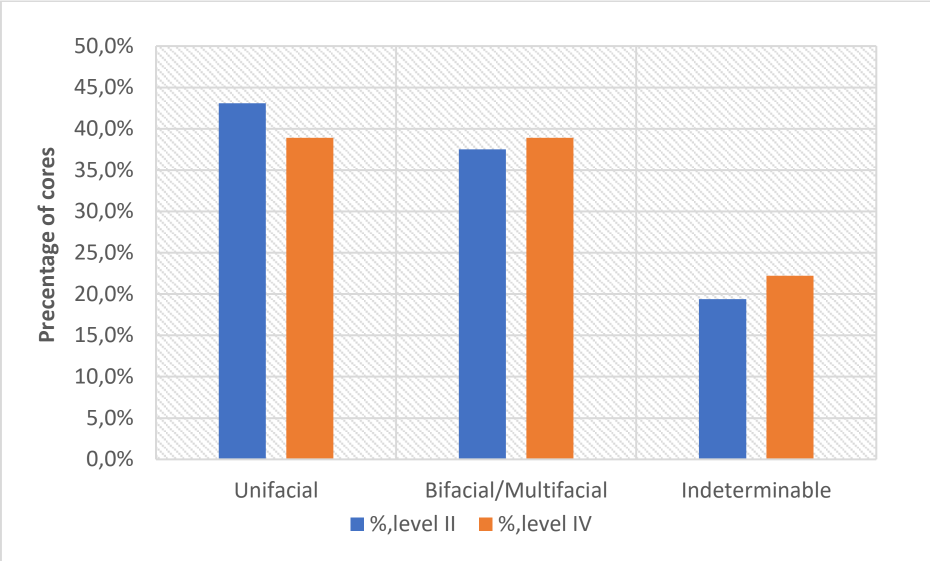

Figure 4.4: The relative frequency of reduction methods in level II and level IV (Figure by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

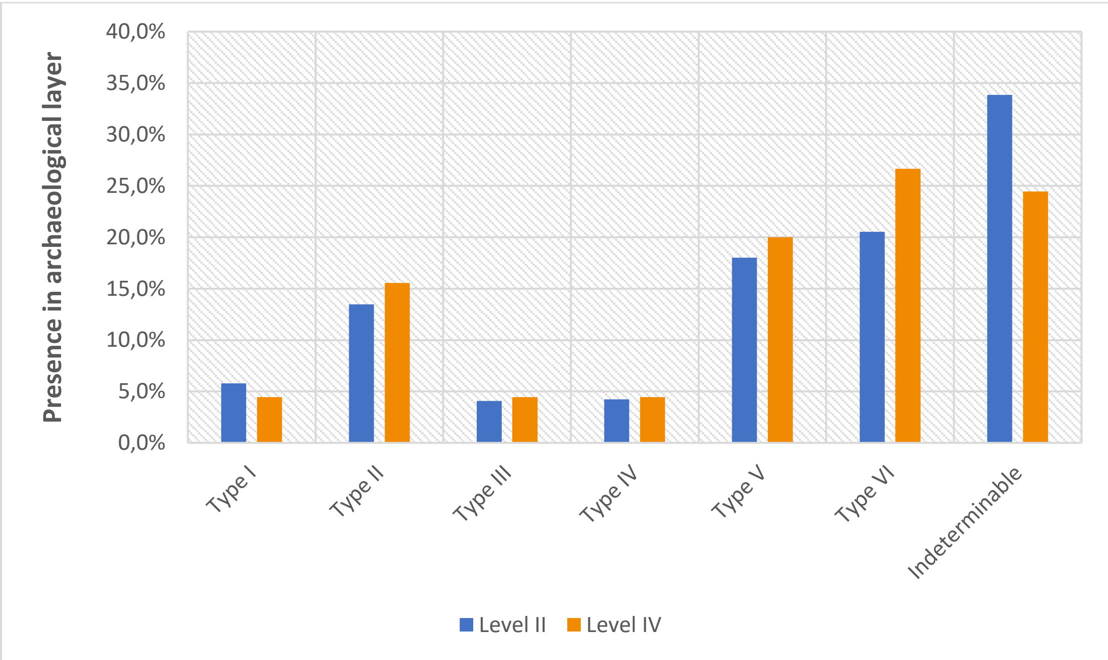

Figure 4.5: The relative frequency of flake types in level II and level IV (see table 4.6 for differences among flake types) (Figure by G.J. Kuijt, data derived from de Lumley *et al.* (2005)).

Chapter 5: Discussion – Evidence of Cumulative culture at Dmanisi

5.1 Inferring fidelity

Tennie *et al.* (2020) describes how perceived patterns in the archaeological record are not always evidence for the presence of fidelity. At times outside factors may constrain the possible solutions to such an extent that multiple independent agents may invent similar behaviours regardless of social transmission. If fidelity is to be identified in archaeology, alternative explanations for similarities in lithic behaviour must first be addressed and excluded.

5.1.1 Biological constraints

To begin with the possible biological constraints emerging from in the presence of such a high degree of hominin diversity within the period of Dmanisi's occupation. Psychological and physiological differences between the level II and level IV populations may have obliged individuals to opt for a specific a technological solution that, in the opposing population, was a socially transmitted behaviour. For instance, a difference in upper limb anatomy may have obliged one population to adhere to a specific knapping gesture. This while the other population may have access to a more efficient knapping gesture, but due to cultural reason still adheres to the less specific gesture. This results in the appearance of fidelity in the archaeological record if this difference in upper limb anatomy is not accounted for.

To begin with the psychological differences, which are complex to assess. The endocranial volume is, besides technological inferences, the only proxy for cognitive abilities. Important to note is that all excavated *Homo* fossils were discover in sediments dating to after the paleomagnetic shift; however, the stratigraphical units used for fossils do not directly correspond to that used for lithics. Both skull 1 and skull 2 were excavated in block 1 strata B1, which corresponds closest to level II. Additionally, these skulls had the greatest endocranial capacity with 730 cm^3 and 650 cm^3 respectively. The remaining three skulls were associated most closely with level IV. Skull 3, with a volume of 601 cm^3**,** originating from block 2 strata B1x. Skull 4 and skull 5, with endocranial volumes of 641 cm^3 and 546 cm^3 respectively, were excavated in block 2 strata B1y (Bermúdez del Castro *et al.* 2014; Ponce de León *et al.*, 2021;). Despite the endocranial differences, general consensus on the overall morphology suggests the presence of a single taxon in all strata (Lordkipanidze *et al.*, 2013; Rightmire *et* *al.*, 2017). This means that the differences in endocranial volume are negligible, because the individuals who's skull was preserved like were not the sole producers of the lithic assemblage. Thus, the two populations likely had similar cognitive abilities and the differences in endocranial capacity may be attributed to a sampling anomaly. Furthermore, based on the conclusion drawn from general technological tendencies de Lumley *et al.* (2005) argues that there is no clear influence on the lithic material over the duration of hominin occupation, with regard to cognition.

Physiological differences will be assessed through upper limb morphology, as the utilization of the hands and arms are most prevalent in lithic behaviours. All data regarding upper limb morphology originated in block 2 and is associated with the strata B1x and B1y, which correspond most to level IV. According to analysis of upper limb fossils in level IV, the general morphology is similar to that of *Australopithecus*, with little to no variability among individual specimen (Lordkipanidze *et al.*, 2007). However, because physiological differences cannot be completely ruled out through comparison of the fossils in each level, the broader evolutionary processes taking place approximately 1.8 mya, must be examined for the possibility of evolutionary developments in upper limb morphology during this period. The most likely anatomical developments related to tool making at the time of Dmanisi were in hand morphology. However, these developments are first documented 1.42 mya in Kenya. (Marzke, 2013; Ward *et al.*, 2014). This leaves very little room for interlevel differences in upper limb anatomy at Dmanisi. Moreover, Faisal *et al.* (2010) convincingly argue that cognitive developments, which are already addressed, were the most crucial component of biological variation in this period. Thus, the presence two population with distinct biological differences related to toolmaking, who invented similar technological solutions at the same location in a the relatively short time span (maximum of 100.000 years), will be considered unlikely.

5.1.2 Raw material constraints

Another factor that could explain similarities and differences in stone tool making is the difference in the availability of raw resources. This may result in one population being obliged to opt for one technological solution due to scarcity in raw materials or pebble morphology, while another will actually adhere to a cultural pattern despite to abundance in resource availability. Evidence points towards all stages of the reduction sequence taking place in the exact same location in both populations. Furthermore, the raw materials gathered by the Dmanisi hominins all originated from about 1000 to several 1000 meters from the site (Mgeladze *et al.*, 2010; Mgeladze *et al.*, 2011). Type B materials (less well suited for knapping) were largely gathered from the proximal alluvial deposits, while type A materials (better suited for knapping) originated from the upper cretaceous formations surrounding the site. The present distribution local of raw materials reflect the distribution found in the archaeological record (Mgeladze *et al.*, 2010), meaning the scarcity of type A materials was not a relevant factor between both levels as upper cretaceous formations are non-replenishable over time. Furthermore, the general availability of lower quality resources (type B) is also apparent in the high number of manuports being transported from the surround region to the site. The difference in pebble morphology may partially be reflected in the decreasing size of whole pebbles, broken pebbles, and cores. It would most likely not warrant a significant difference in lithic behaviour. However, since it would discourage flake procurement rather than the pattern seen in the archaeological record, there is no reason to assume it may have interfered with the apparent fidelity.

5.1.3 Ecological constraints

Lastly, differences in technological goals, due to varying strategies in environmental exploitation, caused by shifts in the availability of resources. This may reflect biases for lithic behaviours that are not accounted for in the experimental model based solely on knapped value. Assessing what the intended use of specific lithic artifacts at Dmanisi may have been, will require more in-depth ecological investigations, not in the scope of what literature research is capable of. Some tentative assumptions are put forward by de Lumley *et al.* (2005). Evidence for pebbles being used as anvils can be seen across the assemblage in scar patterns. Similarly patterns on the cortical surface of core show use as hammerstone, while reduced surfaces may have been used for digging. Moreover, micro retouches on the sharp edges of lithics are indicative of cutting. Finally, because flakes likely played a critical role in animal processing, the reduction strategy across the site primarily shows a preference for flake procurement (Mgeladze *et al.*, 2010). This is in line with the generally accepted notion of the Oldowan, which is maximizing the production of cutting edges through flakes (Semaw *et al.*, 2000; Toth, 1985).

However, Doronichev and Golovanova (2010) argue in favour of two distinguishable Oldowan phases. The first phase had a greater reliance on cores and choppers, while in the later phase flaking and the creation of retouched tools became more widespread. This may be indicative of a difference in technological goals, as flake procurement is less important when reliance or cores and choppers is higher. However, the phases likely transitioned in east-Africa around 1.7 mya and is associated with the emergence of *H. erectus* and the possibility of phase two already being present outside Africa by 1.8 mya has no further evidence behind it. Moreover, the notion of two Oldowan phases has been contested (Semaw *et al.*, 2009).

Overall, the tentative assumption will be held that both populations had a similar technological goal, with the main focus laying on maximizing sharp edge production. That being said, it must be kept in mind that future research into the possible variation in subsistence strategies of both populations, may shed more light into their technological goals.

5.2 Interpretations

The results of the lithic analysis offer insights into the lithic behaviours expressed by the Dmanisi Hominin populations of level II and level IV. More specifically, regarding the artifact types and dimensions, raw material selection, reduction method and flake characteristics. General tendencies in each level are likely to be explained by fidelity in social reproduction since alternative explanations are dismissed. Overall, there is no strong evidence for the presence of behaviour copying at the site of Dmanisi.

Types, classification, and size: The difference regarding the exploitation of singular cores for flake procurement in level II and level IV is suggestive of fidelity, as two differing reduction strategies are maintained within separate populations. However, behaviour copying can solely be determined by the viability of raw materials selected for core exploitation in both populations. Moreover, there is an observable increase of non-Oldowan related artifact types in level IV; however, this can be disregarded since no viability can be assigned to the behaviour as the technological goal is determined to be sharp edge production.

Raw materials and knapped value: Since the raw material preferences are based solely on non-Oldowan related artifact types, no evidence for the viability of raw material selection can be determined in either level, with regard to core exploitation. Thus, behaviour copying cannot be inferred from the observed difference in core exploitation.

Additionally, despite the fact that no viability can be assigned to non-Oldowan related behaviours, the minor increase in type B materials (less suited for knapping) among whole pebbles and broken pebbles, may suggest an awareness surrounding the superior or inferior quality of the raw materials. This is further supported by other literature, as observations drawn from a broader lithic assemblage, than the one presented here, reaches similar conclusions (Mgeladze *et al.*, 2011).

Reduction method and flake type: Lastly, the observable interlevel similarities in reduction method and flake type rule out the possibility for inferences regarding behaviour copying for two reasons. The high frequency of indeterminable artifacts with respect to both variables leaves conclusions with a degree of uncertainty. Moreover, since the assemblage does not align with the model of predictive trends regarding the flake type and reduction methods, created by Stout *et al.* (2019), it does not warrant the future use of the model intended for Gona for investigating behaviour copying at Dmanisi, if the necessary data would become available.

5.3 Limitations

A number of caveat to this conclusion are worth mentioning, to provide some insight into the problems that arose during the investigation for behaviour copying at Dmanisi.

To begin with issues met due to the nature of literature-based research, several limitations in available data has constrained the analysis presented in this thesis. The lacking data on artifact type and dimensions needed to create a robust data driven variable suggestive of detached piece viability. This led to the lack of an extensive experimental methodology based on presentable data, which proved to be a major shortcoming of the analysis. The use of experimental data from the Georgian-Spanish team may have allowed for some validation regarding technological behaviour; however, this was an impossibility as no data on the interlevel variation on the raw materials used for knapping was available. This in combination with the use of incompatible terminology regarding the raw materials, across literature, resulted in a significant degree of generalisation of the data, seriously watering down the conclusion further. This was most evident in the distinction between type A and B materials, which was based solely on knapped value as other variables were impossible due to such constraints. Other concerns about the research method are the absence of definitive data regarding artifact dimensions and related those the process of inferring a learning process, such as the lack of stratigraphically diverse data for upper limb fossils and research related to the technological goals.

Furthermore, the complex stratigraphy related to the pipe and gully formations resulted in difficulties guaranteeing the distinctiveness of level II and level IV. The redeposited lithic material from block 2, strata B1x and B1y likely originated from a layer much closer to the strata the level II material was found in, if not the same strata. Meaning either level IV may be contaminated with material from level II, or level IV may consist of a wider reaching temporal dimension than suspected initially.

The robustness of the data is relatively weak due to the fact that material originated solely during the 1991-1999 excavations. This is especially relevant for the unbalanced proportions of the artifact frequency in both levels. Extending the assemblage to include a broader range of lithic materials from level IV could resolve this problem but would require reaching beyond the available literature.

Lastly, due to the research being based on inductive reasoning it is impossible to logically accept the conclusion will full certainty. It becomes paramount to present the inductive arguments as convincingly as possible. However, the biological factors that may have played a role can be called into question, as there is ongoing debate around the number of species present at Dmanisi.

5.4 Comparison

The lithic analysis did not produce any indication of cumulative culture, as no reliable evidence for behaviour copying could be provided. Based on the conclusions of this lithic analysis, two scenarios will be laid out to contextualize the patterns present between level II and level IV. In the first scenario both populations invented their lithic behaviours independently. While the other scenario follows the conclusions Stout *et al.* (2019) draw from the experimental research at Gona. Because the results from this study do not rule out the possibility of behaviour copying, the assumption may be held that behaviour copying was still present at Dmanisi. Both scenarios allow for speculation regarding broader evolutionary trends in the Lower Palaeolithic.

5.4.1 Scenario 1: no behaviour copying

Firstly, in the event that the ability for behaviour copying was not present at Dmanisi. This would suggest individual cognitive abilities for technological innovation played a more important role than social cognitive abilities during the Lower Palaeolithic, a technological strategy more similar to modern primates. Bonobo's (*Pan paniscus*) and Orangutans (*Pongo pygmaeus*) have for instance, displayed the ability for knapping behaviour, both taught and spontaneous; however, not yet to the extend displayed in the Oldowan (Motes-Rodrigo *et al*., 2022; Toth and Schick, 2009). The creators of the Dmanisi tools were probably cognitively more derived than the closest phylogenetically related species, namely great apes. That being said, perhaps the difference may not be as severe as often considered, previous studies discovered that chimpanzees (*Pan troglodytes*) are capable of maintaining a novel behaviour within a population as well (Davis *et al.,* 2016; Vale *et al*., 2017; Whiten *et al.*, 2009). In this scenario the Dmanisi hominins would, in a cognitive sense, lie relatively closer to chimpanzees that to species capable of cumulative culture.

This is best explained by the ZLS hypothesis developed by Tennie *et al.* (2020). The zone of latent solutions (ZLS) of a species is the range of possible behaviours that an individual be draw upon to achieve a technological goal without social processes. Through cumulative culture a species can improve a technology and maintain that adaptation with behaviour copying beyond an individual's ZLS. In this scenario the cognitive foundations that allow for the extension of technology beyond the ZLS is diverse throughout the lower Palaeolithic, being present at Gona but not at Dmanisi. There is an ability for social transmission within the ZSL among all hominins, but the retention of such technological developments may not as long lasting without the foundation of behaviour copying (Walker *et al.,* 2022). Transmission had a far too demanding cognitive load for behaviour copying, while at Gona this foundation for ratcheting is significantly more present.

5.4.2 Scenario 2: behaviour copying

Alternatively, if the assumption is held that behaviour copying was present at Dmanisi, which is more in line with the conclusions from the research done at Gona (Stout *et al.*, 2019), that would allow for the comparison of cumulative culture at both sites. In this case, the evolution of cumulative culture across the Lower Palaeolithic is more linear and uniform. Additionally, this notion is more in line with the high degree of intercontinental exchange resulting in the phenotypical diversity found at Dmanisi (Lordkipanidze *et al.*, 2013; Rightmire *et al.,* 2017). This would further suggest that the creators of the Oldowan industry at Dmanisi were socially, in a cognitive sense, more derived than proposed in the previous scenario. Primarily with regard to technological transmission, which may have facilitated the proliferation of Palaeolithic technology. (Stout *et al.*¸2019; Toth and Schick, 2018; Pargeter *et* al., 2019)

Furthermore, if this the assumption of uniformity holds true, developments evident in the Dmanisi assemblage at large would be indicative of increased ratcheting, in comparison to Gona, where technology was relatively static (de Lumley *et al.,* 2005; Mgeladze *et al.*, 2010; Stout *et al.*, 2019; Toth, 1985). This notion of increased ratcheting may be supported by previous research into level II and level IV, which was aimed at differences in the presence of intentional retouches, blank selection, and percussion movements (Baena *et al.,* 2010).

These adaptations are not yet evidence for cumulative culture, which is considered to have emerged after the Acheulean industry (Shipton and Nielson, 2015). However, after the emergence of behaviour copying, evolutionary selection processes may have started to favour adaptations that decreased the cognitive load of inventing advantageous variations on known technology. This is because the transmission of new behaviours no longer requires the individual to passively reach similar technological solutions, as they are taught actively by other individuals. In other words, these developments may be reflective of gradual increases in the phenomena of ratcheting, facilitated by evolutionary processes related to epigenetics or genetics (Corbey, 2020; Iriki and Toaka, 2012; Morgan *et al*., 2020).

To elaborate further, species capable of behaviour copying are able overcome their zone of bounded surprisal (ZSB) (Manrique and Walker, 2022). The limiting factor of the ZSB is related to individual top-down cognition models. These top-down models are constructed to create habitual behaviours in an individual, which is achieved by suppressing other possible actions. However, this suppression also affects the ability for social transmission. Key to behaviour copying, and thus cumulative culture, is the ability to overcome the "conservative" cognitive models, but for the majority in favour of behavioural models based on more viable behaviours displayed by other individuals (Davis *et al.*, 2019).

The neurological developments that may have facilitated this behaviour have taken place in the parietal lobe (associated with spatial information) and in the frontal lobe (associated with undertaking actions), specifically the region referred to as the frontoparietal cortex. The remodelling of the frontoparietal cortex likely played a significant role in the evolution of primate tool behaviour and remained important during Hominin cognitive evolution (Hecht *et al.*, 2015; Iriki and Toaka, 2012; Stout *et al.*, 2015). That being said, analysis of the five cranial remains found at Dmanisi are suggestive of a relatively underdeveloped frontal lobe compared to more derived Hominins, meaning the ability for ratcheting was under selection at the time of Dmanisi (Ponce de León *et al.*, 2021). Holding the assumption that behaviour copying was present at Dmanisi, the increased ratcheting in comparison to Gona (Stout *et al.*, 2019), may be explained by gradual remodelling of the frontoparietal region. This in turn, enabled the *Homo* species require less cognitive potential to reach outside their ZSB and ZLS, which would be evidence for the gradual evolution of cumulative culture.

Chapter 6: Conclusion

This thesis demonstrates one approach for finding evidence for cumulative culture in the archaeological record. The Oldowan assemblage of Dmanisi, Georgia (¬1.8 mya) serves a case study in order to further explore larger trends in human evolution during the Lower Palaeolithic. The site is of significant archaeological value as it contains the oldest Hominin fossils outside of the African continent. Two temporal categories, separated by a maximum of 100,000 years, are recognized in order to compare the identified lithic behaviours, with the aim of inferring patterns that suggest the presence of cognitive abilities related to cumulative culture.

This goal is realised by following the model entertained by Stout *et al.* (2019). This model is subdivided in three phases, the first two phases allow for the identification of specific features that make up the phenomena of cumulative culture, and a third phase aimed at reconstructing broad reaching evolutionary scenarios within cognitive evolution. Firstly, an assessment of reproductive fidelity within both temporal categories is made through lithic analysis. Secondly, a guarantee must be made that the patterns of fidelity are explained solely by social transmission. This is achieved by identifying and eliminating other available possibilities that may give the appearance of social transmission, such as population specific biological variation or environmental constraints. Moreover, the viability of the reproduced behaviour found in the archaeological record will be assessed through experimental data based on local raw materials. Thirdly, trends reminiscent of behaviour copying are investigated, which allows for the contextualization of cumulative culture within a broader evolutionary framework. All stages undergone in this thesis are solely based on existing and available literature.

In the case of Dmanisi level II and level IV, two differing socially transmitted behaviours are identified. However, behavioural copying cannot be guaranteed, due to limitations in the research method. Therefore, the analysis fails to find support for the establishment of two equal behaviours under the similar circumstance, thus not proving the active transmission of behaviour within populations. The results for the case study led to the construction of two scenarios that may explain the observed patterns in the lithic assemblage. Since the results of the lithic analysis do not discredit the possibility of behaviour copying being present among the creators of the Oldowan tools at Dmanisi.

In the first scenario, the possibility of cumulative culture being present at Dmanisi is completely ruled out. The behavioural trends may be transmitted with fidelity in the population; however, the ability to retain innovations is considerably lower than if behavioural copying was identified. This suggests the Hominins in level II and level IV were cognitively closer to great apes than to modern humans. Individual innovation may play a prominent role in explaining trends regarding Lower Palaeolithic technologies, with the relatively quick appearance and disappearance of lithics behaviour. In comparison to Gona, a high degree of cognitive variation can be found across the spatiotemporal dimension. Cumulative culture will, in this case, have to be approached with high site specificity and primarily for cognitive developments in sociality during the Oldowan.

The alternative scenario entertains the idea that behaviour copying was present at Dmanisi. In this case, previous research would be suggestive of possible cultural ratcheting at the site (Baena *et al.,* 2010). The overall implications this would entail are a more uniform and linear evolutionary trajectory during the Lower Palaeolithic, as the Dmanisi Hominins display more derived cognitive traits in relation to the Gona Hominins. The mechanism responsible for this pattern may lie in gradual (epi)genetic developments taking place within the frontoparietal region, which may be further explored in the future.

It is evident that demonstrating the presence of behaviours related to cumulative culture in the archaeological record requires a data rich approach. The limits imposed by the research method resulted in insufficient evidence for the presence of behaviour copying could be identified at Dmanisi. Here, several adjustments are proposed in order to generate more robust conclusions. Starting out with, the use of different metrics for the differing reduction strategies and a viability variable that is more reflective of the environment, may allow for the identification of behaviour copying in other aspects of the lithic behaviour. This can be achieved through the reanalysis of the assemblage, in addition to the expansion of the assemblage to include more recent excavations. A suggestion for reduction strategy would be the differing knapping strategies identified by Baena *et al*. (2010). A suggestion for improving the viability variable is to revaluate technological goal, which is this case was solely based on flake procurement. This may be enhanced through further research into the ecological exploitation strategies of Dmanisi Hominins. Moreover, establishing additional temporal categories based on the most recent interpretation of the complex stratigraphy found at

Dmanisi, may increase the robustness of the inductive argument regarding biological constraints.

Abstract

Extensive research has been conducted into cumulative culture; however, whether its evolutionary origins leans more toward learned social or individual cognitive abilities remains contested. The aim of this thesis is to further the process of identifying the relation between social and individual cognitive abilities during the emergence of cumulative culture within human evolution. More specifically, at the Lower Palaeolithic site of Dmanisi, Georgia (approximately 1.8 mya), where the earliest Homo remains were discovered outside Africa. This is attempted by means of the stepwise framework developed by Stout et al. (2019). Here, its use is aimed at differentiating variation in learning mechanisms within the Oldowan lithic assemblages found at Dmanisi. The results of the lithic analysis failed to provide evidence for behaviour copying due to limitations in available data. This results in two possible scenarios that may explain the patterns seen in the assemblage. (1) The Hominins at Dmanisi may have continuously reinvented lithic technologies lacking the ability to retain specific behaviours in the population over large periods of time. There is a high degree of variability in behaviour copying across the spatiotemporal dimension during the Lowerpalaeolithic. (2) The Hominins at Dmanisi did possess the cognitive abilities for behaviour copying. This would suggest the technological tendencies in the lithic analysis are indicative of a more uniform emergence of cumulative culture. Finally, suggestions are provided to investigate the presence of behaviour copying at Dmanisi with higher accuracy.

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