Università degli Studi di Padova

Dipartimento dei Beni Culturali: Archeologia,
Storia dell'Arte, del Cinema e della Musica

Master Degree in
ARCHAEOLOGICAL SCIENCES

Curriculum in
APPLIED SCIENCES TO CULTURAL HERITAGE MATERIALS AND SITES

Early bead-making in prehistoric Baluchistan: a chalcolithic workshop area at Mehrgarh (Pakistan), mid 4th millennium BCE

Supervisor:

Prof. Massimo Vidale

Co-supervisor:

Prof. Lara Maritan

Master Candidate

Irene Caldana

2018795

ACADEMIC YEAR 2022/2023

List of Contents

Acknowledgments

I am deeply grateful to Professor Lara Maritan and Professor Massimo Vidale for their extraordinary patience, guidance and invaluable insights throughout this research endeavour. Their mentorship has been instrumental in shaping this thesis. Special thanks to Dennys Frenez, who taught me and patiently followed me through the process of making the silicone casts of the beads.

I would like to express my heartfelt gratitude to my family for their support during the challenges of this thesis-writing journey. Their constant encouragement has been my pillar of strength. Last but not least, I would like to express my deep gratitude to my partner. Their unwavering belief in me and constant encouragement have pushed me to persevere and never give up, their love and support have been my driving force.

Abstract

Mehrgarh si trova nel Baluchistan centro-settentrionale, in Pakistan, all'estremità settentrionale della pianura di Kachi (Fig. 1). Si tratta un'area planiziaria che si incunea verso nord tra le catene montuose di Sulaiman e aperta a sud/sud-est alle pianure semi-aride della grande valle dell'Indo.

Le pianure di Kachi erano attraversate dal fiume Indo nel Pleistocene, con conseguente deposito di significativi sedimenti alluvionali (Maldonado et al. 2011). Il fiume Bolan, che oggi serpeggia lungo i limiti orientali del sito di Mehrgarh, funge da via di comunicazione fondamentale tra la valle dell'Indo e il Baluchistan. Il passo di Bolan, non lontano dal sito, offre ora, come faceva in epoche preistoriche, una rotta strategicamente vantaggiosa, collegando la valle di Quetta e il Baluhcistan centrale all'entroterra afghano. La Missione Archeologica Francese (Jarrige et al. 1995; 2005; 2013), ha operato soprattutto sui depositi archeologici dei Periodi Neolitico e Calcolitico del sito di Mehrgarh (circa 7000-3000 a.C.), su una superficie totale di non meno di 300 ettari. Altra e conseguente linea di ricerca è stata lo scavo del più tardo sito fortificato di Nausharo, non lontano dal sito preistorico principale, un abitato della Civiltà Harappana o dell'Indo, costruito in forme monumentali e abitato nel corso del 3° millennio a.C.

L'antico insediamento di Mehrgarh riveste un'importanza significativa come una delle prime evidenze dichiarate di occupazione sedentaria, agricoltura e pastorizia nel Sud dell'Asia (Kenoyer 1998, Jarrige et al. 2013). Ha svolto un ruolo fondamentale nelle discussioni sull'inizio dell'agricoltura non solo nel Subcontinente Indo-Pakistano, ma anche sull'evoluzione dell'Eurasia meridionale nel suo complesso. Infatti lunghe stagioni di scavi estensivi da parte della Missione Archeologica Francese (*Mission de l'Indus*), dal 1974 al 1986, hanno sostenuto l'idea che l'agricoltura sia emersa non soltanto nella cosiddetta "Mezzaluna Fertile", ma indipendentemente in varie regioni del sud dell'Eurasia (dal corridoio levantino e i monti delle catene del Tauro e Zagros agli Elburz, al Kopet Dag e alle cinture pedemontane settentrionali del Baluchistan) a causa di fattori come l'ambiente locale, specie vegetali e animali adatte e piogge stagionali (Petrie, 2015; Kingwell-Banham et al., 2015). Prove scientifiche in questo senso sono state le evidenze di prolungati processi di domesticazione locale di specie di cereali (inizialmente soprattutto orzo), e di varietà locali di bovini (in primo luogo il *Bos indicus*), in un quadro organico nel quale la dipendenza alimentare dalle specie selvatiche sfruttate tramite la caccia gradualmente diminuiva, insieme alla taglia degli animali gradualmente addomesticati. Il paradigma dello sviluppo graduale di un'economia di tipo neolitico si accompagna all'idea di una graduale sedentarizzazione della popolazione di Mehrgarh, che avrebbe pian piano abbandonato il nomadismo stagionale dando vita, nell'arco di circa due millenni, a una vita prevalentemente sedentaria. L'ipotesi è attualmente al vaglio di studi micro-istologici sul record

dentario dei numerosi individui sepolti nelle aree funerarie di età neolitica e calcolitica dell'insediamento (L. Bondioli, comunicazione personale).

Lo sviluppo della vita di villaggio a Mehrgarh comportò una parallela intensificazione dei processi di confronto e comunicazione interpersonale all'interno della comunità stanziale, i cui riflessi si colgono nelle *parures* di ornamenti personali rinvenute sugli inumati di età neolitica e calcolitica. Già in età neolitica i morti erano deposti nelle tombe (del tipo "a catacomba", cioè formate da un accesso verticale a pozzo, con camera laterale separata dall'accesso da un muretto di mattoni crudi) con elaborati ornamenti come collane, bracciali, cavigliere, cinture e fasce trapunte di perline; le materie prime usate in queste ornamentazioni comprendono steatite o talco, conchiglia marina, calcite, e più raramente, nel corso del 5° millennio a.C., turchese e lapislazzuli. È stato notato, al proposito, che una percentuale (per quanto minoritaria) delle perline in steatite, già dalle sepolture che appaiono più antiche, era stata sottoposta a processi di cottura ad alta temperatura, secondo concetti e pratiche tecniche che avrebbero conosciuto un'enorme fortuna nei millenni successivi della protostoria del Subcontinente (Jarrige et al 2005: 356-361). Nelle successive sepolture di età calcolitica, tra 5° e 4° millennio a.C., la complessità delle *parures* di ornamenti dedicate ai defunti sembra notevolmente attenuarsi, mentre le sepolture stesse sembrano conformarsi a una dimensione generalmente accettata di uniformità. Per converso, proprio nello stesso arco di tempo le figurine in terracotta (sia maschili sia femminili) sembrano invece ricoprirsi di sovrabbondanti ornamenti, sino ad apparire quasi "barocche". Questa trasformazione, in altre parole, sembra suggerire che alcune dimensioni dell'esibizione delle differenze sociali all'interno della comunità si fossero gradualmente trasferite dall'occasione dei funerali alla sfera della vita degli individui; ed è in questo quadro che la produzione di elementi di collana merita di essere investigata a fondo. Questa produzione rimase comunque importante, continuando a comprendere l'uso di materiali semi-preziosi molto visibili come turchese, lapislazzuli e corniola, tutti ottenuti grazie al commercio a lunga distanza (il turchese dall'Asia centrale, il lapislazzuli dal Badakshan afghano, la corniola dall'India o dall'Iran orientale).

I campioni studiati in questa tesi sono stati rinvenuti durante una ricognizione di superficie nell'area del sito calcolitico di MR2, che copre più di 100 ettari. In questo ampio paesaggio fortemente dissezionato dall'erosione, in un'area ristretta di soli 10 x 10 metri quadrati, sono stati trovati, nei pressi di un edificio nel quale aveva avuto luogo la lavorazione delle conchiglie, più di 400 manufatti, testimonianza di un'importante area di lavoro per la produzione di perle semipreziose (lapislazzuli, corniola, turchese e altre) risalente alla metà del IV millennio a.C.. È uno dei pochi e più antichi siti di produzione di perle finora individuati e completamente registrati nel Subcontinente Indo-Pakistano, insieme alle testimonianze di Harappa (Vidale 2000; Kenoyer 2017c), Lewan nel bacino di Bannu, e Gazi Shah nel Sindhi Kohistan (in entrambi i casi studiate in modo ancora molto parziale).

Anche se due articoli precedenti (Vidale 1995; Vidale et al. 2017) hanno affrontato aspetti specifici dei reperti paleoetnologici di MR2, finora non è stata effettuata un'analisi sistematica e completa di questa importante collezione, che include, oltre alle perle e agli scarti di produzione, un insieme di punte di trapano ben conservate.

Questo studio riconsidera l'intero repertorio rinvenuto in una prospettiva unitaria, tenendo conto delle analisi archeometriche finora effettuate e già pubblicate nei precedenti contributi, applicandosi nuovamente ai materiali con metodi e formati aggiornati, e considerando componenti selezionate dell'industria messa a disposizione della scrivente con tecniche analitiche di microscopia e di analisi molecolare come la microscopia digitale, la microscopia elettronica a scansione, la microscopia confocale e la spettroscopia micro-Raman. Lo studio comprende infatti un Catalogo dei 48 campioni che meritavano un esame più accurato, i risultati delle nuove analisi sinora effettuate, e delle Conclusioni riassuntive.

Mehrgarh is located in north-central Baluchistan, Pakistan, at the northern end of the Kachi Plain (Fig. 1). This is a lowland area wedged northward between the Sulaiman mountain ranges and open south/southeast to the semi-arid plains of the greater Indus Valley.

The Kachi Plains were previously crossed by the Indus River in the Pleistocene, resulting in the deposition of significant alluvial sediments (Maldonado et al. 2011). The Bolan River, which meanders along the eastern limits of the Mehrgarh site today, serves as a key communication route between the Indus Valley and Baluchistan. The Bolan Pass, not far from the site, now offers, as it did in prehistoric times, a strategically advantageous route, connecting the Quetta Valley and central Baluhcistan to the Afghan hinterland. The French Archaeological Mission (Jarrige et al. 1995; 2005; 2013), has been working mainly on the archaeological deposits of the Neolithic and Chalcolithic Periods of the Mehrgarh site (ca. 7000-3000 B.C.), covering a total area of no less than 300 hectares. Another and consequent line of research was the excavation of the later fortified site of Nausharo, not far from the main prehistoric site, a Harappan or Indus Civilization settlement built in monumental forms and inhabited during the 3rd millennium BCE. The ancient settlement of Mehrgarh is of significant importance as one of the earliest stated evidences of sedentary occupation, agriculture and pastoralism in South Asia (Kenoyer 1998, Jarrige et al. 2013). It played a pivotal role in discussions about the beginning of agriculture not only in the Indo-Pakistani Subcontinent, but also in the evolution of South Eurasia as a whole. Indeed, long seasons of extensive excavations by the French Archaeological Mission (Mission de l'Indus) from 1974 to 1986 supported the idea that agriculture emerged not only in the so-called "Fertile Crescent" but independently in various regions of southern Eurasia (from the Levantine corridor and the mountains of the Taurus and Zagros ranges to the Elburz, Kopet Dag, and northern foothills belts of Baluchistan) due to factors such as local environment, suitable plant and animal species, and seasonal rainfall (Petrie 2015; Kingwell-Banham et al. 2015).

Scientific evidence for this was the evidence of prolonged local domestication processes of cereal species (initially mainly barley), and local varieties of cattle (primarily Bos indicus), in organic framework in which food dependence on wild species exploited through hunting gradually decreased, along with the size of the gradually domesticated animals. The paradigm of the gradual development of a Neolithic-type economy goes hand in hand with the idea of a gradual sedentarization of the Mehrgarh population, which would have gradually abandoned seasonal nomadism giving way, over a period of about two millennia, to a predominantly sedentary life. The hypothesis is currently under investigation by micro-histological studies of the dental record of the numerous individuals buried in the settlement's Neolithic and Stone Age burial areas (L. Bondioli, personal communication).

The development of village life at Mehrgarh entailed a parallel intensification of the processes of confrontation and interpersonal communication within the settled community, the reflections of which are captured in the parures of personal ornaments found on Neolithic and Chalcolithic-age inhumates. As early as Neolithic times, the dead were laid in tombs (of the "catacomb" type, i.e., formed by a vertical shaft-like access, with a side chamber separated from the access by a mud-brick wall) with elaborate ornaments such as necklaces, bracelets, anklets, belts and bead-quilted bands; the raw materials used in these ornamentations included steatite or talc, sea shell, calcite, and more rarely, during the 5th millennium B.C, turquoise and lapis lazuli. It has been noted, in this regard, that a percentage (albeit a minority) of the steatite beads, already from the burials that appear oldest, had been subjected to high-temperature firing processes, according to concepts and technical practices that would experience enormous fortune in the later millennia of the Subcontinent's protohistory (Jarrige et al. 2005: 356-361). In later burials of the Chalcolithic age, between the 5th and 4th millennia B.C.E., the complexity of the ornament parures dedicated to the deceased seems to be greatly attenuated, while the burials themselves seem to conform to a generally accepted dimension of uniformity. Conversely, in precisely the same time frame, terracotta figurines (both male and female) seem instead to become covered with overabundant ornamentation, to the point of appearing almost "baroque." This transformation, in other words, seems to suggest that certain dimensions of the display of social differences within the community had gradually shifted from the occasion of funerals to the sphere of the lives of individuals; and it is within this framework that the production of necklace elements deserves to be thoroughly investigated. This production remained important, however, continuing to include the use of highly visible semi-precious materials such as turquoise, lapis lazuli, and cornaline, all obtained through long-distance trade (turquoise from Central Asia, lapis lazuli from Afghan Badakshan, cornaline from India or eastern Iran).

The samples studied in this thesis were found during a surface survey in the area of the MR2 chalcolithic site, which covers more than 100 hectares. In this large landscape heavily dissected by erosion, in a small area of only 10 x 10 meters square, more than 400 artifacts were found near a building in which shell processing had taken place, evidence of an important working area for the production of semiprecious beads (lapis lazuli, cornaline, turquoise, and others) dating to the mid-4th millennium B.C. C. It is one of the few and oldest pearl production sites so far identified and fully recorded in the Indo-Pakistani Subcontinent, along with evidence from Harappa (Vidale 2000; Kenoyer 2017c), Lewan in the Bannu Basin, and Gazi Shah in Sindhi Kohistan (in both cases still studied in a very partial way). Although two previous articles (Vidale 1995; Vidale et al. 2017) have addressed specific aspects of the MR2 paleoethnological finds, until now there has not been a systematic and comprehensive analysis of this important collection, which includes, in addition to beads and production waste, a set of well-preserved drill bits.

This study reconsiders the entire assemblage from a unified perspective, taking into account the archaeometric analyses carried out so far and already published in previous contributions, reapplying to the materials with updated methods and formats, and considering selected components of the industry made available to the writer with archaeometric techniques such as digital microscopy, scanning electron microscopy, confocal microscopy and Raman spectroscopy. In fact, the study includes a Catalogue of the 48 specimens that deserved closer examination, the results of the new analyses to date, and summarized Conclusions.

1 The site of Mehrgarh

Mehrgarh stands out as the best-known early village site in South Asia, providing the earliest evidence for sedentary occupation, agriculture and pastoralism uncovered to date. Its importance lies in its central contribution to discussions of the timing and complexity of the transition to agriculture on the subcontinent (Petrie 2015). Together with the complex stratified remains of its early settlements, a graveyard of more than 300 burials, considered the largest known Neolithic cemetery in the world, has revealed, and continues to reveal, complex patterns of socio-technical development and overall adaptation of local cultures in the first half of the Holocene (Coppa et al. 2006).

The subsequent spread of an agro-pastoral economy based on wheat, barley, sheep, goats and cattle, together with subsequent and continuous advances in pottery, beadwork and metalworking, had a significant impact on the populations of the Indus plains. The proximity to the natural habitat of wild barley has led to speculation about local domestication of barley, especially since modern wild barley exists in Pakistan and Afghanistan. Genetic studies reveal multiple origins of barley, including an eastern group distinct from Levantine and European barley, possibly from regions such as Iran or further east (Kingwell-Banham et al. 2015). The specifics of barley domestication remain a topic of ongoing research, but the presence of distinct genetic groups hints at a complex history. Barley, more resistant to aridity and salinized microenvironments, is reputed to have been a crucial "agricultural colonizing crop" that paved the way to a growing exploitation of varieties of wheat.

In summary, Mehrgarh's archaeological record, for the earlier investigated occupation phases, provides valuable insights into the origins of farming practices in South Asia and the subsequent development of agricultural practices and technological innovations. As we will soon see, its post-Neolithic contexts offer crucial perspectives on the region's social evolution and settlement patterns during the chalcolithic era, showcased by extensive pottery workshops, bone tool production centres, and specialized bead-making activities at the ancient settlement.

1.1 Geographical and Geological overview

Mehrgarh lies on the western edge of the Baluchistan plateau. Its geological context reveals a history of changing environments, from marine to deltaic, and significant tectonic activity that has shaped the landscape, in which the Bolan River plays a crucial role.

The region is mainly characterised by limestone formations attributed to the Himalayan orogeny. The site is located at the western end of the Kachi Plain, which is connected to the Indus Plain, and consists mainly of sedimentary rocks called the Sibi Formation. The Bolan plain (Fig. 1), in which Mehrgarh is located, is surrounded by two mountain ranges: the central Brahui range to the west and the Bannh range to the east. A river runs parallel to the Bolan Plain through this area, eventually disappearing south of the Bannh. In these eroded mountainous areas, the clay and sandstone layers of the Sibi Formation come to an end. The concentration of salt and gypsum in these layers suggests a shallow sea or lagoon-like environment, while occasional layers of coarser granulometry indicate a deltaic environment. Later, during this period, the region experienced significant fluvial activity, which deposited large quantities of pebbles eroded from earlier limestone banks. The current landscape reflects the last Pleistocene tectonic phase, with folds and faults shaping the region. The Central Brahui Range, particularly its eastern slope, demonstrates these geological features. The Bolan River, which flows from north to south, follows the eastern slope of the Brahui Mountains. It receives water from seasonal streams originating in the same mountain range. Upstream, in the Bolan Pass, the river has a steeper mountain-like profile, but downstream it becomes a seasonal river as it enters the Kachi plain. The river's course is marked by further gravel beds and embankments. Further downstream, we observe the evolution of alluvial terraces, which are also found in the main riverbed (Jarrige et al. 2013, Appendix).

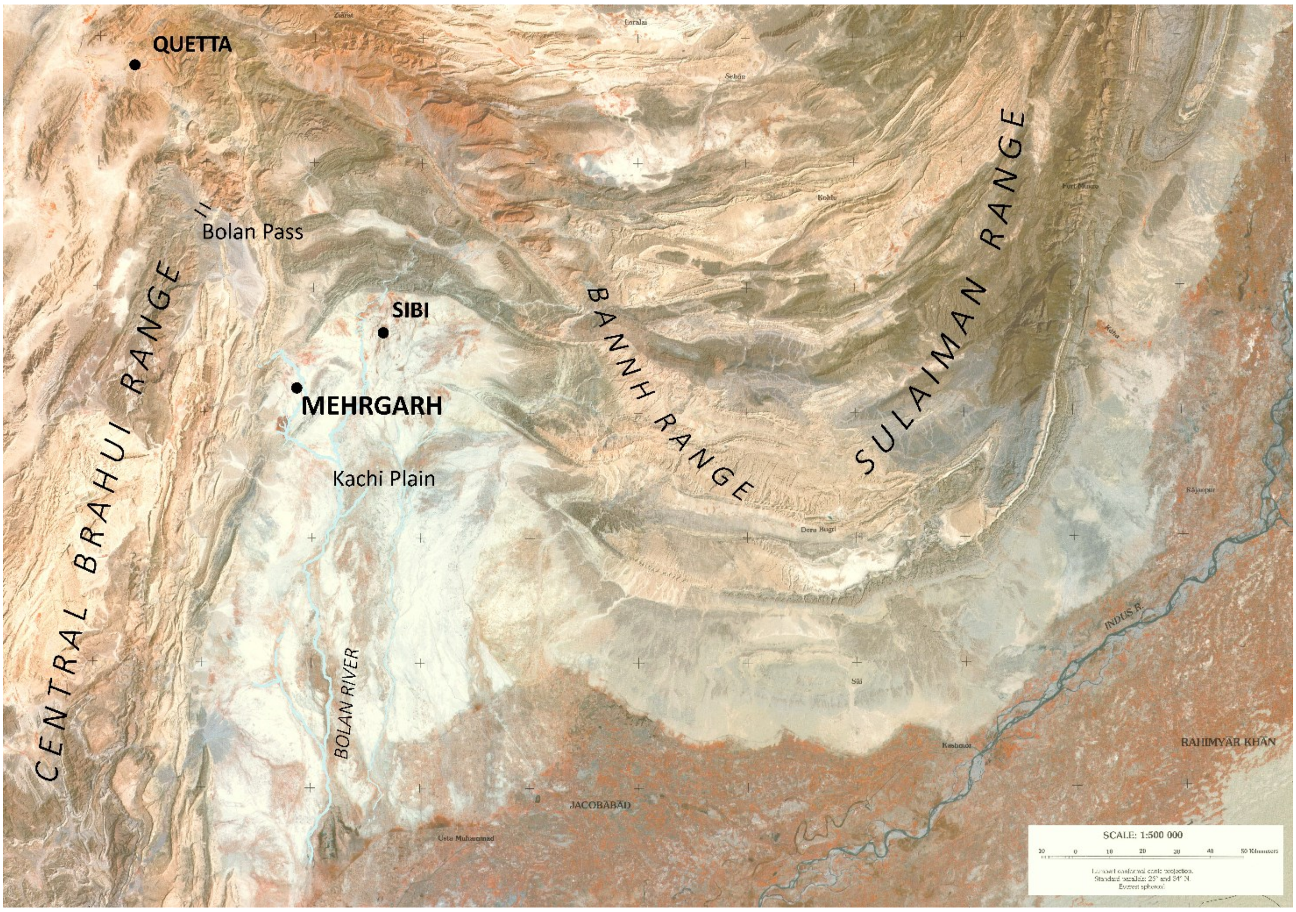

Fig. 1 : N.E Balochistan, Pakistan – satellite image map, published by the Department of the Interior U.S. Geological Survey ; modified by Caldana, I.

1.2 CHRONOLOGY AND CULTURAL SEQUENCE

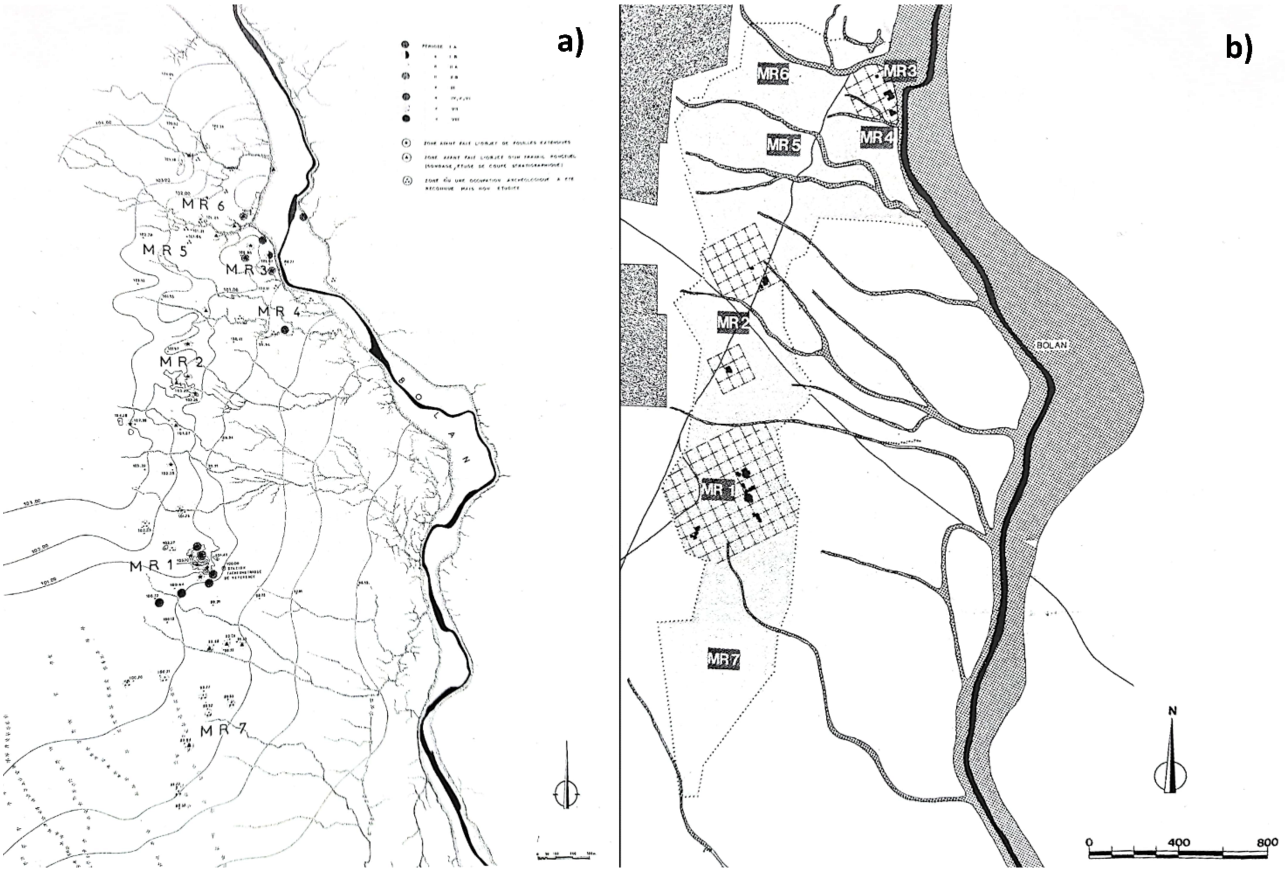

Fig. 2 : a) Topographical map of the site, b) Distribution of the archaeological zones of Mehrgarh, from Jarrige et al. 1995 : 98-99.

The sequence of the site of Mehrgarh is divided into distinct archaeological periods, including Neolithic (Periods I, IIa, and IIb) and Chalcolithic (Periods III, IV, and V).

During Period I, which dates back to around 7000 BCE and spans approximately 500-700 years, the excavated area MR.3 (Fig. 2) aceramic phase, revealed nine separate building phases distinguished by superimposed erections made of mud bricks. This Period is marked by the cultivation of various barley variety, with *Hordeum vulgare* being prominent. Additionally, hunting of animals and incipient goat and cattle (*Bos indicus*) domestication are evident. Graves, in this period, were furnished with stone and bone tools, as well as beads made from marine shell, lapis lazuli, and turquoise, and other goods. For the excavators there are a lot of similarities between Mehrgarh Period I and the early aceramic phase at Kili Gul Muhammad (Jarrige et al. 2005: 64). The later phases of Period I introduced coarse ware and likely involved an intensified domestication of sheep and cattle, a trend that continued into Period II with a development into an agricultural economy.

Period IIa, spanning from 5470 to 4700 BCE in areas MR.3 and MR.4 (Fig. 2b), is characterized by a ceramic phase with chaff temper, slab-built. This phase witnesses an increase in domesticated animals, larger structures, and storage units. Burials associated with mud brick walls or platforms contain valuable items such as ceramics, stone tools, and beads of turquoise, lapis lazuli and other imported stones. In the late phase of Period IIa, fine red ware with iron-rich slip appears in MR.4.

Fig. 3: A view of the buildings during the excavation campaign of 2000 of area MR.3, from Jarrige et al. 2001:415 (Fig. 240).

These developments from Period IIa extend into Period IIb, ranging from 4700 to 4000 BCE. In this phase, fine red ware with minimal chaff tempering, fired at higher temperatures, coexisted with coarse wares. Later, in this period, ceramics adorned with simple motifs, and rare copper objects and steatite beads, as seen in Period III, appeared for the first time. The identification of copper objects cast with a lost wax process, in layers datable to the mid-6th millennium BCE, add to a general picture of evolving complexity (Thoury et al. 2016).

Period III ceramics (4000-3500 BCE), primarily in area MR.2 (Fig. 2b) but also in MR.4, were labelled the Togau A style and the Kile Gul Mohammad Phase II and III (Jarrige C. et al. 1995: 68) which stretches from southern Baluchistan to the present-day Khyber Pukhtunkhwa region. The ceramic repertoire is characterized by fine wheel-made pottery adorned with intricate geometric motives. During this time, the "turnette" (Jarrige et al. 1995: 68) and the potter's wheel became of general use; copper objects begun to spread slowly, and crucible fragments were more and more common. Period III holds particular interest as a pivotal and less explored phase, covering an extension of not less than 100 hectares with ancient ruins, burials, and residues of manifold craft activities. During this Period, the settlement(s) featured compartmentalized buildings (Fig. 4) probably used as seats of storage, dwellings, and artisanal workshop areas.

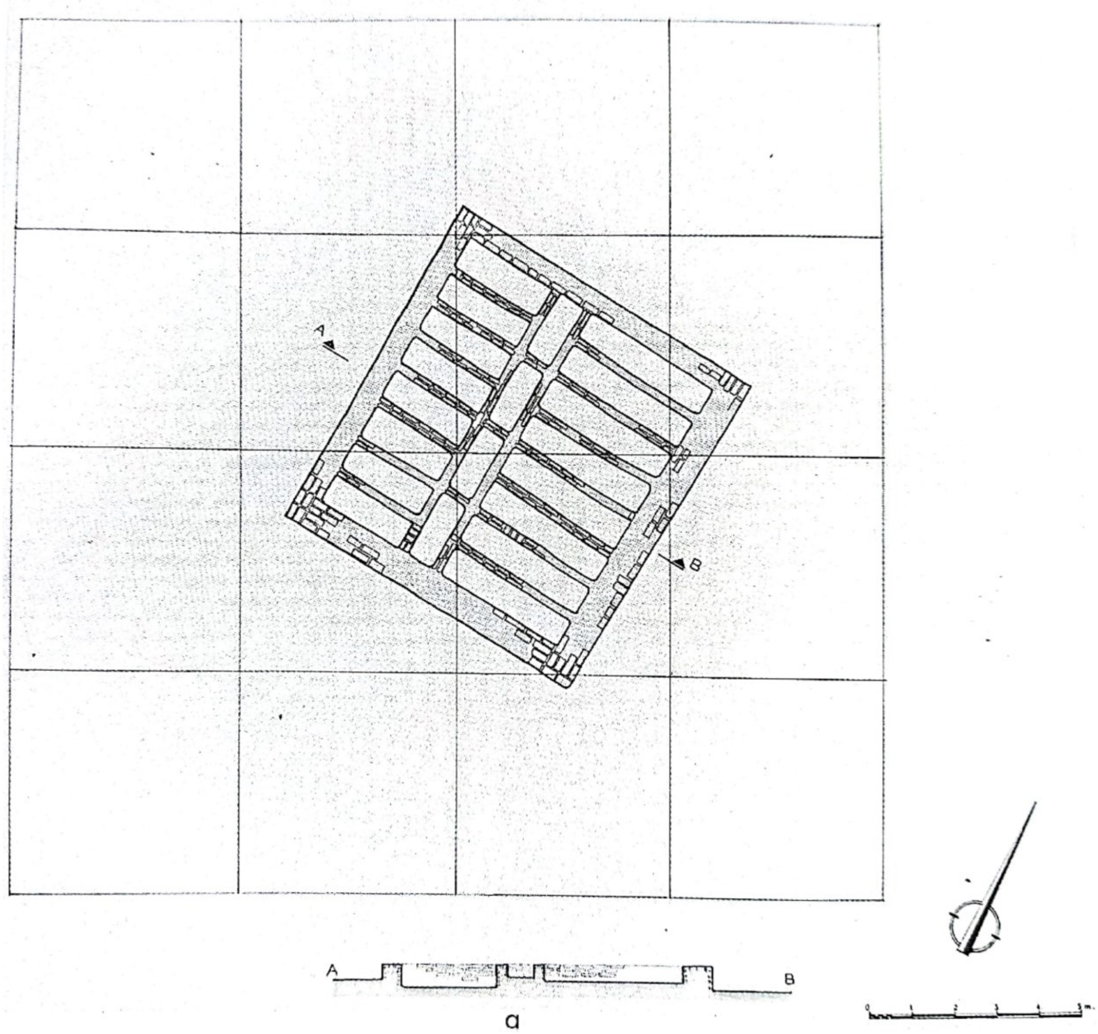

Fig. 4: a compartment building in Area MR.2, period III, form Jarrige et al. 1995: 439 (Fig. 9.9a).

The site MR.2, above other possible locations, stood out with a significant hide and leather production workshop, as revealed by over 190 bone tools mainly crafted from onager bones found near one of these peculiar buildings (Jarrige, C. et al. 1995: 583-613). MR.2's field records, in particular, revealed a thriving pottery-making industry with finely executed polychrome wares (Fig. 5), large-scale open-air pottery firing zones, remnants of copper-melting crucibles and bead-making activities (Jarrige et al. 1995: 69).

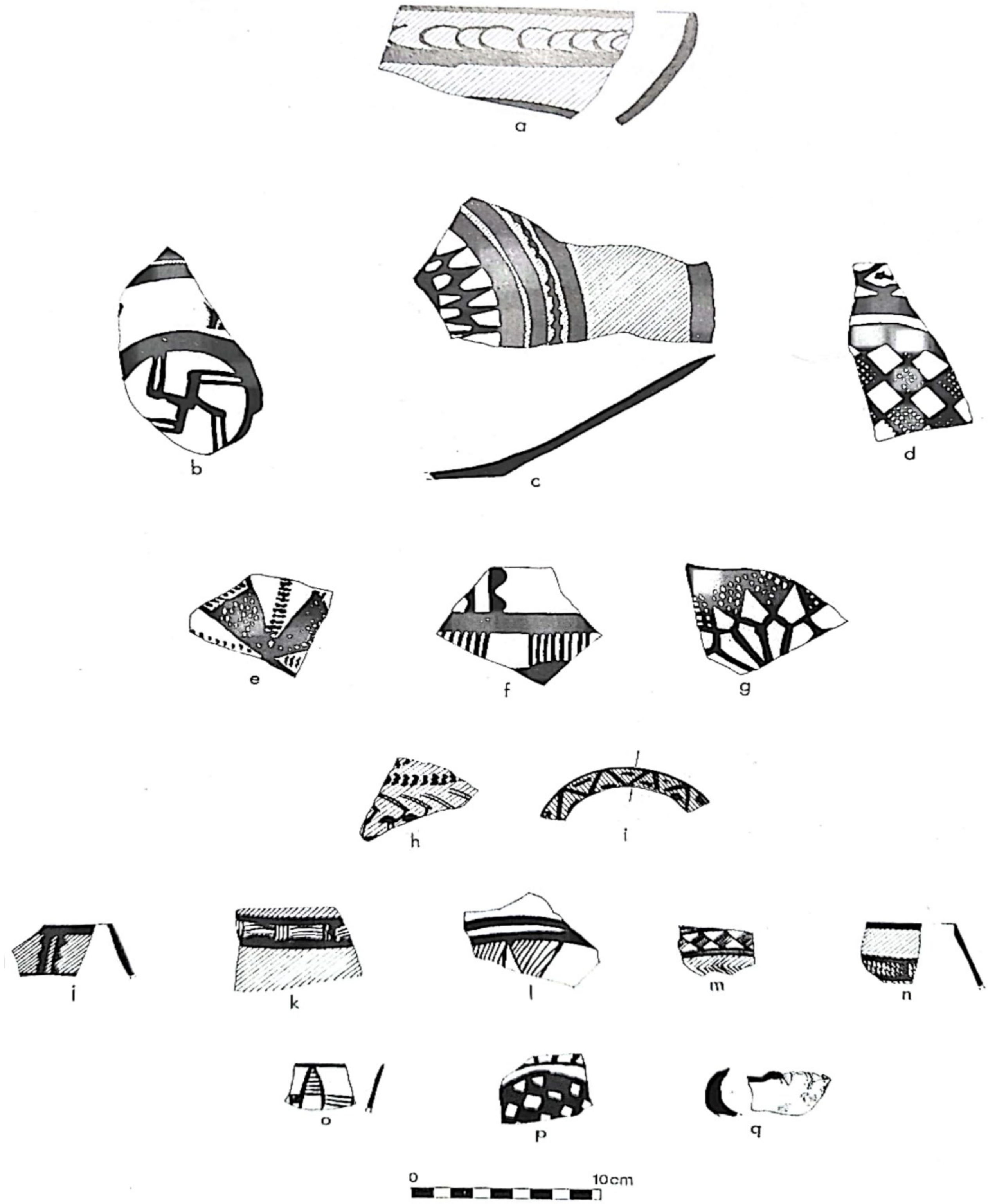

Fig. 5: Some polychrome potsherds of area MR.2, from Jarrige et al. (1995: 394; Fig. 8.16).

The architectural layout of Period III witnessed improvements in the efficient utilization of settlement space, reportedly due to a reduction in flooding in the Bolan plain. This Period experienced a notable increase in population density, with prolonged occupations. The compartmentalized buildings created with mudbricks displayed more intricate designs compared to their Neolithic predecessors, constructed in a similar way to the early buildings, but more complex and built using the headers and stretchers technique. An intriguing observation relates to an apparent change in mudbrick composition. When comparing mudbricks used in Neolithic with those of Chalcolithic buildings, it becomes evident that the former had abundant impressions of chaff, seeds, and grains: in chalcolithic bricks, these vegetal inclusions, to a great extent, are absent, and only chaff impressions are on record. This change suggests an enhancement in threshing techniques. During the most recent excavation season, in the vicinity of storage units in area MR. 2, six houses made of mudbricks were uncovered. These structures featured more extensive rooms compared to the adjacent storage areas and were equipped with doorways and fireplaces. They were arranged in a loose semi-circular configuration, maintaining significant spacing between them.

Within these houses, the excavation team made several discoveries. Alongside pottery, they unearthed a limited amount of chipped stone tools, a lapis lazuli pendant, a carnelian bead, and a substantial quantity of backed steatite beads.

In terms of agriculture, a continuity from Period II to Period III is evident, characterized by the growing importance of cultivating various wheat and barley varieties (*Triticum* and *Hordeum Sphaerococcum*). These crops eventually formed the foundation of the agricultural economy of the Indus Civilization. The practice of animal husbandry remained largely consistent, with a decrease in the quantity of cattle, with respect to the exploitation of sheep and goats. Additionally, the presence of various wild species hints at the possibility of a more widespread hunting practice.

A diversification was noticed in the utilization of regional resources, indicative of a more effective resource exploitation strategy. The most significant shift from the Neolithic to the Chalcolithic period is found in the domain of ceramics. There was a surge in pottery production within designated manufacturing zones. Within the MR.2 area, three substantial open "ovens" or large collective ceramic firing sloping platforms were discovered, and near them an approximately 6 m deep trench with pottery debris (Jarrige et al. 1995:143, 2.5b). This transition is characterized by advanced technological innovations, including more effective polishing techniques, the application of red paint, the incorporation of grog, and the implementation of a more intricate cycle of reduction and oxidation processes during firing.

Periods IV and V, located on mound MR.1 (Fig.2b), are not well preserved due to extensive erosion and agricultural activities around the *tepe*; these Periods seem to align with the Kechi Beg phase (3500-3000 BCE, based on relative ceramic parallels – reportedly due to a lack of reliable radiocarbon dates). These Periods are characterized by finely decorated polychrome (black, red and white) ceramics, seals, and a decline in the use of flint tools. In the area MR.1 was discovered a settlement of smaller size than the ones of Period III, with houses with low entryways and courtyards, often endowed with large storage jars (never found in Period III, despite the abundance of finds related to domestic activities). Jarrige et al. (1995) and Thiébault (1988a and b; 1992) hypothesise that a significant transformation occurred in the Bolan Basin during period IV and V, impacting the dynamic between humans and their environment. This transformation led to a decrease in flooding within the region, which, in turn, spurred the advancement of canal irrigation systems. As a result, this development encouraged the establishment of a more sedentary lifestyle, primarily due to the reduced impact of seasonal changes. Furthermore, this period saw the cultivation of barley (*Hordeum sphaerococcum*) and locally grown grape varieties, alongside the spreading practice of ovicaprine husbandry.

1.3 NEOLITHIC AND CHALCOLITHIC GRAVEYARDS

The Neolithic graveyards of Periods I and II consist of nine layers of burials, alternating with nine building levels. The typical burial tradition at this site involves digging a pit about "one meter deep" (Jarrige et al. 2005: 132) with a small niche created within the chamber for placing grave goods. The deceased individuals were usually laid in a flexed position on their sides, and often oriented in an east-west direction. Once the body was placed within the chamber, it was sealed off using clay or mudbricks and then filled with earth. Among the items discovered in these burials were clay figurines, beads and ornaments, meticulously crafted from a variety of materials, including shell, white and black steatite (Jarrige et al. 2005: Figs. 270, 271), copper, lapis lazuli, turquoise and few cornelian and calcite beads. The presence of a substantial quantity of beads and other ornaments crafted from semi-precious stones sourced from distant locations, along with the exceptional craftsmanship exhibited, indicates a significant societal investment in the burial practices and rituals associated with the deceased individuals at Mehrgarh. The grave goods extended beyond jewellery and ornaments, raw materials played a significant role in these offerings, with the inclusion of substances like ochre, bitumen lumps and small blocks of galena. Tools were also an integral part of the grave goods, illustrating the skills and trades of the deceased. Stone axes, hammerstones, chisels, and spatulas crafted from bone and flint items were often placed alongside the departed. These tools, carefully selected for their utility in life, served as a testament to the person's occupation or role within their community. What sets these grave goods apart is the lack of association or repetition among them. Unlike some burial traditions where specific items are consistently included in grave offerings, the diversity of materials, ornaments, raw resources, and tools found in these burials defies a clear pattern. In the lower level graves, bodies were sometimes accompanied by offerings of young goats, arranged in a semi-circle around the legs of the deceased (Jarrige et al. 2005: Fig. 141). Each grave appears to be a unique reflection of the individual's life, beliefs, and societal context, with no standardized or repeated combination of grave goods.

The graveyard of Period III (Fig. 6), situated to the north of excavation site MR. 2X, covers an area of 85 sq. m, this burial ground holds the remains of 73 individuals. The graveyard of Period III displays fewer graves belonging to children, suggesting potential changes in demographics or cultural templates and practices over time. The method of interment in Period III remained consistent, with the deceased being placed in a flexed position on their sides and oriented in an East-West direction. What sets Period III apart from its Neolithic predecessors is the intriguing uniformity in grave goods. Unlike the Neolithic phases, where the wealth or social status of the deceased could often be inferred from the objects buried with them, the individuals of the Period III graveyard were all interred with mostly the same types of objects. This uniformity in grave goods complicates attempts to gauge the economic status or occupations of those buried in this site.

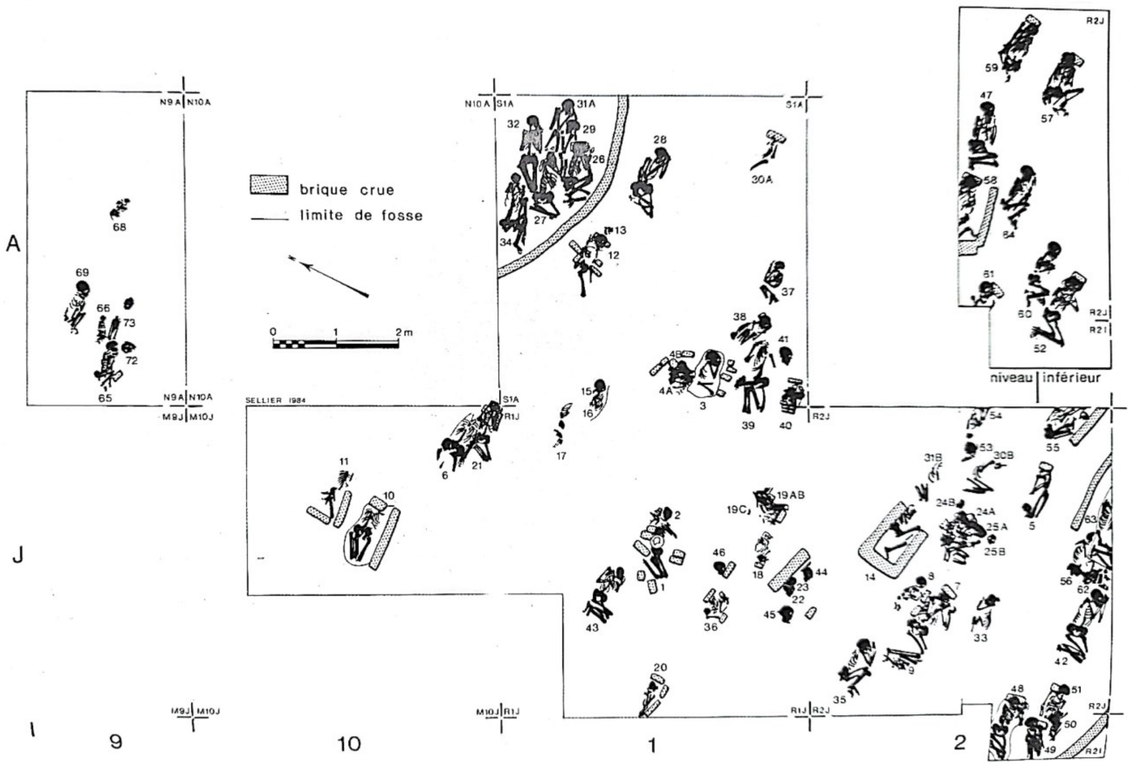

Fig. 6: The graveyard's central sector of Period III, form Jarrige. et al. (1995: 486, Fig. 10.18).

1.4 MR.2, EVIDENCE OF CRAFT ACTIVITIES

The area MR2 of Mehrgarh has gained renown for the rich array of crafting activities that once flourished there. It includes ceramic, metal, bone and beadmaking craft activities. As stated above, the evidence of ceramic production features three substantial open kilns and is strewn with thousands of pottery fragments and other residues of firing activities. Thirteen crucibles, indicative of the presence of copper metallurgy, were discovered in the same area, suggesting that metalworking was an integral part of the activities carried out at MR.2. The abundance of lithics further attests to the diversity of craftsmanship occurring at the site.

The bead-making area, which occupies a flattened surface spanning approximately 50 sq. m, is characterized by the presence of scattered potsherds and is intersected by numerous gullies. It is in close proximity to a workshop seemingly designated for marine shell crafting; within this area, a cluster of discarded beads, drill heads, and the remnants of the bead-making process were uncovered. This assemblage suggests that they might have been discarded in a specific occasion, not a prolonged deposition. The objects here studied were collected on surface by the French members of the Mission (Jarrige. et al. 1995: 299, Fig. 4.11a), apparently exhausting what was left of the original deposit. It is assumed that the sedimentary fractions of the original deposit had been completely removed by erosion. In fact, subsequent visits and careful scrutiny of the same location did not reveal further relevant items. As the assemblage was collected during a series of surface visits, we have to take into account the possibility that some of the finds do not date back to the late chalcolithic horizons of the majority, but were more recent additions due to the passage on the spot of people and animals (because some kinds of beads, even today, are fixed to leather bridles). In fact, at least three carnelian bead fragments, at closer inspection, turned out to be most likely modern (as detailed below).

2 The samples

In this Chapter, we take into account and explore the collection of bead-making products and debitage from the described Mehrgarh's Period III settlement, area MR.2. This material is the result of the systematic and comprehensive collection mentioned above, covering an area of 10 x 10 m, given to M. Vidale as a finished collection, that exceeds 400 finds. To a great extent it is formed by lapis lazuli debitage. While lapis lazuli flakes are not considered individually, as already studied: this part of the collection, in fact, was studied in some detail and published in Tosi and Vidale (1990) and in Vidale et al. (2017).

Here, ultimately, we will integrate the research delving deeply into the study of 48 objects which were left unpublished or, as in the case of the lapis lazuli bead blanks and beads, deserve further analytical attention. They consist of stone beads and flakes made of carnelian, lapis lazuli, turquoise, and a set of green jasper tubular drills heads. Not all the artefacts mentioned or photographed in the first original publication of the activity area (Vidale et al. 2017) were present in the assemblage that was made available for the present research. Area MR.2 was recognized and recorded for the residual evidence of its industrial activities, including pottery making and copper melting or smelting, as well as beadmaking. The finds appear to have been discarded near a dwelling location, suggesting – as already stated - a single, focused event rather than multiple episodes of deposition. This Chapter includes a catalogue of these specific objects to gain insights into the beadmaking practices and their significance within the context of Mehrgarh's archaeological framework. The material documentation and description will follow the indications suggested for bead research by Kenoyer (2017c: 163, Appendix 1).

2.1 Beads

2.1.1 Carnelian

The carnelian specimens, eleven in total, were drawn and then photographed under the stereomicroscope (see Fig. 7); below is a table listing the measurements and a brief description of each bead (Tab. 1).

SAMPLE	MAX LENGTH ALONG THE DRILLING AXIS (mm)	MAXIMUM WIDTH (mm)	DRILLING HOLE DIMENSIONS (mm)		DESCRIPTION
			MIN	MAX	
M1	3.5	5.2	1.1	2.2	dark-reddish carnelian bead, biconical in shape with rounded edge, complete with no damage, polished surface.
M2	3.0	5.3	0.8	3.1	orange-reddish carnelian bead, octagonal transversal section, truncated-biconical in shape, complete with no damage, whitened surface.
M3	3.1	4.2	1.0	2.4	orange carnelian bead, spherical shape, split longitudinally, polished whitened surface.
M4	7.8	10.4	1.3	3.8	orange carnelian bead, sub-spherical shape, split longitudinally, polished whitened surface.
M5	5.7	9.9	1.2	3.9	orange carnelian bead, heptagonal transversal section, truncated-biconical in shape; whitish patina on all the surface, complete with no damage, whitened surface.
M6	3.7	6.9	0.7	3.4	orange-brownish carnelian bead, octagonal transversal section, truncated-biconical in shape, complete with no damage, whitened surface.
M7	3.1	4.5	1.0	2.7	dark-reddish carnelian bead, octagonal transversal section, truncated-biconical in shape, complete with no damage half surface whitened
M8	6.0	6.3	2.3	2.9	red and orange-banded carnelian bead, cylindrical in shape with bevelled ends, fragmented with one end only, split longitudinally, polished surface.
M9	5.2	6.0	1.8	2.7	light orang carnelian bead, cylindrical in shape, fragmented, portion not determinable, split longitudinally, polished surface.
M10	4.1	7.9	1.1	2.9	light-orange carnelian bead, biconical in shape with rounded edge, complete slightly chipped, polished surface.
M11	11.9	9.9	2.8	2.9	light orange carnelian bead, elongated octagonal transversal section, truncated-biconical in shape, complete with no damaged surface.

Tab. 1: carnelian industry: table showing measurements and descriptions of each bead.

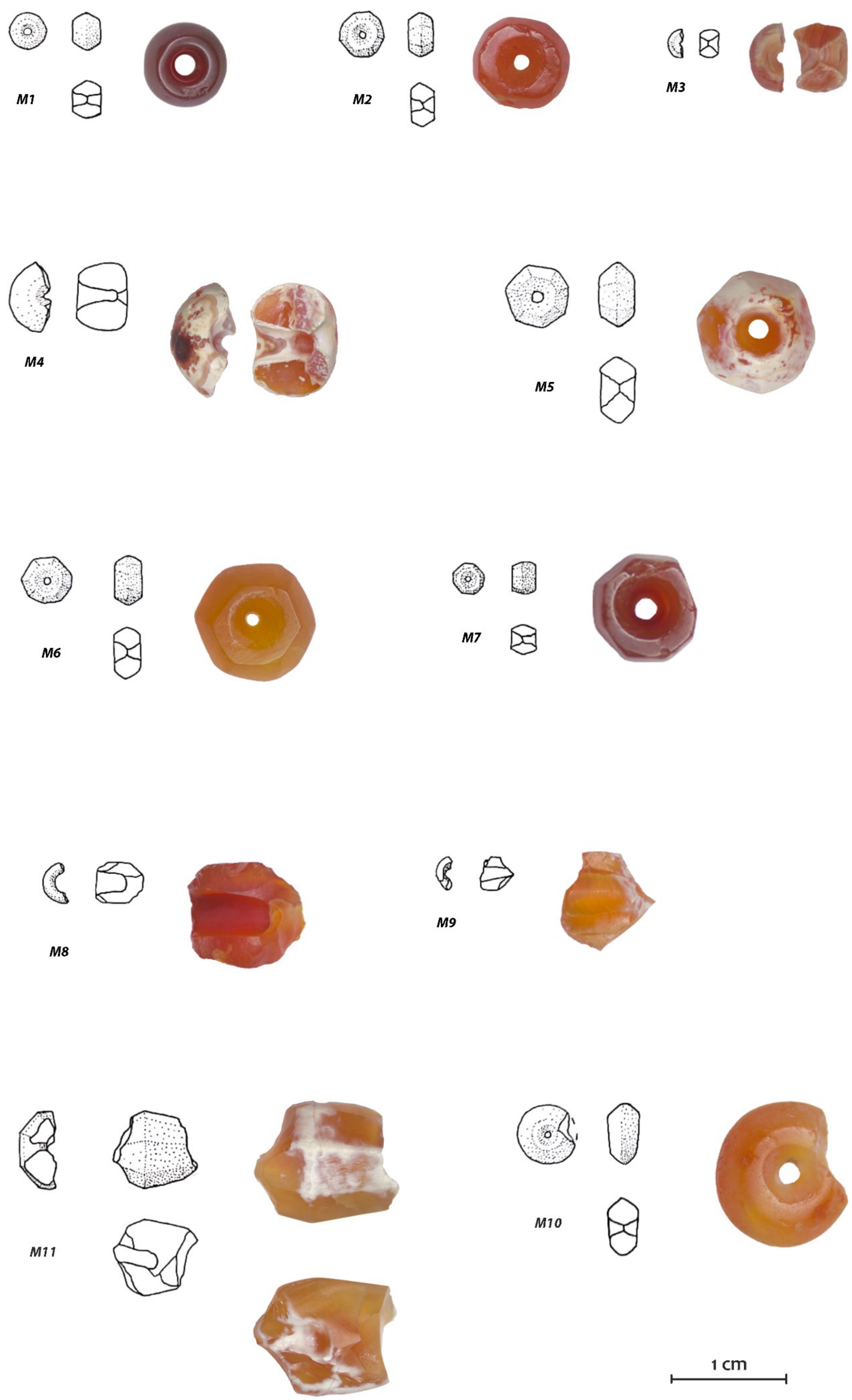

Fig. 7: carnelian beads: drawings and images taken with the stereomicroscope.

2.1.2 Lapis lazuli

There are a total of 13 lapis lazuli beads of the disc and barrel type, most of which were broken during drilling, and are shown in Figure 8 with drawings and stereomicroscope images. Below follows a table with measurements and a brief description of each bead (Tab. 2).

SAMPLE	MAX LENGTH ALONG THE DRILLING AXIS (mm)	MAXIMUM WIDTH (mm)	DRILLING HOLE DIMENSIONS (mm)		DESCRIPTION
			MIN	MAX	
M36	1.5	3.1	0.3	1.1	lapis lazuli bead, small flat disk shape, fragmented, split in half longitudinally during perforation
M37	1.8	3.1	0.7	0.9	lapis lazuli bead, small flat disk shape, fragmented, split in half longitudinally during perforation
M38	1.9	4.0	0.9	1.2	lapis lazuli bead, small flat disk shape, fragmented, split in half longitudinally during perforation, perforated only on one side.
M39	5.2	4.0	0.7	1.4	lapis lazuli bead, cylindrical in shape, fragmented with one end only, split longitudinally.
M40	5.8	4.1	0.8	2.0	lapis lazuli bead, cylindrical in shape, fragmented, split longitudinally during perforation.
M41	5.0	4.0	1.2	2.3	lapis lazuli bead, cylindrical in shape, complete slightly chipped, drilling holes unaligned.
M42	2.2	4.1	1.1	2.1	lapis lazuli bead, disk shaped, complete, unpolished
M43	2.6	6.2	1.1	2.1	lapis lazuli bead, disk shaped, complete, unpolished, polygonal section.
M44	8.7	5.4	0.4	0.9	lapis lazuli bead, cross-shaped, fragmented, split longitudinally.
M45	2.8	3.9	1.2	1.8	lapis lazuli bead, disk shaped, complete, unpolished
M46	11.9	9.9	2.8	2.9	lapis lazuli bead, disk shaped, complete, slightly chipped, unpolished
M47	1.4	3.9	1.2	1.6	lapis lazuli bead, small flat disk shape, fragmented, split in half longitudinally
M48	2.3	4.6	1.2	2.0	lapis lazuli bead, biconical disk shaped, complete, polished

Tab. 2: Lapis lazuli industry: table showing measurements and descriptions of each bead.

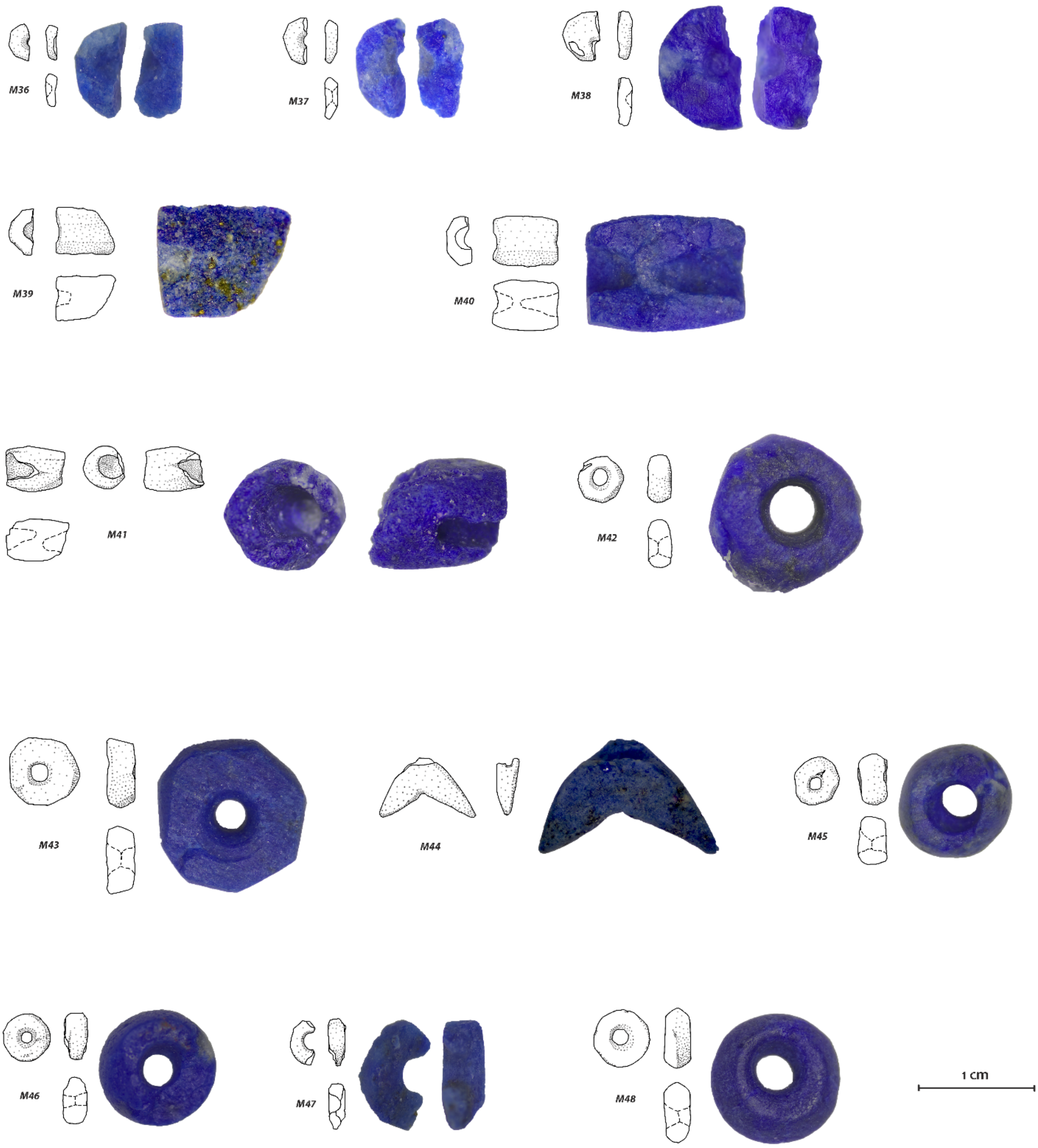

Fig. 8: lapis lazuli beads: drawings and images taken with the stereomicroscope.

2.2 EVIDENCE OF BEAD-MAKING

2.2.1 CARNELIAN MANUFACTURING WASTE

Only four samples of carnelian debitage are present in this collection, specifically three chips and one almost parallelepiped block. Below a table with measurements and descriptions (Tab. 3) and then in Figure 9 drawings and stereomicroscope images of the four samples.

SAMPLE	MAX LENGTH (mm)	MAX WIDTH (mm)	MAX HEIGHT(mm)	DESCRIPTION
M12	10.0	7.5	0.3	light pink-orange carnelian blank; whitish patina on the surface
M13	9.9	4.8	4.4	orange banded carnelian flake
M14	7.8	4.3	4.8	light pink carnelian flake; whitish patina on 2 fractures
M15	12.4	8.2	5.1	light orange carnelian flake.

Tab. 3: Carnelian debitage: table showing measurements and descriptions of the samples

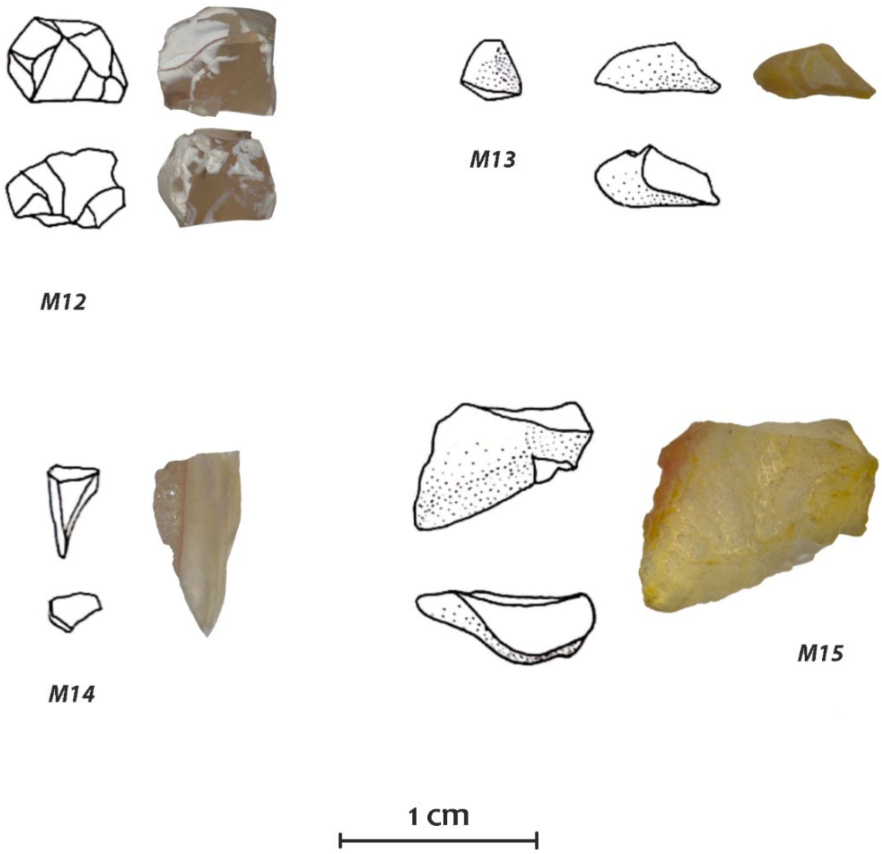

Fig. 9: carnelian debitage: drawings and images taken with the stereomicroscope.

2.2.2 LAPIS LAZULI MANUFACTURING WASTE

Some drawings of the lapis lazuli debitage studied in detail in Tosi and Vidale 1990 and Vidale et al. 2017 are shown below in Figs. 10 and 11. In the 1990 publication, Tosi and Vidale report that the operational sequence for the production of disc and barrel-shaped beads consisted in an initial reduction of the raw material by exploiting the inner cleavage planes of the stone, dividing it into parallelepiped-shaped blocks. The next steps in the creation of beads were the chipping of these blocks and the following abrasion to give them an almost complete shape before drilling. the use of the grooving-and-splitting reduction technique has been reported, albeit minimally.

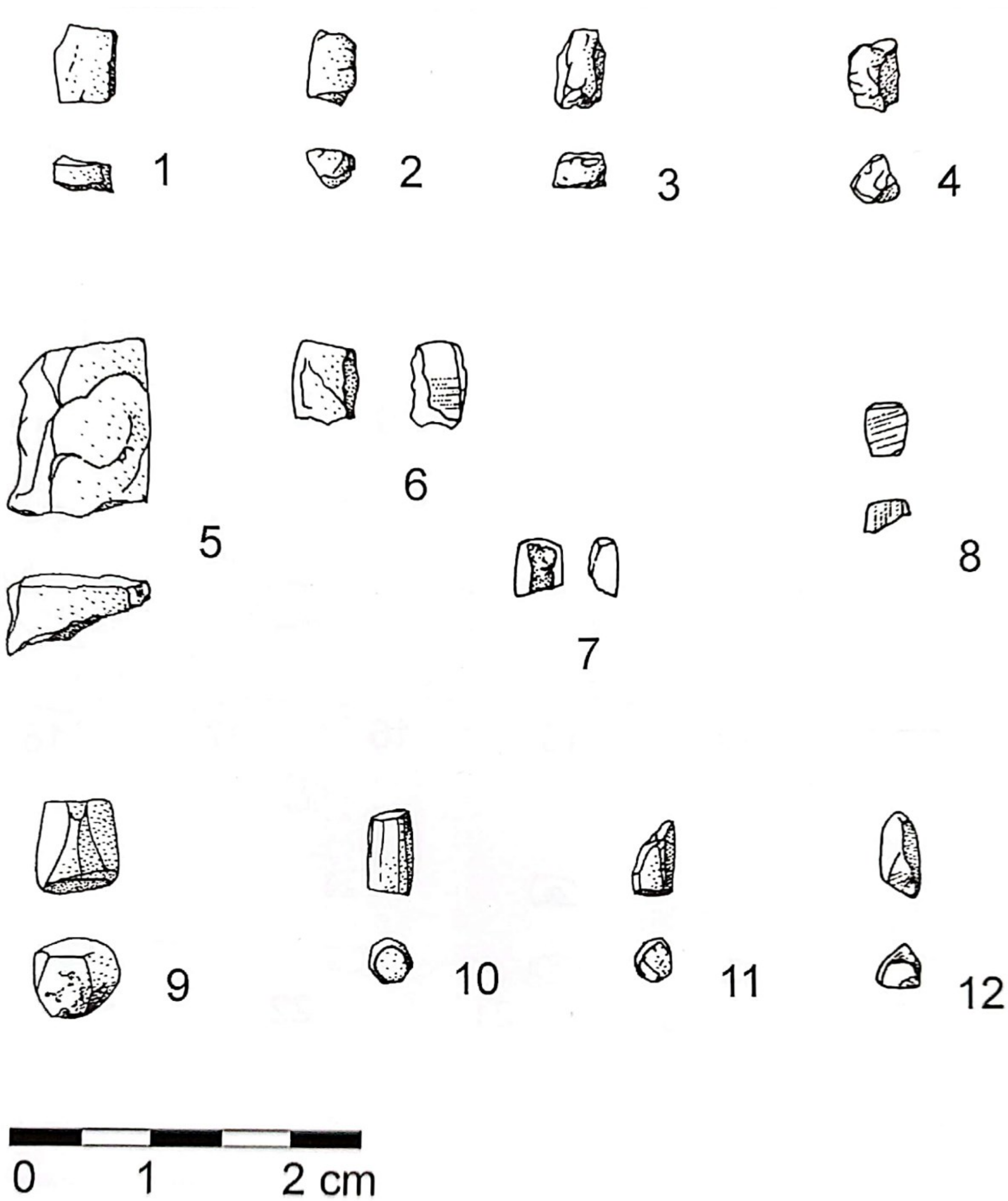

Fig. 10: lapis lazuli debitage from the production of barrel-shaped beads, in Tosi and Vidale, 1990.

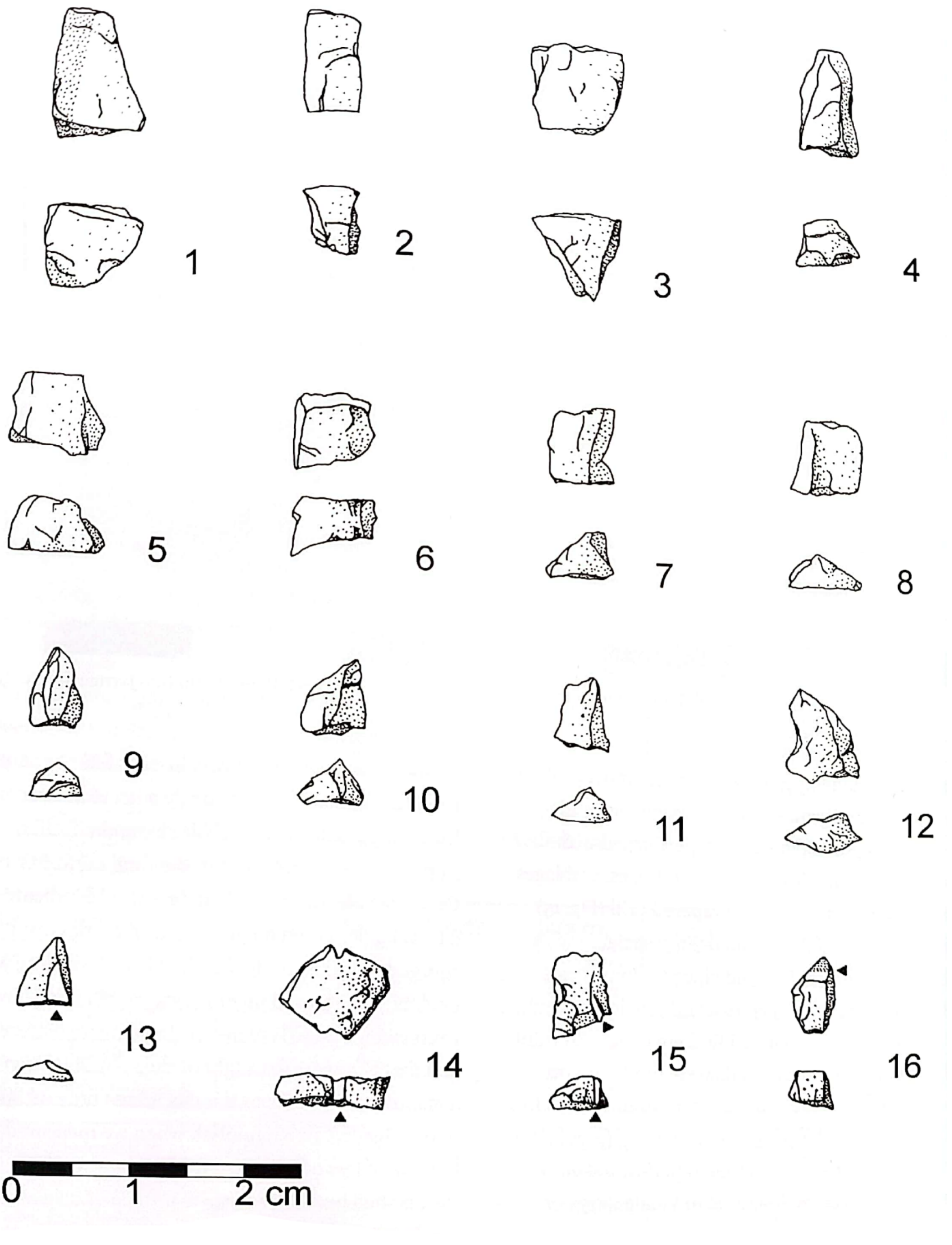

Fig. 11: lapis lazuli debitage from the early processing stages, in Tosi and Vidale, 1990.

2.2.3 DRILL HEADS

The following table (Tab. 4) presents the eight jasper drill heads belonging to this collection. They belong to the tapered drills type because of their gradually narrowing shape. Six out of eight have a broken tip; only two are complete and have a recessed cupped, or dimple, shape on the tip (samples M30 and M31, see Fig. 18). The bases, where the drill connected to the handle, are chipped, and in all samples the detachment fractures are still visible. The tips, instead, are all polished, so they no longer show the traces of chipping. In Figure 12, all eight samples were drawn and photographed using the stereomicroscope.

SAMPLE	MAX LENGTH (mm)	MAX DIAMETER OF THE TRILLING POINT (mm)	DIAMETER AT THE TIP (mm)	DESCRIPTION
M28	14.9	3.6	2.7	tapered cylindrical jasper drill, fragmented
M29	17.9	4.2	2.8	tapered cylindrical jasper drill, fragmented
M30	16.4	3.3	3.1	tapered cylindrical jasper drill, complete
M31	16.8	2.5	2.1	tapered cylindrical jasper drill, complete
M32	16.9	3.5	3.0	tapered cylindrical jasper drill, fragmented
M33	18.3	4.3	2.8	tapered cylindrical jasper drill, fragmented
M34	14.4	4.5	2.5	tapered cylindrical jasper drill, fragmented
M35	12.8	3.3	3.2	tapered cylindrical jasper drill, fragmented

Tab. 4: Jasper drill-heads: table showing dimensions and descriptions.

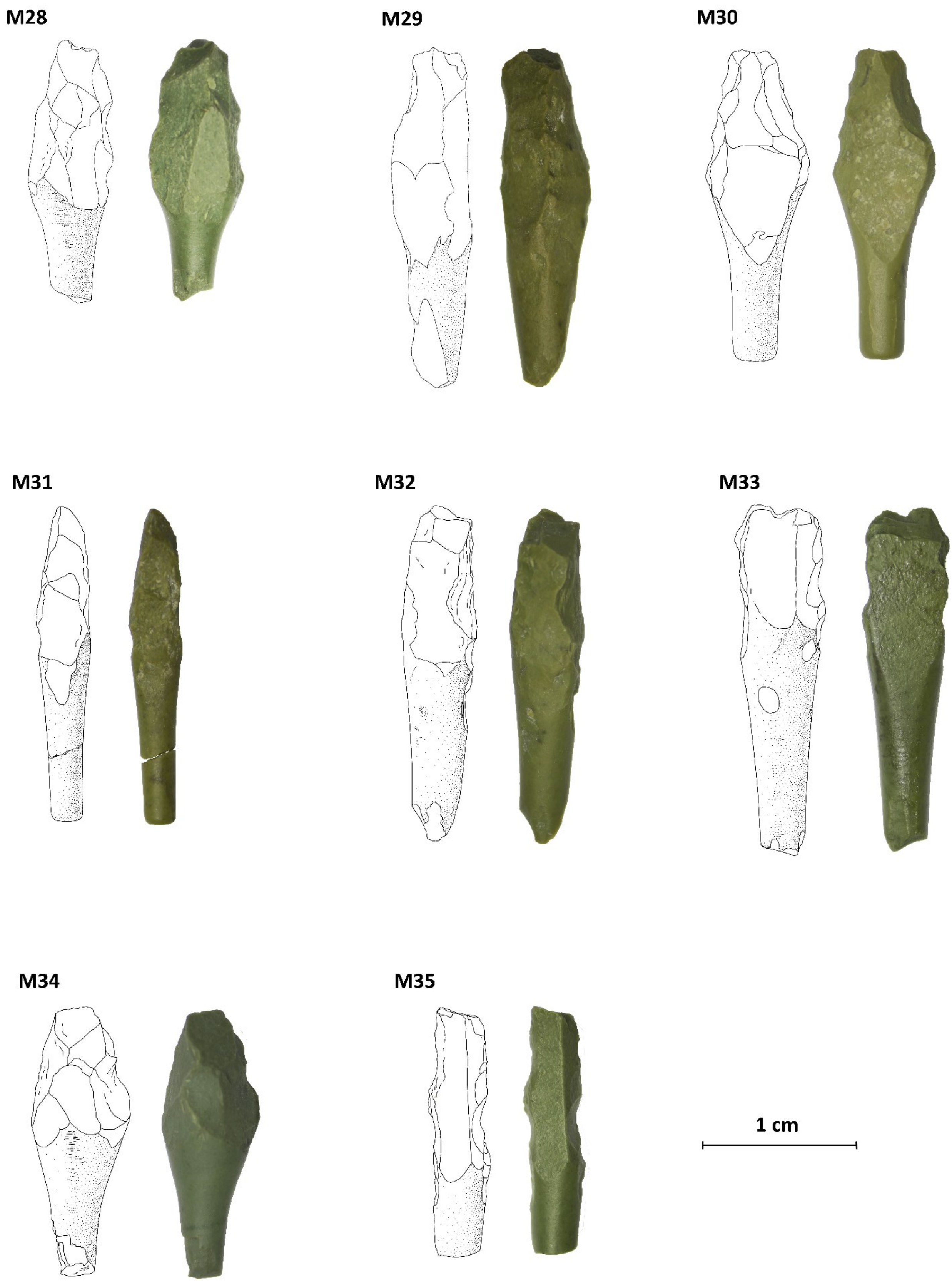

Fig. 12: tapered drill-heads in jasper: drawings and images taken with the stereomicroscope.

Archaeometric investigation of selected finds

Previous studies on the Mehrgarh bead industries had employed a variety of techniques for characterizing the base materials and gaining insight on production technologies of beads of different periods, including some of MR.2. Vidale (1995) identified by the means of X-ray diffraction (XRD) and scanning electron microscope coupled with energy dispersive spectrometry (SEM-EDS) the base material of a substantial deposit of the 5th millennium BCE, rich in disk beads making debitage, as talc with a certain amount of calcite, and proposed a detailed reconstruction of the beads' production sequence. Barthélemy de Saizeu and Rodière (2005) then identified one of the cylindrical drill heads from MR.2, by the means of XRD, as pumpellyite (a fibrous-lamellar soro-silicate, blue to green, about 5.5 of hardness in Mohs' scale). This identification is apparently problematic for a drill head, given the limited hardness of pumpellyite; as we shall see, more recent XRD tests on the same drill heads rather suggest a hard metamorphized jasper. The article, however, rather focuses on micro-morphology and manufacturing micro-traces of beads and drill heads, proposing a first classification of drilling holes and the relative techniques in four types: 1. bipolar drilling with conical stone tips ; 2. bipolar drilling with cylindrical bits ; 3. bipolar pecking drilling ; and 4. a fourth type, witnessed by a single specimen (the same bead labelled M4 in this Catalogue), in which drilling techniques 2 and 3 are combined. The same article places types 1 and 3 in the Neolithic period, recognizes all types in the early Chalcolithic period, and again types 2 and 3 in the late Chalcolithic (pre-Harappan) as well as in the Harappan or Indus period.

Vidale et al. (2017: 242-243) reports for the lapis lazuli industry of MR2, XRD analyses of the white-transparent component or gangue, that define it as made of various minerals including quartz, micas (including phlogopite) and diopside; and the blue phase as lazurite, plus other minor components. The article then deals with turquoise: a green variety was properly identified, with the same technique, as such, plus quartz and a clay mineral. The reasons of the chromatic variations of turquoise debitage (green and blue) remained unexplained.

Other flakes found in the same activity area are clinochrysotile, chlorite, dickite (a phyllosilicate of hydrothermal origin, blueish in color) and goethite ; clinochrysotile and chlorite might have been exposed, purposefully or unwinllingly, to high temperatures. All the green cylindrical drill heads found in the same area, one of which had been previosuly identified as pumpellyite, were identified by XRD as a hard green metamorphized jasper (Vidale et al. 2017: 248, fig. 16).

In order to verify this set of hypotheses and deepen our knowledge of the lithic assemblage of area MR.2, four different techniques of observation and analytical approaches were applied to different groups of artifacts, in order to solve specific questions. These techniques are stereomicroscopy, confocal microscopy, scanning electron microscopy (SEM) and micro-Raman spectroscopy. The following pages are devoted to report the scientific issues and the results of these applications, in the previously defined order.

2.3 STEREOMICROSCOPY

All the available artifacts of the assemblage (with the exception of three, deemed not very relevant) were carefully observed and photographed with a Zeiss Stemi 305 microscope, connected to an Axiocam 208 (1.2 Megapixel Wi-Fi camera), with a magnification range of 4x – 200x, for obtaining a complete and high resolution visual recording of the objects, acquired via WLAN though Labscope imaging app, and observing more carefully the surface features and the holes of the beads. Another goal was to inspect in greater detail, or ruling out, the possible presence on turquoise and other stone flakes of abrasion/smoothing surfaces caused by beadmaking operations. The systematic Catalogue of the following Chapter 3 is the main result of this stage of the research.

For lapis lazuli, this type of observation had been already developed both in Tosi and Vidale (1990), who described the lapis lazuli collection as a distinct activity area or a complex of smaller units within a site. The material recovered is assumed to be related to a single industry and roughly contemporary. The classification is based on 3 types: one for producing biconical disk-like beads "type 1" and another for simpler cylindrical beads labelled as "type 2". A separate class includes unique items like a cross-shaped bead and three fragmentary pendants, likely produced alongside more common types. The classification follows a proposed flow scheme where rough-outs are pre-forms reduced by chipping, and blanks are pre-forms further shaped by grinding. Despite the expectation of flint or chert drills, only tapered drills are found within the context area of MR.2. Further on, in Vidale et al. (2017), the base material of some lapis lazuli samples of deep blue color was analysed with XRD analysis, understanding that the intensity of the color is linked to the fineness of aggregation rather than to the presence/absence of specific minerals, and the mineral composition of the early industrial assemblage is most likely identical to later workshops at Shahr-i Sokhta. The lapis lazuli finds from the Shahr-i Sokhta worksops are likely sourced from the mines of Sar-i-Sang in Badakhshan, dating back to around 2900–2800 BCE.

When I focused on turquoise debitage, I could not observe any kind of abrasion or reduction that could have been explicitly linked to one or more reduction steps (i.e., I was unable to identify, on such bases, clear bead rough-outs and blanks). The same observations, carried out on carnelian items, revealed only one positive specimen, number M6; which has streaks parallel to each other on all surfaces, which could indicate primary or coarse polishing (Fig. 13). Counting also the presence of a limited number of chipped rough-outs seems sufficient to hypothesize that the lithic debitage, at least in part, was due to a carnelian bead manufacturing sequence. Such morphological considerations and attributions will be subsequently matched with the results of SEM observations and those obtained by the means of confocal microscopy of the green jasper drill-heads of which we were able to find, on several spots, residue of an ancient glue or adhesive (Fig. 14).

Fig. 13: A photo taken with the stereomicroscope of sample M6, the only one among carnelian beads that suggests a kind of abrasion on its surfaces that could be linked to a rough polishing.

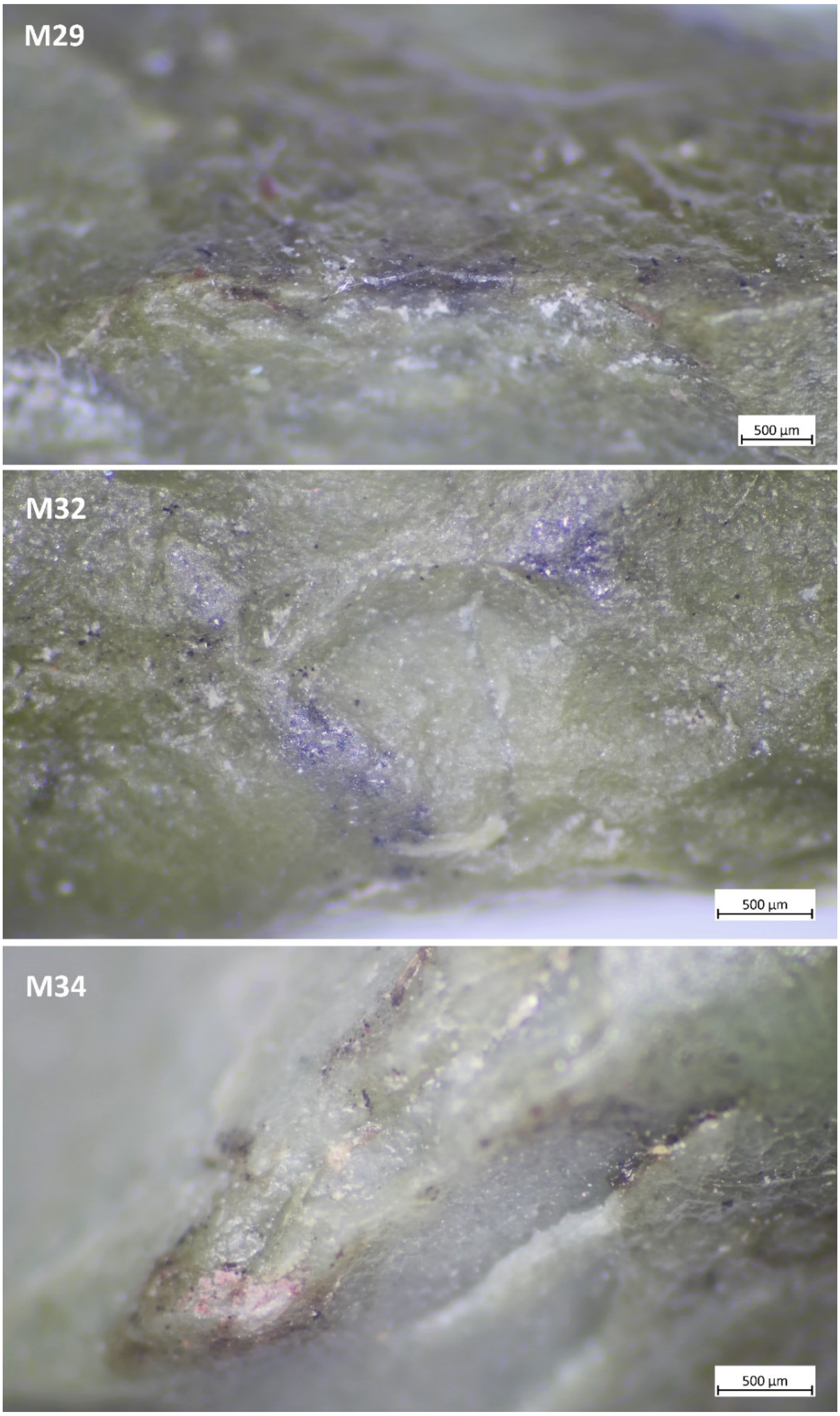

Fig. 14: photos taken with the stereomicroscope of the glue on the drill heads, samples M29, M32 and M34. The blackened spots on the surface were identified as a glue, most probably of vegetal origin. Trapped in this material, it is possible to see remains of unidentified vegetal fibers and soil particles. The fibers might have been rolled around the haft section of the lithic drill head to act as a buffer into the cavity of the drill's wooden handle.

2.4 CONFOCAL MICROSCOPY

After confirming under the stereomicroscope that there were traces of an ancient adhesive on most of the drills (Fig. 14), it was decided to further this research by putting the samples under the confocal microscope and SEM (see section 2.5). The instrument used is an Olympus OLS 4000 LEXT, a laser confocal microscope that can take high resolution 3D images; the z axis resolution is 10 nm and the x-y resolution is 120 nm; magnification range 108X - 17280X.

The primary purpose was to take a closer look at those areas on the surface of the drill heads where we knew the glue was located, with the idea of looking for whether traces of the filament used to connect the drill head to the handle were still preserved inside, as noted in Vidale et al. (2017: 250, fig. 10). The second was to take 3D images of these fibers to better understand whether they were animal or plant based.

The instrument allowed us to recognize many more fibers (Fig. 15) than noted by SEM, and it was also possible to detect, in many areas with the glue, even if the fiber was no longer preserved, the presence of fiber imprints on the glue (Fig. 16). However, it was not possible to make 3D acquisitions; the surface of the drill heads was very uneven, especially in the areas where the adhesive was still well-preserved; it had a pockmarked surface, full of bubbles, holes, and hollows. Even after trying to tilt the specimen as perpendicular to the laser as possible, we could not get good results. In addition, although the confocal microscope allowed us to detect much more filament residue on the drill heads, the image clarity is much better in SEM. Whether it is then an animal or plant fiber will be discussed in the next section and in the closing chapter.

The remains of ancient adhesive were not the only things observed on the drill bits; this technique was also very useful for examining the traces left by the drilling process on the drills themselves. In Figure 17, it can be observed the grooves left by on the body of the head drill. In Figure 18 the small cup that forms on the drill tip, probably the result of the friction between the drill and the loose material produced during drilling.

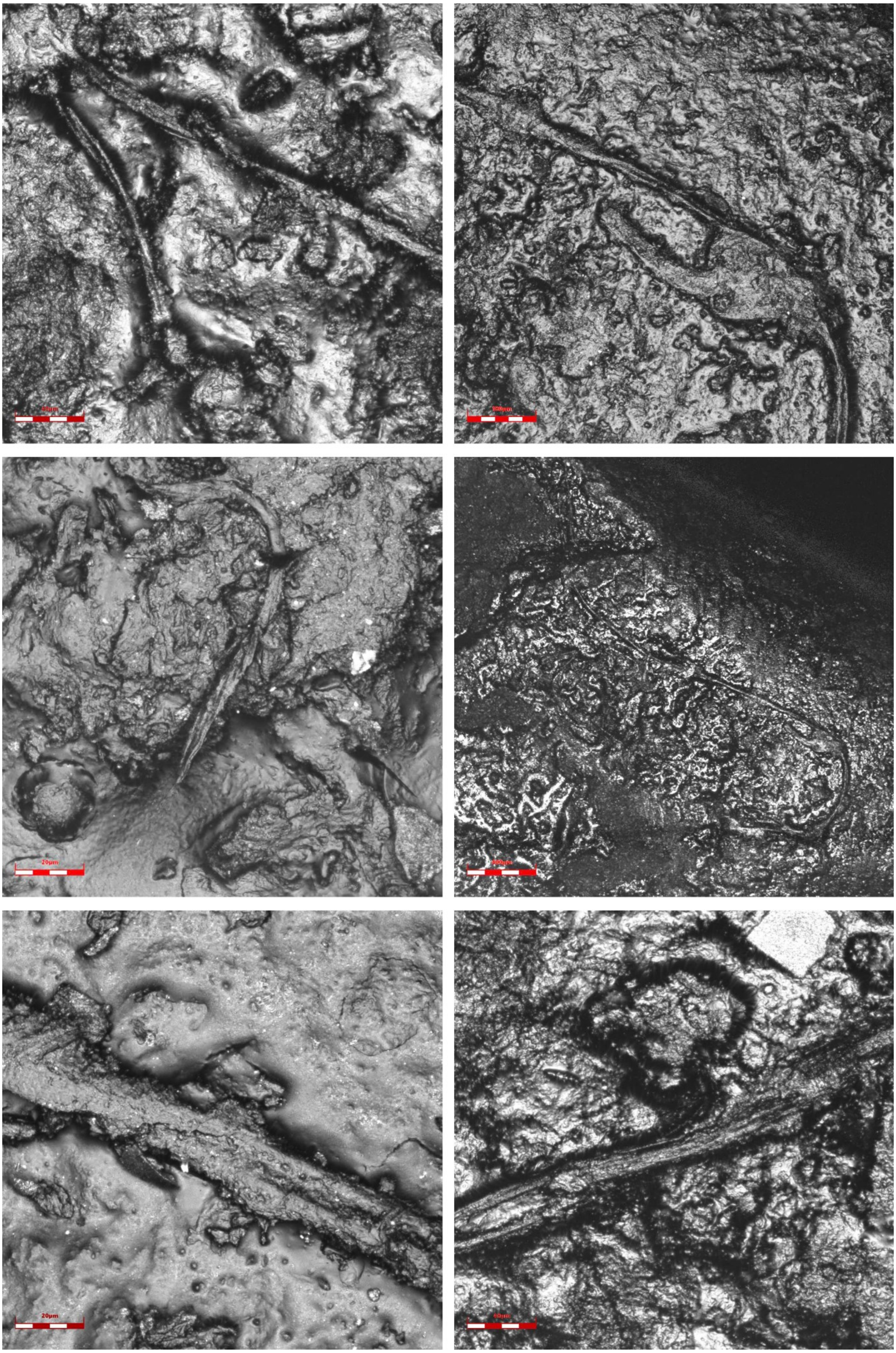

Fig. 15: some images acquired by confocal microscopy showing residual filaments still preserved in the adhesive.

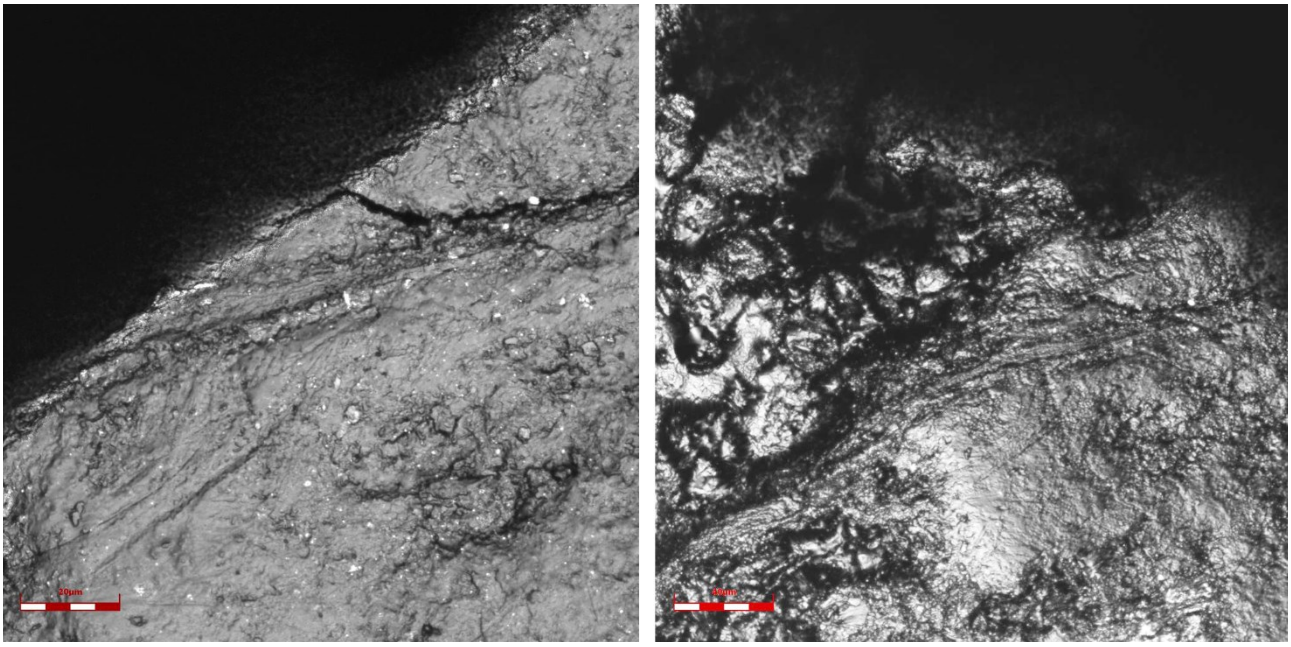

Fig. 16: two images acquired by confocal microscopy showing on sample M29 the remains of ancient adhesive, in which still remains the impressions of fibers/filaments that are no longer preserved.

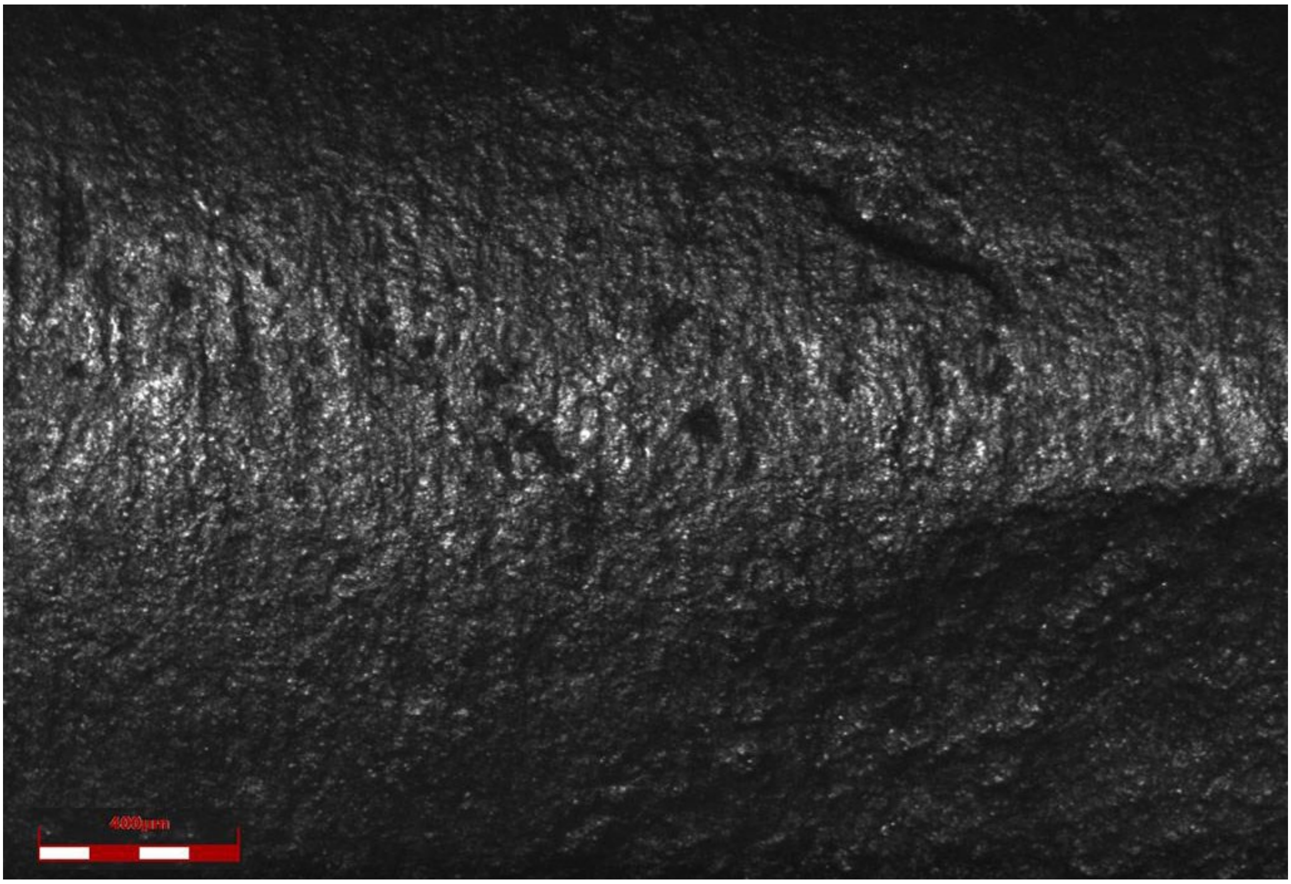

Fig. 17: the grooves on the proximal part of the drill head, caused by the abrasion during the perforation process, on specimen M33.Image taken under the confocal microscope.

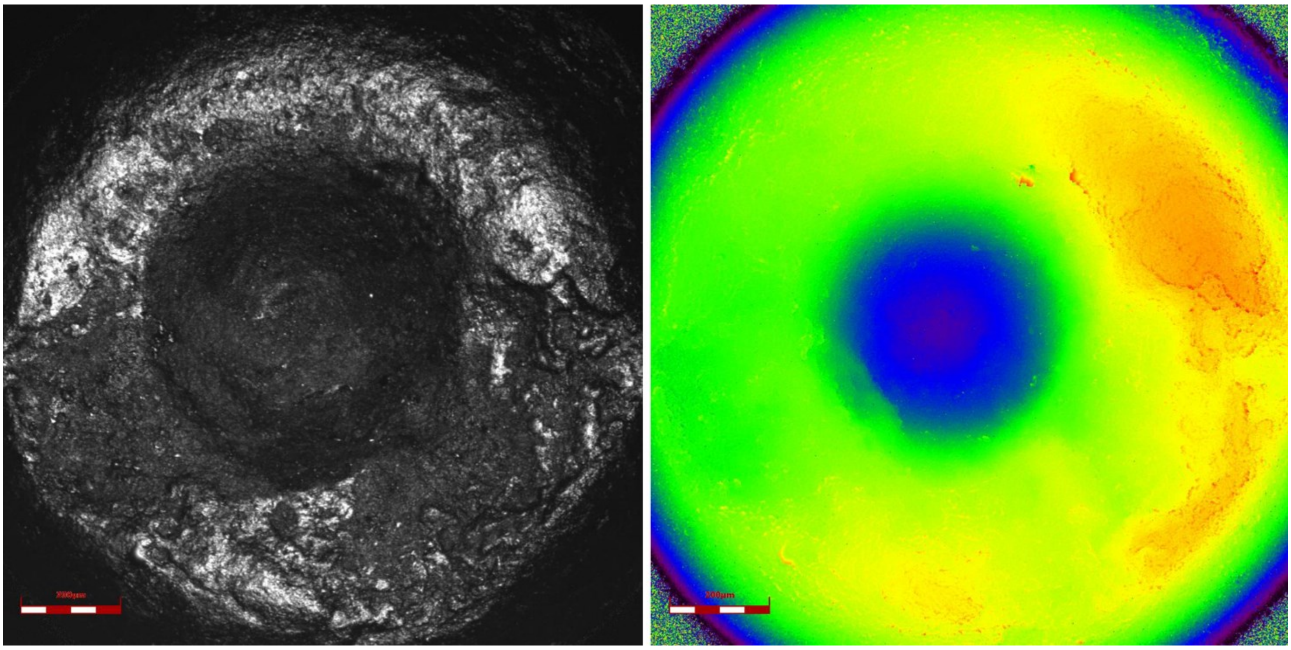

Fig. 18: the miniature cup formed at the drill tip of specimen M31, likely arising from the friction between the drill and the loose material generated during the drilling process. Left: image taken under the confocal microscope in laser intensity mode; right: the same image taken with high intensity mode.

2.5 Scanning electron microscopy

For a detail analysis of the beads and of their casts was used a table bench scanning electron microscope (HV and LV SEM), COXEM EM 30AX plus model, equipped with tungsten filament (W), SE Detector, BSE Detector (Solid type 4 Channel), energy dispersive X-ray detector (EDX) EDAX Element- C2B; HV 20.00 kw.

A total of 33 objects (including all the available lapis lazuli and carnelian beads or bead fragments, and the jasper drills) were observed in low vacuum, avoiding to coat the samples with conductive but invasive layers of carbon or gold.

2.5.1 Micromorphology of drill heads

The drill heads were analysed using the SEM to observe with greater detail the abrasions and grooves indicating the drilling process, as previously noted under the stereomicroscope. Moreover, careful examination was conducted on the deeper grooves to determine if remnants of drilling powders were trapped within them. The observations is that the traces of deeper abrasion are concentrated on the apical and proximal parts of the drill bit, rather than at the center (Fig. 19). The apical grooves can be easily explained by the friction among drill, bead, and the loose drilling powders in between, which roughens the drill's surface and also creates the distinctive cup-shaped depression at the tip (see Fig. 18). However, the reasons for the grooves/abrasions being highly visible in the proximal part of the drill head are more uncertain. We hypothesized that they may have resulted from unintentional rotational movement against the outer surface of the bead, which had not yet been polished. The search for drilling powder particles in the grooves has been unsuccessful.

Finally, out of the eight observed drill bits, two have intact tips (M30 and M31, Fig. 19), while the others are all fractured. In Figure 19, the example of sample M28 is provided, which is indicative of the others (with the exception of M35). The way in which the tips of the drill bits appear to break obliquely, creating three fractures, may suggest breakage during the rotational phase of drilling.

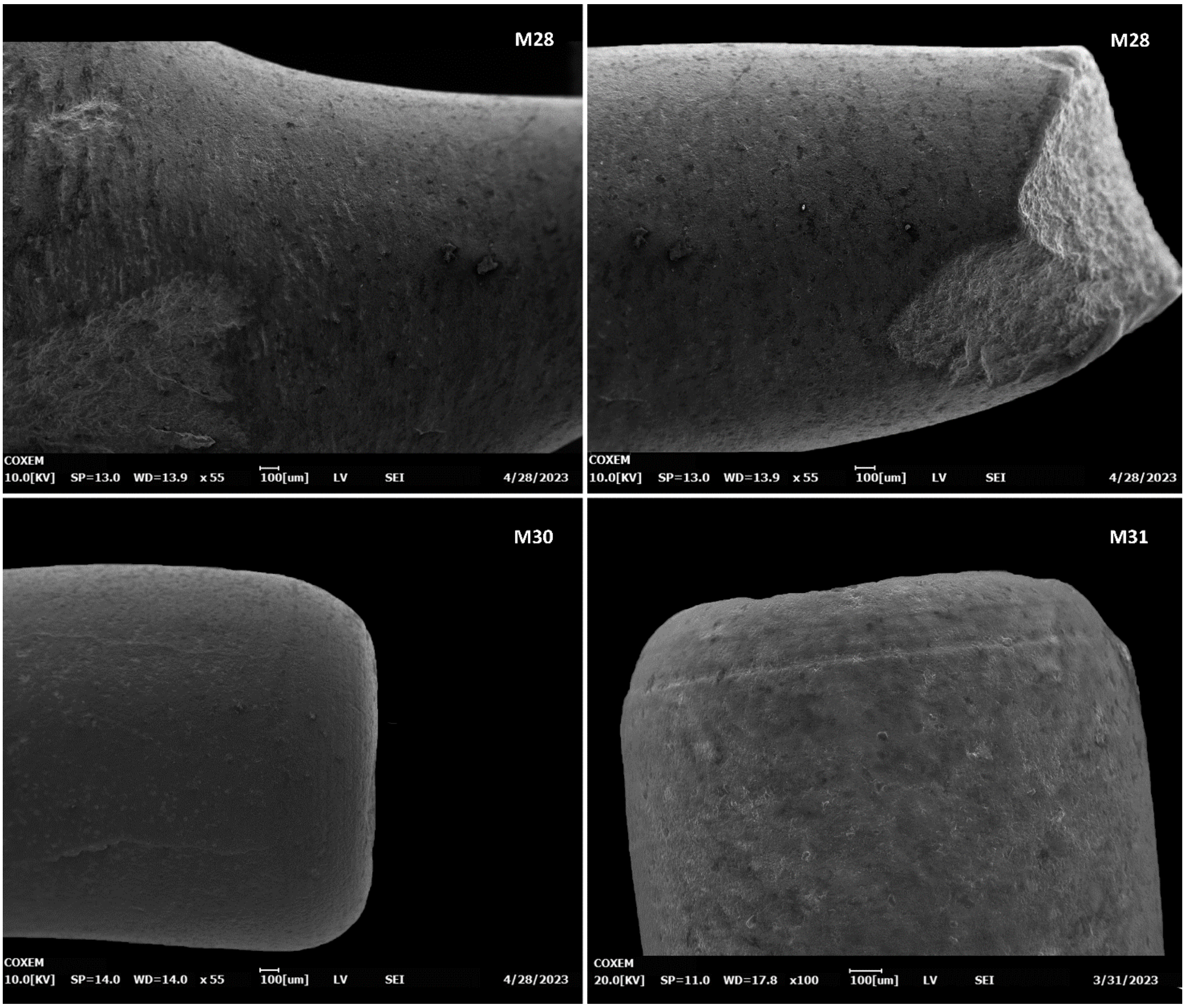

Fig. 19: Secondary electron images (SEM-SE) of some samples of drill heads; the images show the grooves left on the proximal part of the drill head, sample M28, and a detail of the broken tip of the same sample, likely fragmented during the rotation. Below are the two intact drill tips belonging to M30 and M31, with characteristic grooves on the apical part.

2.5.2 MICROMORPHOLOGY OF BEADS AND SILICONE CASTS

A first preliminary stage of inspection on the actual objects, let us understand that the observation would have been more effective on silicone casts of the holes drilled into the beads, rather than on the bead itself; following the methodological traces and identifications provided in papers such as Kenoyer (2017) dealing with methodological standards; Uesugi et al. (2018) Harappan beads, second half of the 3rd millennium BCE; Uesugi (2019) early historic beads from Taxila; Barthélémy De Saizieu and Rodière (2005) beads from Mehrgarh and Nausharo, from Neolithic to Harappan periods; Kenoyer and Vidale (1992) Harappan bead making, second half of the 3rd millennium BCE; Lazzari and Vidale (2017: 217-223) dealing with the early 3rd millennium lapis lazuli industry of Shahr-i Sokhta.

Images obtained at SEM show that almost all of the carnelian beads, excluding samples M8, M9 and M11 (to be discussed later), were drilled using the pecked drilling technique, probably through chipped flint drill bits, similar to those found for the oldest periods (Jarrige et al. 1995: 263, Fig. 5-10b; 438, Fig. 9.8a; Kenoyer 2017a: Figs. 9-11). This technique involves a set of blows on the bead's flat end alternating with discontinuous rotatory movements, and results in cone-like cavities whose surfaces tend to be rough, with peculiar, diffuse micro-fractures (Fig. 20, M2a and M2b), called "sharp angular flake scars" by Kenoyer (2017a: 418), the author continue explaining that if those "scars" are no longer visible, is because they have been polished intentionally or because they have been rounded and worn by the use, like in the case of samples M5 and M10 (Fig. 20).

This technique is "bipolar", meaning that two drilling holes were made from the opposite distal sides of the carnelian blank (Vidale and Lazzari, 2017: 222). The holes often are not perfectly aligned with each other.

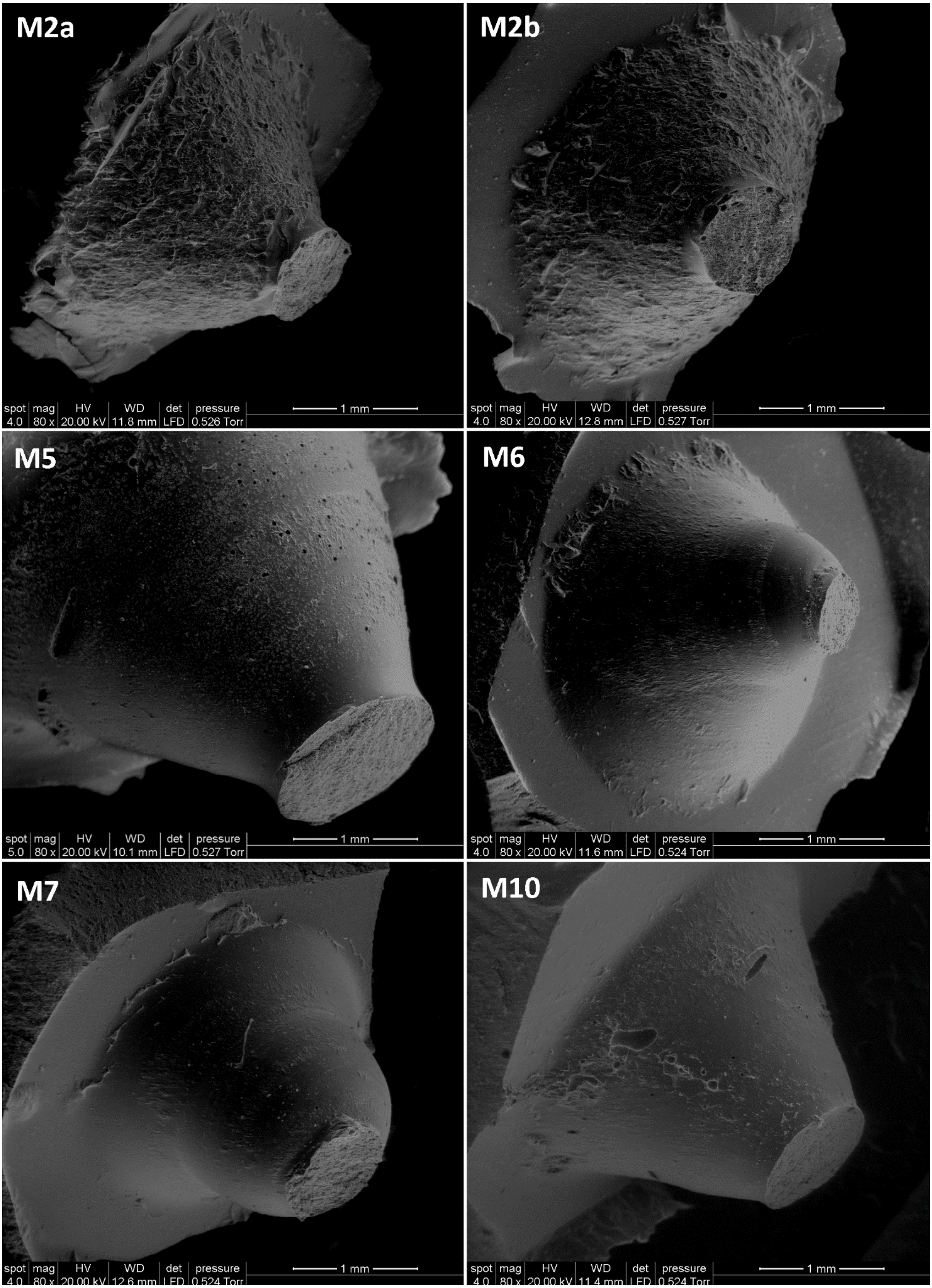

Fig. 20: Secondary electron images (SEM-SE) of some silicone molds of drilling holes from carnelian beads.

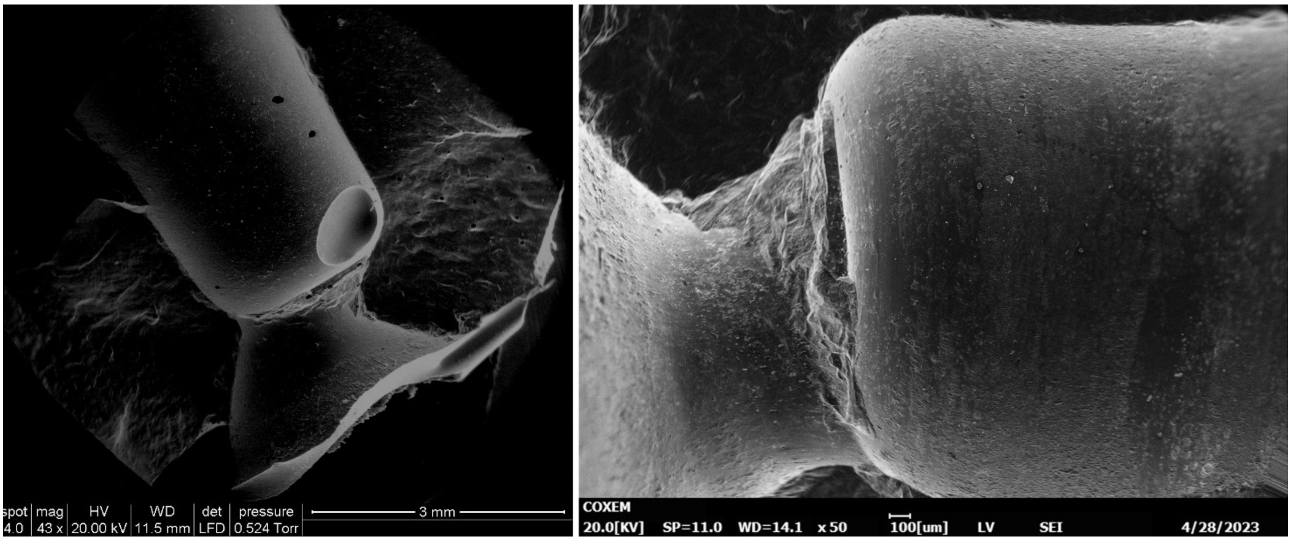

Fig. 21: Secondary electron images (SEM-SE) of sample M4, left: the silicone mould, right: image of the drilling hole taken directly from the specimen.

Of great interest is sample M4, a *unicum* in this collection, exactly as it was in the broader survey of Barthélemy de Saizeu and Rodière 2005. The bead, in the light of our new images, was actually drilled using two different techniques, or rather two different drills (Fig. 21). It appears that it was first drilled from one side using a tapered cylindrical drill with a diameter of 2.5 mm (corresponding to the average drill bit diameter of jasper drills), then drilled from the opposite side using the pecking technique, eventually connecting the two holes. The tapered drilling technique using chert or jasper drills depend on the microcrystalline structure of the drills and the beads. In our case the microcrystalline structure of carnelian is fibrous, whereas the one of jasper is granular, helping the drill head in holding up better heat and pressure during the drilling process (Kenoyer 2017b; Luedtke 1992). The hole left by the drilling can be cylindrical or conical, and as attested at Harappa (Kenoyer 2017a: 420, fig. 6c) two different sized drills could have been used. That is seemingly the case of samples M6 and M7 (Fig. 20), which moreover, is not free from errors and flaws; the second drilling is off-center compared to the first as we can observe in M6.

It remains difficult to assert with certainty if jasper drills found at the site were definitely used in the drilling of carnelian, given the case of samples M6 and M7; certainly, the SEM-SE images suggest the complementarity of the two techniques, maybe corroborate by the *unicum* M4.

As for the remaining three samples, we have contrasting evidence. Judging from the shape of the beads, they seem more recent, as there are no similar forms documented in the Chalcolithic periods. However, observing the silicone molds of the holes, what is noticeable for samples M8, M9, and M11 is that the inner surface is highly polished, the hole is cylindrical, but the terminal part is less smooth, with a deep dimple, maybe the result of prolonged drilling (see sample M11 in Fig. 22). Having made these observations, we hypothesize that these last three samples were drilled using a modern drill, and belong to a period subsequent to the rest of the assemblage. As for how much more recent, we couldn't say for sure. The dilation of the drill's tip visible in the silicone casts of the following image (M11a, M11b) might suggest the use of a copper drill, modified during its activity by the intense friction produced by attrition.

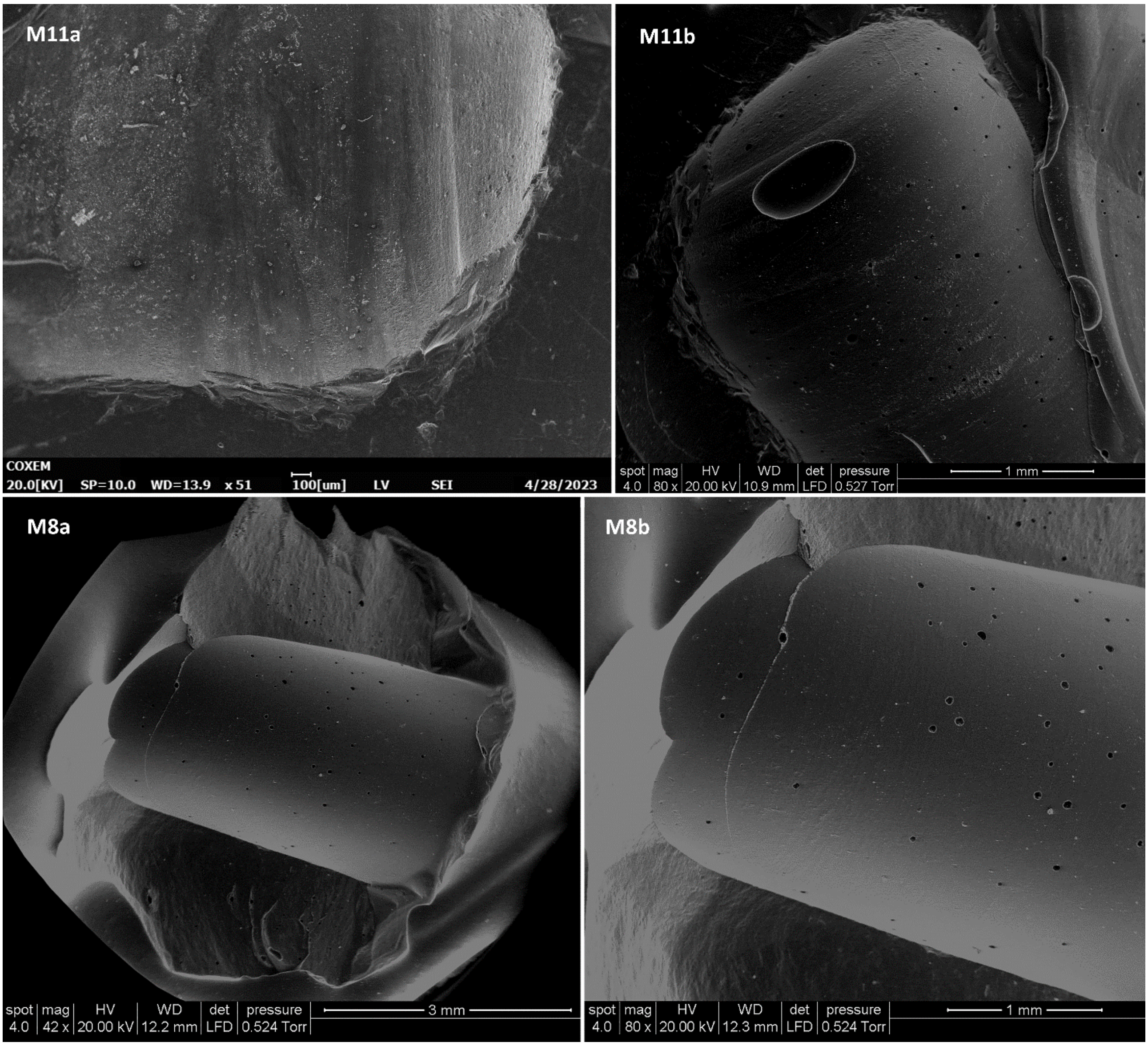

Fig. 22: Secondary electron images (SEM-SE) of samples most likely lost on the investigated spot in modern times. The dilation of the drill's head tip recognized in M11a and M11b might suggest the use of a copper drill.

Understanding which drilling techniques were used for lapis lazuli beads is equally difficult because this stone has a lower hardness (between 5 and 6 on the Mohs scale) compared to carnelian (7 on the Mohs scale). Beads made of lapis lazuli from the MR.2 area experienced a strong erosion over an extended period. The SEM-SE images of the silicone casts of the holes of these beads, even if less clear than the images obtained from the holes of carnelian beads, reveal a more intricate and varied landscape of techniques. Four samples (M40, M41, M44, and M47) are characterized by irregular and not always horizontal parallel striations of varying depth, possibly caused by the addition of a loose abrasive such as quartz (see Kenoyer 2017: 425, 427). Additionally, the terminal part of the holes, left by the drills' tips, is not flat, as in the case of stone drills, but ends in a rounded convex extremity, considered in the quoted bibliography compatible with the use of a copper drill head (Fig. 23). The holes of samples M37, M43, and M48, on the other hand, closely resemble the forms most likely due to the use of pecking on carnelian beads: the holes are shallower, with a triangular cross-section, and look more irregular (Fig. 24). The remaining samples (M36, M38, M39, M45, and M46) were probably drilled with tapered cylindrical drills (Fig. 25). As the average diameter of the holes in the latter samples varies between 1.5 and 2.6 mm, while the diameter of intact jasper drill tips (of those fully preserved with the tip intact) ranges from 2 to 3 mm, it is still difficult to determine whether the jasper drills found alongside these beads were actually used to perforate them. The poorly defined context of deposition of the surface activity area of MR.2, once more, does not help.

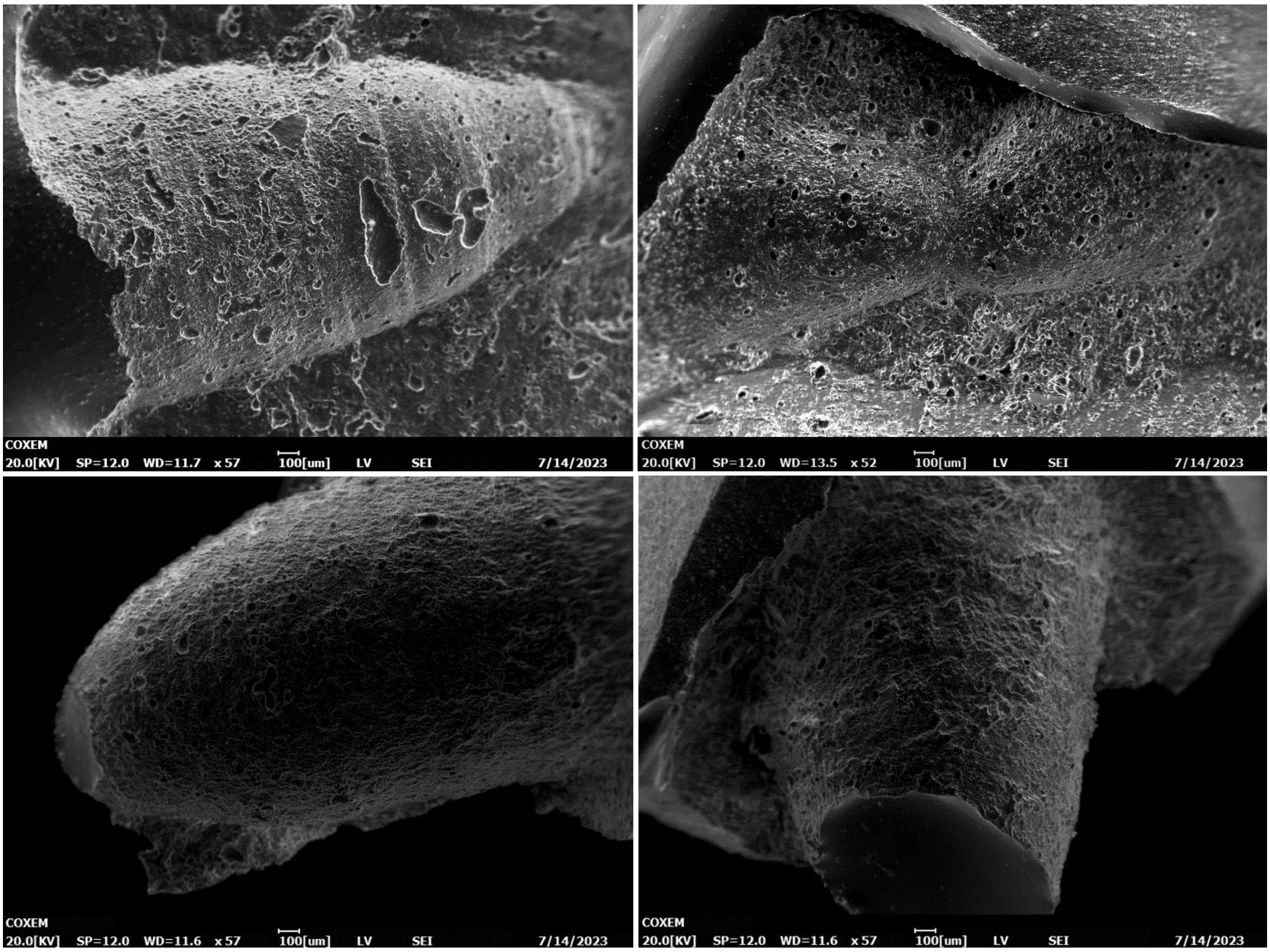

Fig. 23: Secondary electron images (SEM-SE) of lapis lazuli silicone holes' impressions

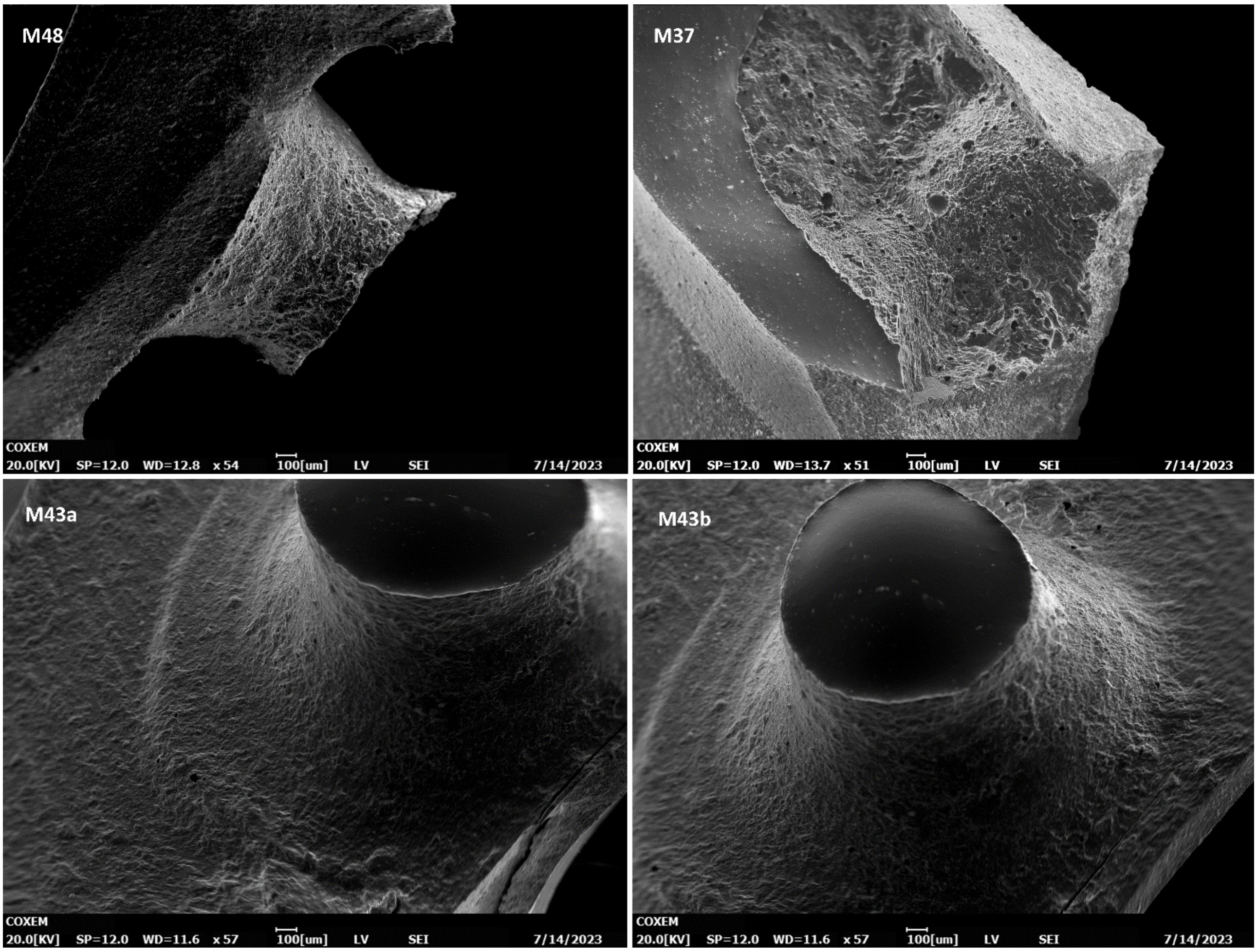

Fig. 24: Secondary electron images (SEM-SE) of lapis lazuli silicone holes' impressions).

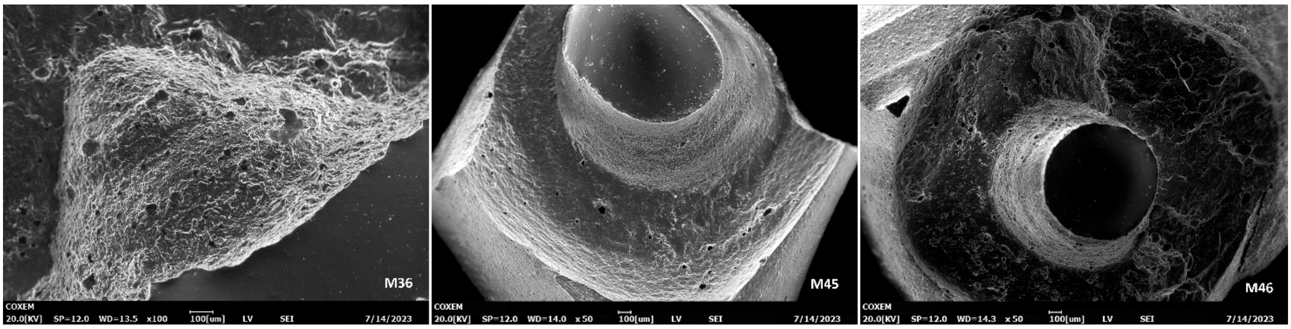

Fig. 25: Secondary electron images (SEM-SE) of lapis lazuli silicone holes' impressions.

2.5.3 MICROMORPHOLOGY OF FIBERS INSIDE THE ADHESIVE

Having already been observed under the stereomicroscope and confocal microscope, the adhesive residues on the drill bits were finally analysed using the SEM. This was done to acquire high-resolution images that could aid in identifying the fiber/thread used to attach the drill heads. Additionally, the SEM images in backscattered electrons were utilized to recognize organic matter present on the drill's surface. The first noticeable aspect was that, while the stereomicroscope revealed a limited evidence of adhesive residues, the SEM showed that the surface of the drill was actually largely covered by them (Fig. 26). Actually, it was possible to observe some fibers still preserved within the adhesive resin. Figures 27 and 28 present magnifications of these fibers, captured first in SE and then in BSE, confirming the findings of Vidale et al. 2017 and providing more detailed images.

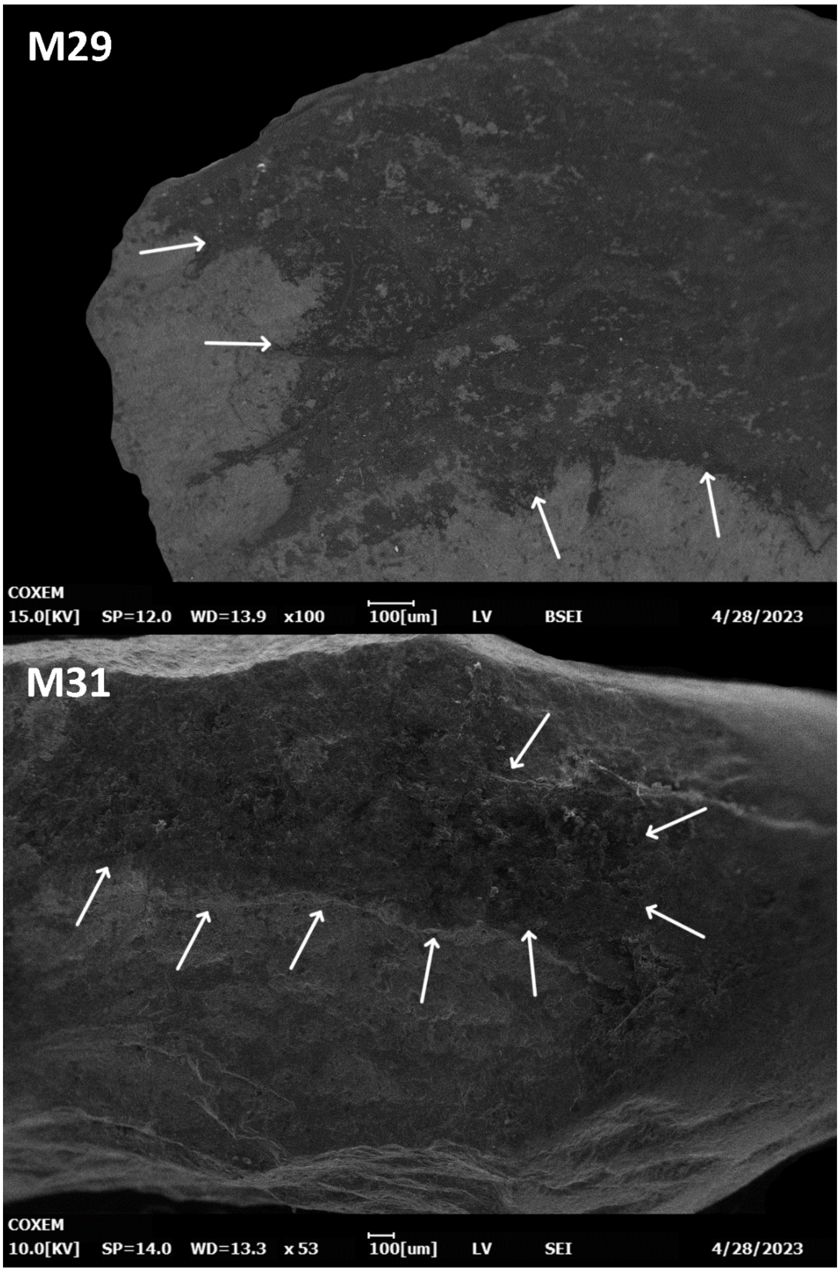

Fig. 26: SEM images showing the extent of resin on the drill heads; image of sample M29 in SEM-BSE; image of sample M31 in SEM-SE.

Of particular interest are the SEM-BSE images that display a color variation representing the difference in the average atomic weight between the jasper drill surface and the resin (obviously rich of organic matter), and therefore resulting darker in the image. Vidale et al. (2017: 249-250) analyzed this plant fiber and resin (present on sample M29 in this catalog) through preliminary FTIR measurements. The results showed a certain similarity in the spectra of fibers and resin, this latter possibly originating from Pistacia or Acacia species (Fig. 29), as well as with the basic composition of the so-called Dammar resins, produced from these and other plants, still common in South and South-Eastern Asia.

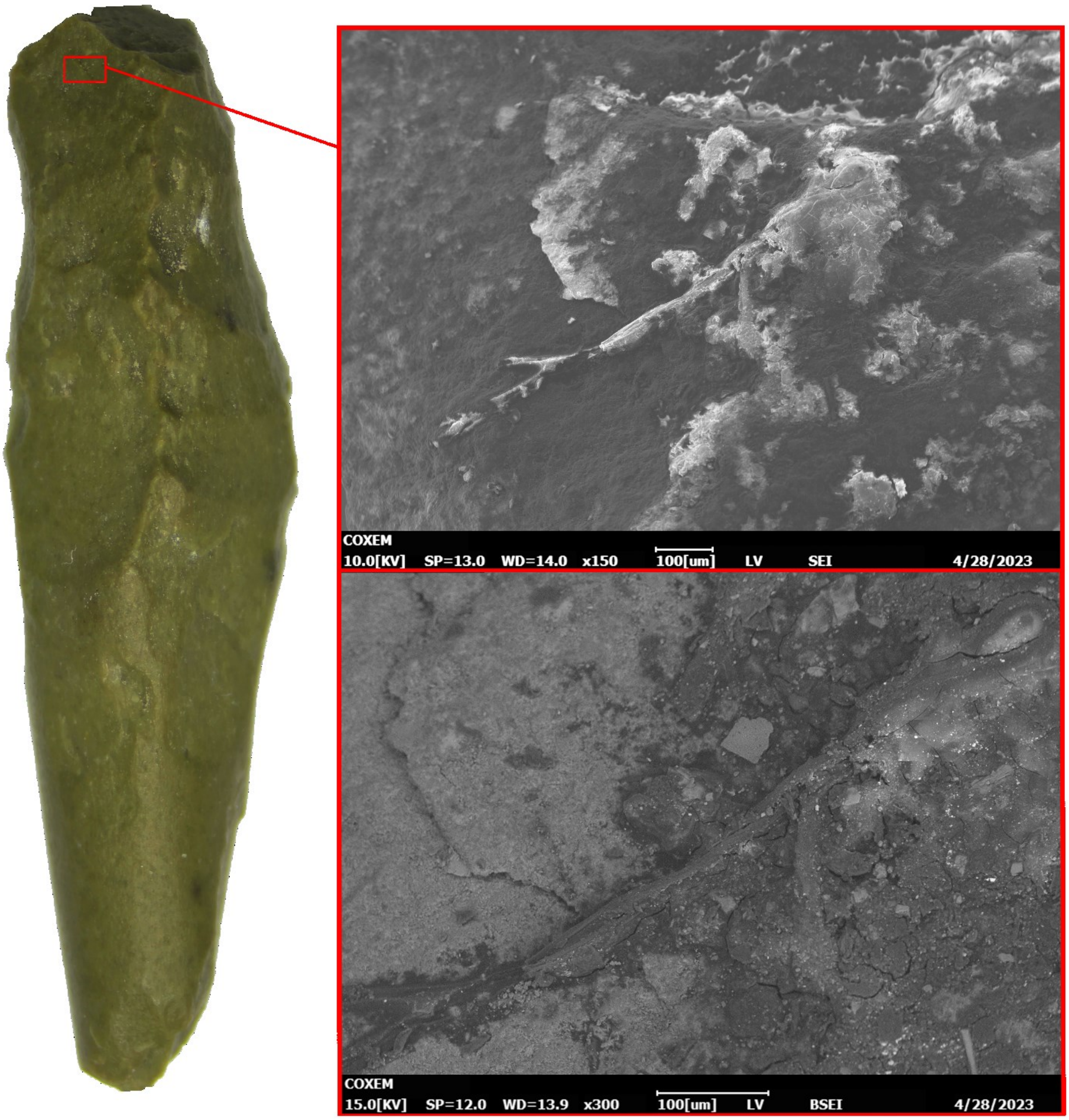

Fig. 27: Jasper drill M29 photographed on the left with the stereomicroscope, and on the right under the SEM it can be seen the fiber embedded in resin: top image taken in SE, bottom one in BSE, respectively.

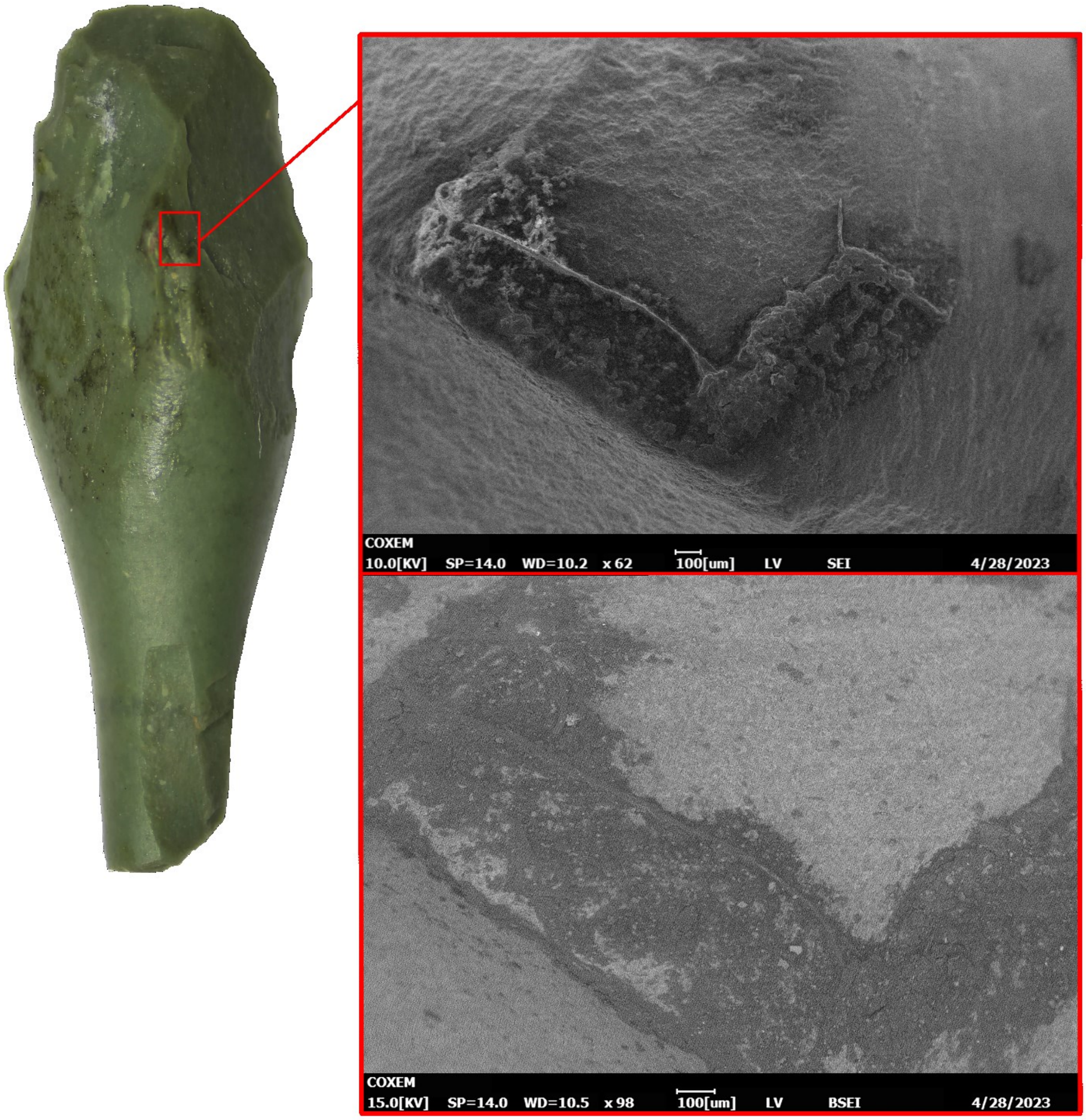

Fig. 28: Jasper drill M34 photographed on the left with the stereomicroscope, and on the right under the SEM it can be seen the fibers embedded in the adhesive: top image taken in SE, bottom one in BSE, respectively.

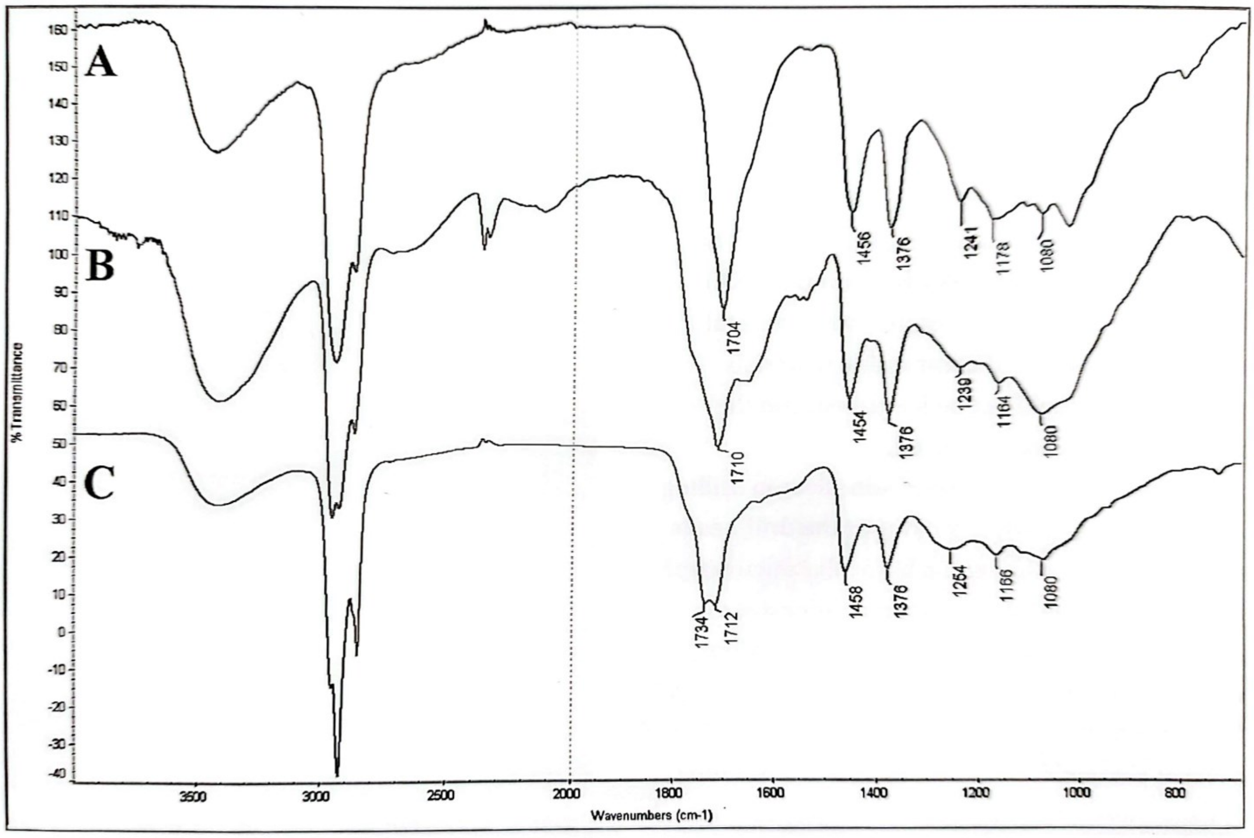

Fig. 29: FTIR spectra of: A) Pistacia resin, included for purposes of comparison; B) sample of ancient glue taken from the haft of a micro-drill head of the MR.2 activity area; C) extracted fraction in CH_3Cl of the sample, from Vidale et al. 2017: 250, fig. 20.

2.6 Raman spectroscopy

The turquoise samples were also analysed by the means of micro-Raman spectrometry to gain more information, and validate whether the visual subdivision into blue turquoise and green turquoise (Figs. 30 and 31) suggested in Vidale et al. (2017) could be due to a mineralogical or chemical difference. The analytical evidence showed that the green turquoise owes its coloration to the presence of a clay mineral, according to the authors possibly dickite or montmorillonite (Vidale et al. 2017: 244, fig.10). Specifically, a goal of this experiment was to see if the Raman spectra of the blue and green samples showed any difference. Raman analyses on 8 samples of green and blue turquoise were carried out in the laboratories of the Faculty of Geosciences, under the supervision of Lisa Santello; the instrument used is a Raman Witec alpha 300 R + Zeiss microscope attached (10x, 20x, 50x LD, 50x, 100x obj.s); Spectrometer 1: UHTS 600 (VIS) (with 2 spectrographs), Spectrometer 2: UHTS 400 (NIR) (with 2 spectrographs). Motorised x-y-sample scanning stage for confocal Raman imaging, TrueSurface microscopy and automated measurements routines (50x50 mm2 travel range in reflection builds; Software controlled); PC Windows with 2 software: Control Five (operate system) + Project Five (data treatment). We used a green 532 nm laser, and for the first acquisition we set the following parameters: 1s, 60 accumulations, 3 mV; corrected for the second acquisition to: 1s, 80 accumulations and 2 mV.

Fig. 30: blue turquoise debitage, from Vidale et al. 2017: 245, fig. 11.

Fig. 31: green turquoise debitage, from Vidale et al. 2017: 245, fig. 9.

The Raman spectra of turquoise show no difference between blue and green speciments, but what we were able to notice was that out of eight samples (M16-M23), four offered a clear spectrum (Fig. 32). The other four (Fig. 33) although peaks indicative of turquoise were visible, had a meaningful fluorescence curve.

We initially thought that the fluorescence was caused by dirt on the samples (as they had been probably handled for a long time with little care), or by depositional diagenesis. Even though we carefully cleaned them by soaking them in acetone, no better results were obtained.

It was finally decided to break the samples to analyse their cores in fresh fractures, but still the fluorescence curve was present. Looking at these samples under the microscope, and comparing them with the four that had offered a clear spectrum devoid of fluorescence, we realized that their crystal structure was poorly formed: it was like looking at a homogeneous phase, almost devoid of crystals. Therefore, we hypothesized that the cause of the fluorescence was a high concentration of amorphous material in some of the MR.2 turquoise samples, which is visible even to the naked eye, because these samples show a lighter, faded colour than the other three.

Further analysis would aid in comprehending whether the turquoise discovered within the MR.2 area originated from a common source displaying varying degrees of quality; or whether, precisely because some specimens are more intense in colour than others, the turquoise arrived at Mehrgarh from different sources.

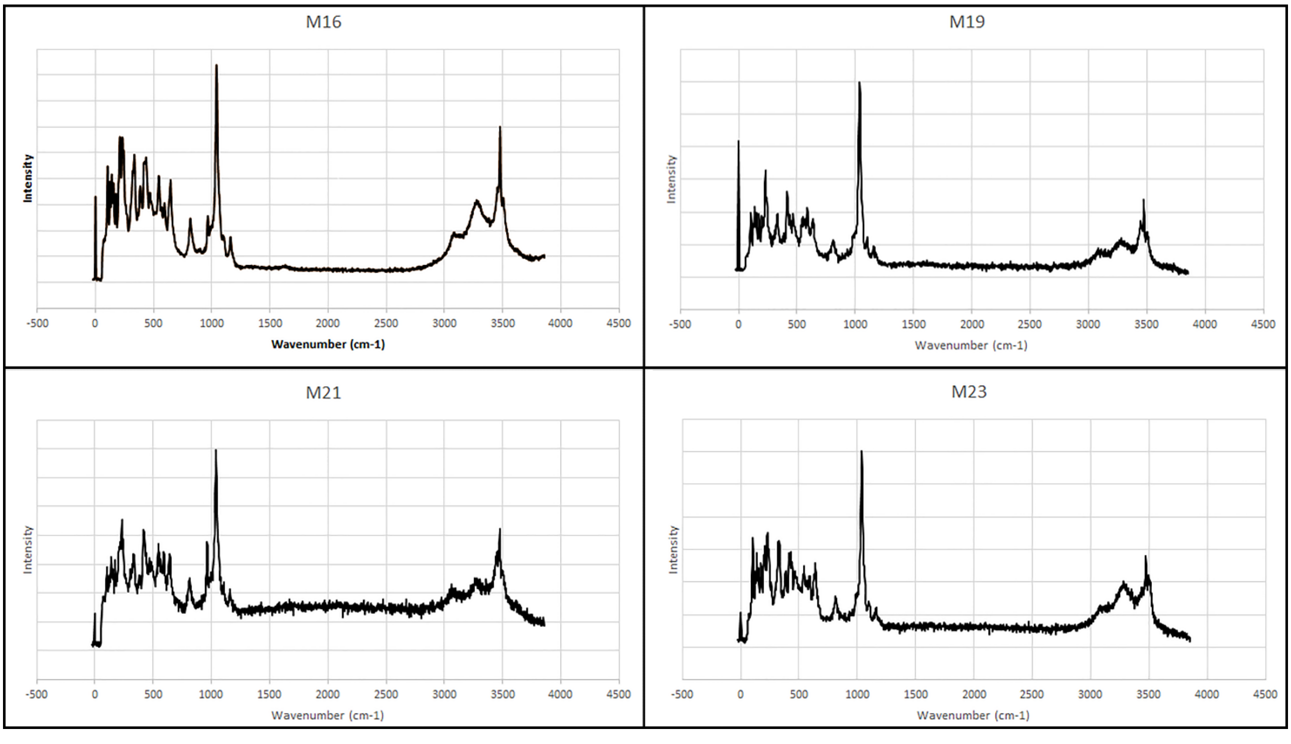

Fig. 32: Raman spectra of green and blue turquoise.

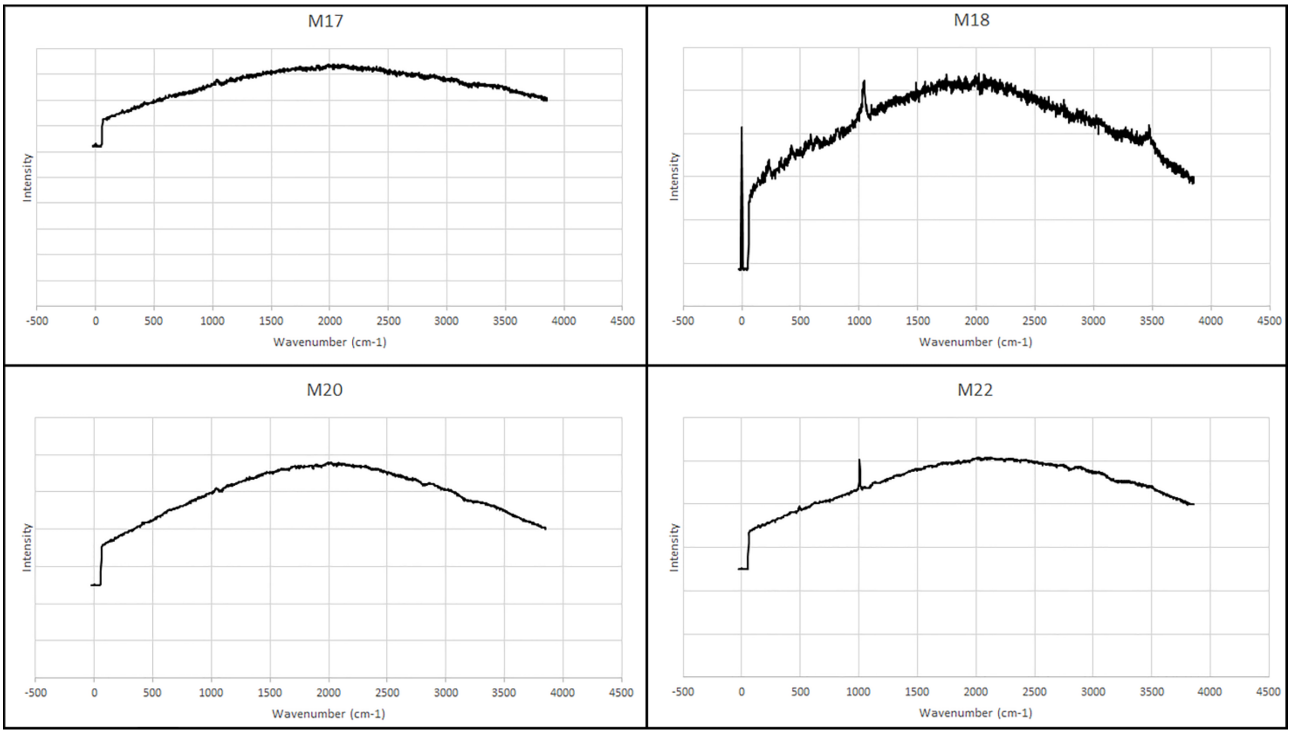

Fig. 33: Raman spectra of green and blue turquoise showing a fluorescence curve, probably caused by the high concentration of amorphous material.

Conclusions

To verify the set of hypotheses and enhance our understanding of the lithic assemblage in area MR.2, several observation techniques and analytical approaches were employed on various artefact groups to address specific inquiries. Four techniques, including stereomicroscopy, confocal microscopy, scanning electron microscopy (SEM), and micro-Raman spectroscopy, were used. Examining the turquoise debitage through the stereomicroscope, no abrasion or reduction that could be linked to any reduction steps was observed. Similarly, the examination of carnelian items yielded only one positive specimen, identified as M6, which exhibited parallel streaks on all surfaces suggestive of either primary or coarse polishing. Taking into account the presence of a limited number of rough-outs that appear to have been intentionally flaked, it is reasonable to assume that the lithic debitage was partially a result of a local carnelian bead production. In addition, traces of a former adhesive substance were carefully observed and newly recorded on a number of green jasper drill heads following examination of several areas.

The use of a confocal microscope facilitated the identification of a higher number of fibers than observed through SEM. Moreover, it enabled the recognition of fiber imprints on the glue in several regions, despite the fibers' lack of preservation. Unfortunately, 3D acquisitions were not feasible. Nevertheless, this method proved helpful in scrutinising the marks initiated by the drilling procedure on the drills themselves, whereby we were able to examine the grooves engraved on the surface of the head drill caused by the friction produced from its contact with the loose debris during drilling.

The SEM analysis indicates that deeper abrasion traces are concentrated on the apical and proximal sections rather than the center of the drill tip. Friction among the drill, bead, and loose drilling powders generates the easily explained apical grooves that roughen the drill and create a distinct cup-shaped depression at the tip. However, the reasons for the highly visible grooves and abrasions in the proximal part of the drill head are unclear. It has been suggested that they may have been caused by an inadvertent rotational movement of the drill against the outer surface of the bead, which had not yet been polished. Additionally, the fractured tip of the drills indicates that these may have broken in a spiral fashion, during the rotational phase of drilling.

SEM images of silicone casts of the bead holes revealed that various perforation techniques were employed, as well as different types of drill heads, not all attributed to the green jasper drills found in this collection. The most evident techniques on record were pecking, possibly with a chert or flint blade (not discovered in this collection but present in the site's archaeological evidence from both Neolithic and Chalcolithic periods), and tapered drilling with jasper drills. It is hypothesized, based on the shape of the beads and the distinctive perforation observed via SEM, that at least three carnelian samples, possibly perforated with a copper drill, may belong to a more modern, albeit uncertain, period. One significant factor needs consideration; few beads in this collection have drill holes of sufficient diameter to confirm that they were drilled using the green jasper drills.

A last consideration was that the SEM, using the confocal microscope, allowed us to obtain the best images of the residual plant fibres still trapped in the resinous coating on the surface of the drills. Unfortunately, our current knowledge of fibres from the 4th and 5th millennium BCE in this area is still quite limited. According to Margarita Gleba, whom we consulted on this matter, the fibers are not cotton, but belong to a different, unidentified local species. Therefore, we aim to conduct further analyses and research to deepen our knowledge on this topic. The micro-Raman analysis conducted on green and blue turquoise indicates that no difference can be observed between the two semiprecious stones of the two contrasting colours from the spectra. However, turquoise fragments without any traces related to bead-making activities exhibit substantial variance. Half of samples are rich in amorphous material, while the rest are of good quality. The turquoise samples from Mehrgarh will be studied again in the frame of a new archaeometric project of high resolution chemical characterization of a large number of samples from different mining areas of southern Eurasia, currently planned by the Metropolitan Museum of Art, with the aim of the creation of a database for this large area and the contextualisation of the extraction of turquoise, with which the present writer has been invited to collaborate.

The research allowed use to review the entire collection from a unified perspective, adding new insight made possible by the mentioned archaeometric applications. This involved considering previously conducted archaeometric analyses that have already been published, and reapplying updated methods and formats to the materials. Some questions have been solved, whereas others, like always, were better defined and will guide further analytical studies.

References

BARTHÉLÉMY DE SAIZIEU B., RODIÈRE B.J., 2005, *Beaddrilling: A look from Mehrgarh and Nausharo. Preliminary results of micro-traces analysis*, in FRANKE-VOGT U., WEISSHAAR H.J. (eds.), South Asian Archaeology 2003 u. pp. 39-48. Aachen: Linden soft.

COPPA A., BONDIOLI L., CUCINA A. et al. 2006, *Early Neolithic tradition of dentistry*. Nature 440, 755–756 (2006). https://doi.org/10.1038/440755a.

HERMANN G. 1968, *Lapis lazuli: the early Phases of its trade*, Iraq 30(1): 21-57.

JARRIGE C., JARRIGE J.F., MEADOW R.H., QUIVRON G. 1995, *Mehrgarh Field reports 1975 to 1985 – From the Neolithic to the Indus Civilization*. Karachi: department of culture and tourism, Government of sindh, Pakistan, in collaboration with the French Ministry of Foreign Affairs.

JARRIGE J.F. 2008, *Mehrgarh Neolithic* Pragdhara, 135–154.

JARRIGE, J.F., JARRIGE C., QUIVRON G. 2005, *Mehrgarh Neolithic: the updated sequence,* in JARRIGE C., AND LEFÈVRE V. (eds.), *South Asian Archaeology* 2001, vol. I, 129–141.

JARRIGE, J.F., JARRIGE C., QUIVRON G., WENGLER L. 2013, *Mehrgarh: Neolithic Period – Seasons 1997–2000*. Paris: Éditions de Boccard.

KENOYER J.M. 1998. *Ancient Cities of the Indus Valley Civilization*, OUP Pakistan.

KENOYER J.M. 2017a, *Using SEM to Study Stone Bead Technology,* in KANUGO A.K. (ed) *Stone Beads of South and Southeast Asia: Archaeology, Ethnography and Global Connections*. Aryan Books International, New Deli.

KENOYER J.M. 2017b, *History of Stone Beads and Drilling: South Asia,* in KANUGO A.K. (ed) *Stone Beads of South and Southeast Asia: Archaeology, Ethnography and Global Connections*. Aryan Books International, New Deli.

KENOYER J.M. 2017c, *Stone Beads of the Indus Tradition: New Perspectives on Harappan Bead Typology, Technology and Documentation,* in KANUGO A.K. (ed) *Stone Beads of South and Southeast Asia: Archaeology, Ethnography and Global Connections*. Aryan Books International, New Deli.

KENOYER J.M. and VIDALE M. 1992 2. *A New Look at Stone Drills of the Indus Valley Tradition*, in VANDIVER P., DRUZICK J.R., WHEELER G.S. and FREESTONE I. (eds.) Materials Issues in Art and Archaeology III pp. 495-518. Pittsburgh: Materials Research Society.

KENOYER, J.M. 1995a., *Interaction systems, specialized crafts and culture change: the Indus Valley tradition and the Indo-Gangetic tradition in south Asia, in the indo-aryans of ancient south asia*, *Language, Material Culture and Ethnicity,* in ERDOSY G. (ed.), pp. 213-257. Berlin: W. de Gruyter.

KINGWELL-BANHAM E., PETRIE C.A. AND FULLER D.Q. 2015, *Early agriculture in South Asia, in* BACHER G. AND GOUCHER C. (eds.), *The Cambridge World History, Volume II: A World with Agriculture 12,000 BCE- 500 CE*, Cambridge University Press 2015: 261-288.

LUDVIK G., KENOYER J.M., PIENIĄŻEK M. AND AYLWARD W. 2015, *New perspectives on stone bead technology ar Bronze Age Troy.* Anatolian Studies, vol. 65: 1- 18.

LUEDTKE B.E. 1992, *Archaeologist' Guide to Chert and Flint.* Instiute of Archaeology, University of California, Los Angeles.

MALDONADO F., MENGAL J.M., KHAN S.H. AND WARWICK P.D. 2011, *Summary of the Stratigraphy and Structural Elements Related to Plate Convergence of the Quetta-Muslim Bagh-Sibi Region, Balochistan, West-Central Pakistan,* U.S. Geological Survey, Open-File Report 2011–1224. Reston, Virginia 2011.

MORRELL P.L. AND CLEGG M.T. 2007, *Genetic evidence for a second domestication of barley (Hordeum vulgare) east of the Fertile Crescent,* PNAS, vol. 104 no. 9: 3289–3294.

PETRIE C.A. 2015, *Mehrgarh, Pakistan*, in BACHER G. AND GOUCHER C. (eds.), *The Cambridge World History, Volume II: A World with Agriculture 12,000 BCE- 500 CE*, Cambridge University Press 2015: 289-305.

PIPERNO M. 1973, *Micro-drilling at Shahr-I Sokhta: the making and using of lithic drill Heads*, in HAMMOND N. (ed.), South Asian Archaeology 1971 pp. 119-129. London.

THIÉBAULT S. 1988a, *Palaeoenvironment and ancient vegetation of Baluchistan based on charcoal analysis of archaeological sites*. Proceedings of the Indian National Science Academy 54: 501–509.

THIÉBAULT S. 1988b, *L'évolution de la végétation à Mehrgarh*, in JARRIGE J.F. (ed.) *Les cités oubliées de l'Indus*: 44–5. Paris: Musée National des Arts Asiatiques Guimet.

THIÉBAULT S. 1989. *A note on the ancient vegetation of Baluchistan based on charcoal analysis of the latest periods from Mehrgarh, Pakistan*, in FRIFELT K. and SØRENSEN P. (ed.) *South Asian Archaeology 1985* (Papers from the eighth International Conference of South Asian Archaeologists in Western Europe, Moesgaard Museum, Denmark, 1-5 July 1985): 186–188. London: Curzon & Riverdale (MD): Riverdale Company.

THIÉBAULT S. 1992, *Complementary results in anthracological analysis from sites in Baluchistan*, in JARRIGE C. (ed.) *South Asian Archaeology*, 1989 (Papers from the tenth International Conference of South Asian Archaeologists in Western Europe, Musée National des Arts Asiatiques-Guimet, Paris, 3-7 July 1989): 271– 276. Madison (WI): Prehistory Press.

THOURY M., MILLE B., SÉVERIN-FABIANI T. et al. 2016, *High spatial dynamics-photoluminescence imaging reveals the metallurgy of the earliest lost-wax cast object*. Nat Commun 7, 13356 (2016). https://doi.org/10.1038/ncomms13356.

TOSI M. 1974. *The lapis lazuli trade across the Iranian Plateau in the 3rd Millennium bc*, in FORTE A. (ed.) Gururajamanjarika: studi in Onore di Giuseppe Tucci, pp. 3-22. Napoli: Istituto Universitario Orientale.

TOSI M. AND PIPERNO M. 1973. *Lithic technology behind the ancient lapis lazuli trade*, Expedition 16: 15-23.

TOSI M. AND VIDALE M. 1990. *4th Millennium BC lapis lazuli working at Mehrgarh, Pakistan*, Paléorient 16(2): 89-99.

UESUGI A. 2019, *Stone Beads from Taxila.* Ancient Pakistan, Vol. 30: 1- 22.

UESUGI A., KUMAR M. AND DANGI V. 2018, *Indus Stone Beads in the Ghaggar Plain with a Focus on the Evidence from Farmana and Mitathal,* in FRENEZ D., JAMISO G.M., LAW R.W., VIDALE M. and MEADOW R.H. (eds) *Walking with the Unicorn: Social organization and Material Culture in Ancient South Asia*. Archeopress Publishing LTD and ISMEO.

VIDALE M. 1989. Early Harappan steatite, Faience and Paste beads in a necklace from Mehrgarh-nausharo (Pakistan), East and West 39(1-4): 291-300.

VIDALE M. 1995. *Eearly beadmakers of the Indus tradition: The Manufacturing sequence of talc beads at Mehrgarh in the 5th Millenium bc*, East and West 45(1-4): 45-80.

VIDALE M. 2000, *The archaeology of Indus crafts. Indus craftspeople and why we study them.* Reports and memoirs - Series minor, ISIAO.

VIDALE M., AND LAZZARI A. 2017, *Lapis lazuli bad making at Shahr-i Sokhta*. Padova: Antilia.

VIDALE M., MARIOTTINI M., SIDOTI G. AND ZAHIR M. 2017, *Early Evidence of Beadmaking at Mehrgarh, Pakistan: A Tribute to the Scientific Curiosity of Catherine and Jean-François Jarrige,* in KANUGO A.K. (ed) *Stone Beads of South and Southeast Asia: Archaeology, Ethnography and Global Connections*. Aryan Books International, New Deli.