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Bérénice Bellina, Cloé Georjon, U. Aung Aung Kyaw, Daw Tin Tin Win, Daw Thu Thu Win, Baptiste Pradier, Anna Willis, Peter Petchey, Yoshiyuki Iizuka, Eric Gonthier, et al.

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Title: Late Neolithic to Early-Mid Bronze Age semi-precious stone bead production and consumption at Oakaie and Nyaung'gan in central-northern Myanmar

Authors: Cloé Georjon<sup>1</sup> - Formal analysis, Investigation, Writing - Original Draft, Visualization

U Aung Aung Kyaw<sup>2</sup> - Resources, Project administration

Daw Tin Tin Win<sup>2</sup> - Resources, Project administration

Daw Thu Thu Win<sup>2</sup> - Investigation, Resources

Baptiste Pradier<sup>3</sup> - Investigation, Resources

Anna Willis<sup>4</sup> - Investigation, Resources

Peter Petchey<sup>5</sup> - Investigation, Resources

Yoshiyuki Iizuka<sup>6&7</sup> - Formal analysis, Investigation, Supervision, Funding acquisition

Eric Gonthier<sup>8</sup> - Supervision

Jacques Pelegrin<sup>9</sup> - Methodology, Supervision, Writing - Review & Editing

Bérénice Bellina<sup>9</sup> - Methodology, Supervision, Writing - Review & Editing

T. O. Pryce<sup>9&10</sup> - Conceptualization, Methodology, Resources, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition – also corresponding author

Affiliations:<sup>1</sup>Préhistoire et Technologie, UMR 7055, MAE, Université de Paris-Nanterre, 92000 Nanterre Cedex, France, <sup>2</sup>Department of Archaeology and National Museum, Ministry of Religious Affairs and Culture, Myanmar, <sup>3</sup>Préhistoire et Technologie, UMR 7055, MAE, Université de Paris-Nanterre, 92000 Nanterre Cedex, France, <sup>4</sup>College of Arts, Society & Education, James Cook University, Australia, <sup>5</sup>Archaeology Programme, University of Otago, New Zealand, <sup>6</sup>Institute of earth Sciences, Academia Sinica, Taipei, Taiwan, <sup>7</sup>Centre for Cultural Resource Studies, Kanazawa University, Japan <sup>8</sup>Muséum national d'Histoire naturelle, Département Hommes et Environnement, UMR 7194, Paris 75016, France, <sup>9</sup>Centre National de la Recherche Scientifique, Préhistoire et Technologie, UMR 7055, MAE, 92000 Nanterre Cedex, France, <sup>10</sup>LAPA-IRAMAT, NIMBE, CEA, CNRS, Université Paris-Saclay, CEA Saclay 91191 Gif-sur-Yvette, France,

Abstract:

For many decades, the appearance of semi-precious stone ornaments in Mainland Southeast Asian late prehistoric assemblages was closely associated with external actors: Taiwan and Island Southeast Asia in the case of nephrite, and South Asia in the case of carnelian. Carnelian beads in particular have long been held as a type marker of early contact across the Bay of Bengal, from the mid-late 1<sup>st</sup> millennium BC. With this paper we demonstrate, from the central-northern Myanmar settlement and cemetery sites of Oakaie and Nyaung'gan, not only the presence of semi-precious stone beads, but also their production during the Late Neolithic to Early-Mid Bronze Age, late 2<sup>nd</sup> millennium to early-mid 1<sup>st</sup> millennium BC. We employed the *chaîneopératoire technique* to establish reliable links

between the industrial and funerary evidence, as represented by 489 finished beads and a vast quantity of production debris. The sites in question are chronologically-overlapping and separated by only five kilometres, but such ornaments are found across the region and it is of fundamental importance to provide a solid foundation to expand semi-precious stone ornament studies and unravel the complex networks of social interactions that led to their exchange.

## 1.0 Introduction:



*Figure 1: Myanmar as the sub-Himalayan crossroads, with capital and major cities, plus principle sites mentioned in the text.*

## 1.1 The Southeast Asian implications of late prehistoric carnelian beads

This paper discusses the archaeological evidence for and historical implications of semi-precious stone bead production in late 2<sup>nd</sup> /early-mid 1<sup>st</sup> millennium BC, Late Neolithic to Early Bronze Age, north-central Myanmar. However, this topic, particularly where it concerns carnelian beads in Mainland Southeast Asian (MSEA) archaeological contexts, has for over forty years been closely associated with the initiation of the regional Iron Age (from ca. late 5th-4th c. BC, see Bellina, 2014; Carter, 2016; I. C. Glover, 1990). In MSEA this transition is synonymous with the development of cultural and economic interaction with South Asia and increasing regional social complexity – partially based on the non-standardised adoption of Indic behaviours by Southeast Asia's nascent elites as they confronted an increasingly dry climate (as derived from predominantly Thai datasets, Myanmar analyses forthcoming, see e.g. Castillo et al., 2018; Wohlfarth et al., 2016). These carnelian beads, often of superb raw material and artisanal quality, were first noted at Ban Don ThaPhet, in west-central Thailand (Figure 1) (Chin, 1976; Ian C. Glover, 1990; I. C. Glover, 1990), alongside other material culture with South Asian cultural associations (notably hot-worked and quenched high-tin bronze bowls, Bennett and Glover, 1992; Murillo-Barroso et al., 2010; Rajpitak and Seeley, 1979). At the time these claims were controversial, as according to traditional architectural, statuary and textual approaches, South-Southeast Asian cultural interaction did not start in earnest until the mid-1<sup>st</sup> millennium AD, with the development of regional 'Indianised' states (e.g. Cœdès, 1969, 1968, 1944); with the Pyu in

Myanmar an earlier outlier (Hudson, 2012; Stargardt, 1990) and northern Vietnam under Han state influence from 111 BC (Higham, 2014; Kim, 2015; Taylor, 1983).

The concept of late prehistoric cultural exchange processes between South Asia and Mainland and Island South East Asia (ISEA) was strongly supported by Bellina's (2001) thesis on semi-precious stone bead production and consumption across South and Southeast Asia. 1500 detailed bead *chaîneopératoire* analyses provided firm linking evidence for the extremely high skill levels required for the production of the finest carnelian and agate beads, using the 'Cambay technique' attested historically and studied in great ethnoarchaeological detail in India (Bhan et al., 2017; Insoll and Bhan, 2001; J.M. Kenoyer et al., 1991; Jonathan M. Kenoyer et al., 1991; Roux, 2000; Vidale et al., 1993, 1992), and beads excavated in Southeast Asia. This is the technological foundation for the now prevalent understanding, that evidence for the *production* of such beads in late 1<sup>st</sup> millennium BC MSEA implied the presence of South Asian artisans, and/or Southeast Asians extensively trained by the former (Bellina, 2007, 2003). The discovery of a major bead (and other specialised industries) production and urban centre at Khao Sam Kaeo, in upper peninsular Thailand (Figure 1), reinforced this early-mid Iron Age model; for limited South Asian migration of highly skilled artisans serving MSEA indigenous elites (Bellina, 2017, 2014). The entire case for this historical reconstruction rests upon the confluence of: high quality raw materials, highly-skilled Indian craft techniques, evidence for production adapted to regional styles and the absence of a local high skill level bead traditions.

Meanwhile, Theunissen's (2000; 2003) geochemically-focused research on carnelian and agate ornaments from later Iron Age (early centuries AD) northeastern Thailand demonstrated some of them could have been locally made. This was interpreted as evidence of Southeast Asia's culturally independent path from India, following a post-colonialist trend initiated in the 1960s amongst academics (e.g. Benda, 1962; Smail, 1961) that emphasised endogenous factors of regional social and political change, as opposed to the preceding paradigm that largely viewed Southeast Asia as the passive recipient of exogenous cultural configurations (e.g. Cœdès, 1944). The 1980s opened the avenue to more mixed perspectives, emphasising the innovations resulting from the local adoption and adaptation of the Indian models. It is, for instance, the "localisation" of Wolters (1982) the "vernacularisation" of Pollock (2006). Theunissen's thinking is in agreement with Bellina's technologically-focused findings for the later periods (2017, 2007, 2001), and these scholars' results were subsequently reinforced by Carter's (2016, 2015, 2013) Cambodian hard stone ornament production research for later Iron Age sites.

Another step in regional ornament research was recently made by Carter and Dussubieux (2016), who pushed LA-ICP-MS-based provenance analyses to complement the work done on manufacturing techniques. They showed that many stone beads found in Cambodia and Thailand had similar elemental compositions to raw materials from the Deccan Traps, and in so doing added fresh data supporting a complex view of late prehistoric exchange network. Overall, Iron Age stone ornament studies in Southeast Asia have, despite being fairly recent, significantly contributed to understanding complex late prehistoric social, economic and political developments and the region's cultural trajectory (Bellina, 2017, 2014, 2007, 2003, 2001; Carter, 2016, 2015, 2013; Carter and Dussubieux, 2016; Theunissen et al., 2000; Theunissen, 2003).

We have summarised the current late 1<sup>st</sup> millennium BC paradigm in some detail before we present our late 2<sup>nd</sup> millennium and early-mid 1<sup>st</sup> millennium BC carnelian bead production and consumption data from north-central Myanmar, but emphatically do *not* make a comparable interpretative step to South Asian contact. The requisite confluence of material and technical circumstances do not apply. Nevertheless, we suggest our findings are a significant step in understanding Southeast Asian semi-precious stone ornament technologies, complementary to those seen for nephrite in Island Southeast

Asia from 5000 BP (Hung et al., 2007; Hung and Bellwood, 2010), in that they appear to be an indigenous development.

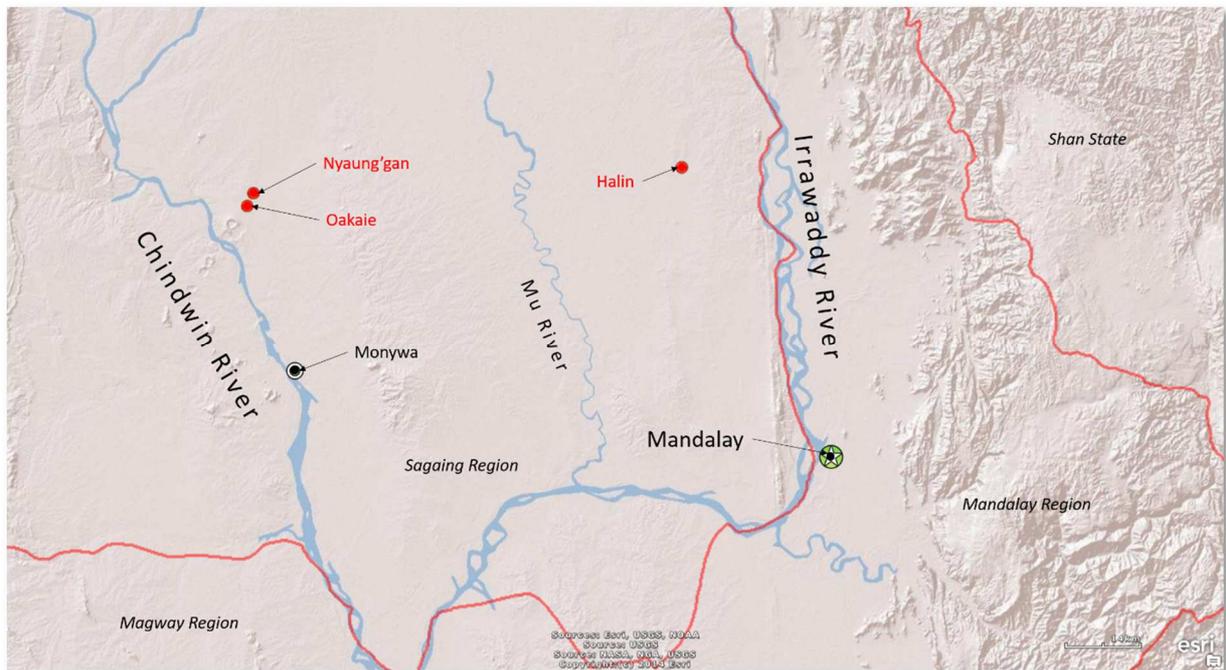
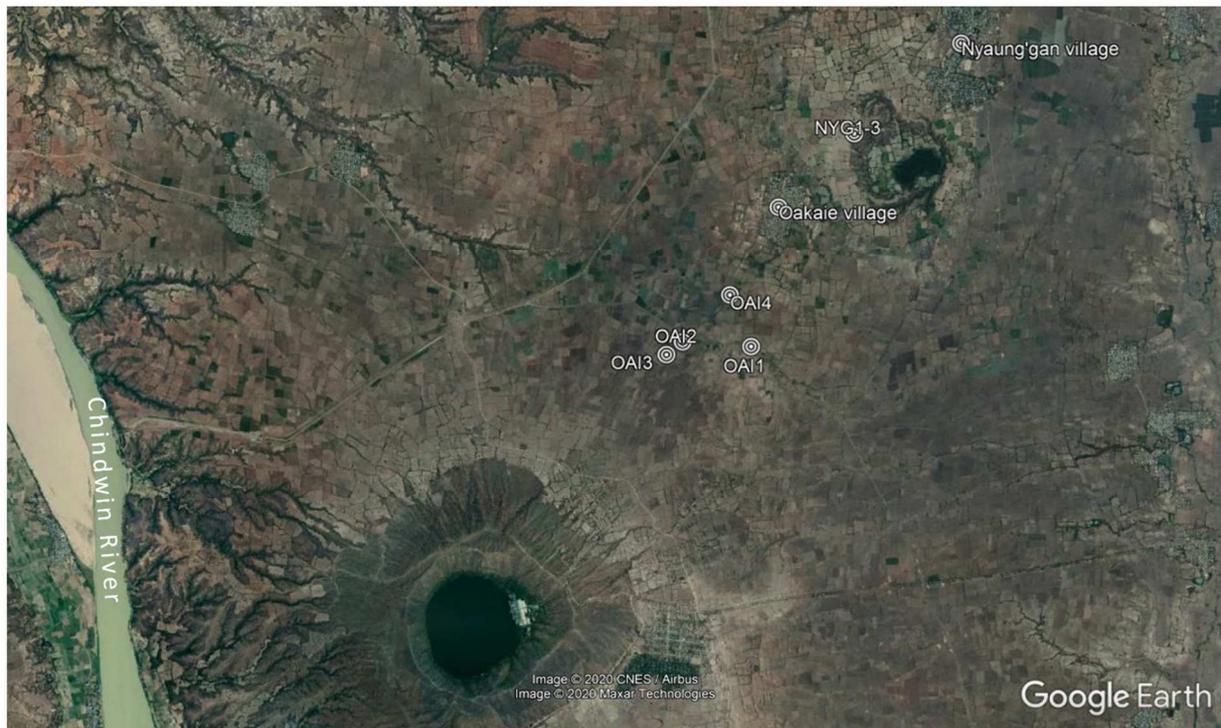


Figure 2: MAFM 2014-16 and MAFM 2017-2020 areas of investigation at Oakaie/Nyaung'gan and Halin, respectively.

## 1.2 Semi-precious stone bead production and consumption at the Oakaie/Nyaung'gan Late Neolithic- Early/Mid Bronze Age complex

The Oakaie/Nyaung'gan site complex is located on the eastern banks of the Chindwin River, ca. 115 km ENE of Mandalay, or ca. 30 km NNW of Monywa, in Budalin Township, Sagaing Division (Oakaie village dig house 22.404843°N, 95.052537°E). The geological setting is one of Upper Miocene – Pliocene sedimentary rocks of the Irrawaddy Formation with Cenozoic andesitic volcanic craters running SW-NE (Soe Thura Tun et al., 2014). This area also corresponds to the northern boundary of Myanmar's 'arid, steppe, hot' (BSh) with the 'tropical, savannah' (Aw) Köppen–Geiger climate classification zones (Beck et al., 2018). As reviewed in Pryce et al. (2018b), Nyaung'gan was the first site in Myanmar attributed to the Bronze Age, following villager finds in the mid-1990s (Moore and Pauk, 2001; Tayles et al., 2001). Detailed studies, including radiometric dating, were not possible at this time, so the *Mission Archéologique Française au Myanmar* (MAFM) returned to the area for three field seasons, 2014-16, with the aim of providing much improved reconstructions of life and industry, environment and economy, and death and health for the area. Such studies, some of which remain ongoing as student or professional research projects, rely upon a reliable chronological framework, including relative techno-stylistic pottery seriation (Favereau et al., 2018), regional metal exchange network cross-dates (Pryce et al., 2018a), and funerary micro-phasing (Pradier et al., 2019), all anchored to a 52 determination radiocarbon date sequence (Pryce et al., 2018b). These combined studies were able to provide a first locking together of late prehistoric Myanmar into the contemporary MSEA puzzle, exposing late 2<sup>nd</sup> millennium BC Neolithic phases as well as a ca. 10<sup>th</sup> c. BC Bronze Age transition, highly comparable to that recently identified in Yunnan (Yao et al., 2020), and within a couple of centuries of the best-dated sites in Thailand (Higham et al., 2019, 2015, in press).



*Figure 3: The Oakaie area sites in relation to the Chindwin River and Twin Taung volcano crater. The latter is a potential source of andesite but not of carnelian and other semi-precious minerals.*

See Pryce et al. (2018b) for details on excavations and dating but the Oakaie loci investigated include: OAI1, a 52 individual cemetery with two Neolithic and one Bronze Age phases; OAI2, a 114 m<sup>2</sup> settlement exposure of Bronze Age living surfaces with post-holes and sub-floor neo-natal burials; OAI3, a 1.7 m deep 16 m<sup>2</sup> sounding of Bronze Age and Neolithic settlement and industrial deposits, providing the key radiocarbon and ceramic sequences, as well as most of the bead production material for the present study; and OAI4, a lower density deposit similar to OAI3. At Nyaung'gan itself, whereas the 1998-99 Myanmar Ministry of Culture excavations had concentrated on exposing the uppermost layer of burials to produce a site museum, the MAFM's 2016 excavations penetrated through to sterile soil, bringing to light a Neolithic phase as per OAI1. All the aforementioned cemeteries included stone beads as grave goods, though not equally distributed between individuals<sup>1</sup> (Pradier et al., 2019), and all the settlement sites produced stone bead production waste flakes, fragments and failed attempts, though with by far the greatest concentration at OAI3 (Figure 5).

Although the visual similarity of beads in funerary and settlement/industrial sites separated by just a couple of kilometres may seem evident, this is no way to build a rigorous framework for regional analysis of semi-precious stone ornament exchange networks, their social organisation and complexity. So, with this paper, we begin at the beginning, with a 605 artefact (debitage fragment, roughout, preform and finished bead) study to reliably test the technological links between Oakaie/Nyaung'gan sites.

### 1.3 The Oakaie/Nyaung'gan assemblage

<sup>1</sup> We do not have exact locations for all the funerary beads within each grave, many of which were recovered during flotation. This was especially the case from the 2015 season at OAI1, where a burst irrigation pipe at the end of the season flooded the pit and collapsed most of the exposed graves.



Figure 4: Examples of carnelian, chlorite, quartz, nephrite and andesite beads from the Nyaung'gan and Oakaie 1 cemeteries. The scale is 2cm long in total, the black graduation markers in its right part are separated by 1mm.

Our corpus totalled 489 finished beads of **rondel**, **cylinder** and ellipse form, in a variety of stone types, coming from Oakaie/Nyaung'ganfunerary (365) and settlement/industrial (124) contexts, plus associated production waste at the latter. Of the complete beads, 236 came from the 2016 excavations at Nyaung'gan, found in five of the six burials excavated, and over half of those in burials NYG2/S3-S3b and NYG3/S6. In the OAI1 cemetery, 129 beads were recovered from 11 of the 55 burials. The OAI2 settlement did not yield any beads, as opposed to the settlement/industrial loci of OAI3, 88 beads, and OAI4, 36 beads: including perforated but damaged examples. OAI3 and OAI4 also yielded extensive evidence for the bead production chain: raw materials blanks, preforms, pre-perforation broken beads and cones ejected during perforation.

The aim of this study is to reliably test the link between these production and consumption sites, in close proximity, to provide a technological foundation to expand, geographically and chronologically, research on this precocious semi-precious stone bead exchange network.

Table 1: Summary of finished bead distributions.

Site	Period Late Neolithic or Early Bronze Age	Context/ Burial #	Finished beads #
NYG1		S2	6

NYG2	LN	S3a	43
NYG2	LN	S3b	46
NYG3	EBA	S6	134
NYG3	LN	S7	4
NYG3	-	50005, L1 S2	1
NYG3	-	50017, L1 S9	1
OAI1	LN	S3	6
OAI1	LN	S4	2
OAI1	LN	S5	2
OAI1	LN	S6	13
OAI1	LN	S7	18
OAI1	LN	S8	1
OAI1	EBA	S15	1
OAI1	LN	S19	51
OAI1	LN	S19a	16
OAI1	LN	S21a	2
OAI1	LN	S21b	14
OAI1	LN	S26	1
OAI1	LN	S51	2
OAI3	EBA		29
OAI3	LN2		51
OAI3	LN1		7
OAI4-1	EBA		12
OAI4-2	EBA		6
OAI4-2	LN		19

## 2.0 Methodology

### 2.1 Excavation

MAFM excavations are executed on the basis of 4 x 4 m squares, the multiplication of which depends upon the anticipated depth and complexity of the deposit, and the time available. Flotation is used on all contexts, for archaeobotanical purposes but generally for the recovery of micro-charcoal for dating, preferably of short-lived species. The current study relied on stone material from cemetery and settlement loci, in particular OAI3 for the latter. For the former, the MAFM uses the *anthropologie de terrain* or 'field anthropology' approach to understanding cemeteries, wherein a firm understanding of human anatomy and decomposition processes allows for a fine-grained reconstruction of burial practices and to seek out differences and similarities with spatio-chronologically congruous populations. (e.g. Duday et al., 1990; Duday, 2005; Willis and Tayles, 2009). Further laboratory analyses (diet, mobility, aDNA etc) are carried out on exported skeletal samples, and all grave goods are studied according to the *chaîneopératoire technique* by team specialists.

Monsoon-washed tropical settlement sites are notoriously difficult but attentive trowelling can and does reveal features to allow excavation by context, postholes, hearths, middens etc (e.g. Bellina, 2017; Higham et al., 2014; Kim, 2013; Oxenham et al., 2011; Pryce et al., 2018b). When layers cannot be followed in plan, arbitrary spits of 100 mm are removed until features are again revealed and context numbers harmonised to provide a full recording with the completed, cleaned, photographed and drawn sections.

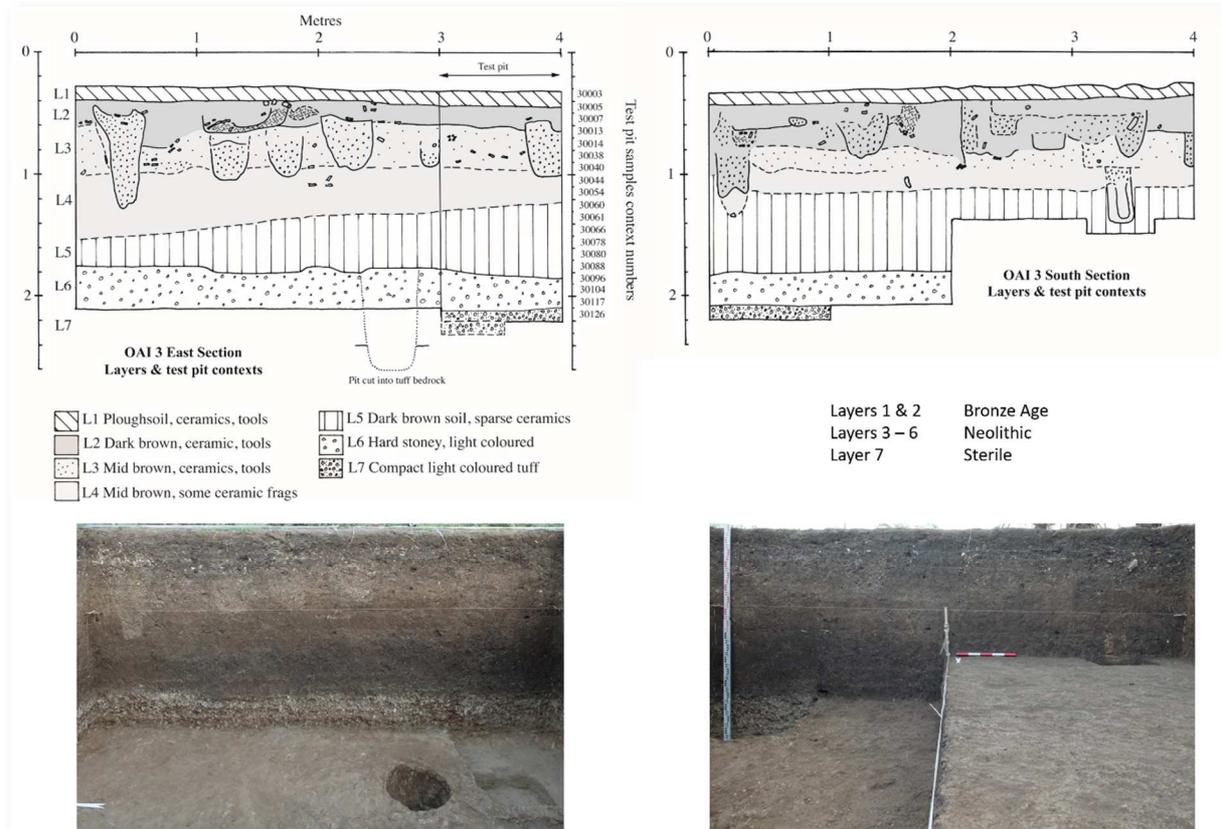


Figure 5: The OAI3 eastern (left) and southern (right) sections, showing the critical LN/EBA boundary layer (after Pryce et al., 2018b: Figure 4).

Targeting sterile layers, OAI3 was excavated as a single 4 x 4 m unit as above but, as a control for the recovery of fine lithic and other fragments, the southeastern corner was treated separately as a 1 m<sup>2</sup> column with 100% wet-sieving of all sediments through a 2mm mesh. Furthermore, systematic archaeobotanical flotation of excavated sediments through a 250 µ mesh allowed for the recovery of very fine lithics. This proves essential for distinguishing the continuity of lithic production through Early Bronze Age and Late Neolithic levels, and the eventual diminution of material with increased depth. OAI3 benefitted from fifteen <sup>14</sup>C dates and was, until recent work at Halin (Pryce et al., in preparation), the best-dated testpit in Myanmar by some margin (Pryce et al., 2018b).

## 2.2 The *chaîneopératoire* approach

The technical description of archaeological beads can be traced back to the work of Horace C. Beck (1928) but has been greatly refined to take into account the *chaîneopératoire*. This study is a technological characterisation of the stone technical systems based on the reconstitution of the “*chaîneopératoire*” (Leroi-Gourhan, 1964). The core idea is that groups’ specific values and beliefs are expressed by the technological choices they make during the manufacturing process. So ways of making objects reflect a social and economic organisation. Characterising the techniques involved at different stages of the *chaîneopératoire* is a way to identify social groups and their organisation (Costin, 2001; Lemonnier, 1993).

The MAFM assemblage’s classification began with the identification of mineral species, as performed by a professional geologist (Iizuka) equipped with a portable energy dispersive (ED) X-ray Fluorescence Spectrometer (p-XRF: Xmet-7500, Oxford Instruments Co., UK) for bulk chemical analysis. A 9mm

diameter primary X-ray beam irradiated each specimen for 60 seconds. Exited X-ray intensities were counted over twelve cycles of the primary beam conditions of (1) light element (> Ti): 13 kV and 45mA for 4 seconds, and (2) heavier elements: 40 kV and 10mA for 1 second of the acceleration voltage, beam current, and exposure time, respectively. Measured ED X-ray intensities were corrected by Low Elements Fundamental Parameter for lithic specimen (mining LE-FP method), and then output as oxide forms in weight percent, such as SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub>, FeO, MnO, MgO, NiO, CaO, K<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub> and SO<sub>3</sub>. The cation ratios were calculated from oxide data. Measured ED spectra and cation ratios were referred to mineral identification with established databases (e.g. Iizuka et al., 2005, in press; Moutsiou and Kassianidou, 2019).

Upon this foundation, the three-dimensional appearance and metrics of the artefact were taken into account to produce morphological categories, as well as more subjective criteria like colour, opacity, homogeneity (presence of flaws) and potentially decoration<sup>2</sup>. Then followed the painstaking analysis of micro-traces that, based upon extensive ethnoarchaeological research, can reconstruct the production process. We make clear our understanding that systematic differences and similarities in production techniques between chronologically and spatially contiguous populations can throw light upon the persistence, or otherwise, of social interactions, with the most skilled techniques indicating the greatest proximity of learning environments (Pelegrin, 1991).

The detailed study of recently practicing expert bead craftsmen in the Indian state of Gujarat has given us a finely detailed model of relevant *chaînes opératoires*, against which we can evaluate our archaeological assemblage (e.g. Roux, 2000; Roux and Pelegrin, 1989). The relative proximity of two study areas, ca. 2300 km, is not directly relevant here due to the chronological separation and, more importantly, the cross-cultural basis of the ethnoarchaeological study, pertinent for all homo sapiens-produced assemblages.

The first stage of the production sequence consists of removing the unnecessary raw material, followed by the roughing out of the desired form. The third stage is the production of a preform of the final shape, before the fourth step, perforation. The fifth and final stage is that of finishing, whether by polishing, etching etc or a combination. The number and duration of intermediary stages is intimately linked to the raw material used: its hardness, homogeneity, effects of heating on colour and fracture characteristics and the complexity of the desired product. At the Oakaie production sites six classes of lithic material were identified: raw materials, reduction waste, roughouts, preforms, abandonments due to a production failure, and finished artefacts. In this study we followed the methodological practices, as adapted and practiced for Southeast Asia by Bérénice Bellina (2014, 2007, 2003, 2001). Skill is evaluated through morphologies and polished surface regularity. This regularity is evaluated giving scores (summarised in the table 2).

Score Symmetry OAI1	1 $\Delta \geq 0,5\text{mm}$	2 $\Delta \leq 0,5\text{mm}$	3 $\Delta \leq 0,2\text{mm}$
Theoretical examples of the $\Delta$ of the dimension and the impact on symmetry			

<sup>2</sup>None of the beads in our assemblage were decorated, inscribed, etched etc.

Table 2. Table explaining the variations of symmetry observed on the beads through theoretical examples of cross-section measurements. “ $\Delta$ ” corresponds to the difference between the two measurements of the cross-section (left/ right and up/bottom) observed on each bead to determine the degree of symmetry.

“1” scores a bad symmetry or a complete lack of symmetry: difference ( $\Delta$ ) between the two measures  $\geq 0,5\text{mm}$

“2” scores a medium symmetry: difference ( $\Delta$ ) between the two measures  $\leq 0,5\text{mm}$

“3” scores an almost perfect symmetry: difference ( $\Delta$ ) between the two measure  $\leq 0,2\text{mm}$

The main tools used for the technological analysis were a digital caliper accurate to hundredths of a millimetre, a digital balance accurate to thousandths of a gram (Smart Weigh Mini Balance 50g), fine drill bits with which to establish perforation diameter, a jeweller’s loupe and a DSLR (Nikon D610) with a true macro lens (Tokina AT-X M100 Pro D AF 100mm f/2.8) on a heavyweight tripod, with remote trigger, light-diffusing tent and appropriate scale bars.

### 3.0 Results

From a techno-functional point of view, our results confirm the presence of the same simple morphologies of beads between the four sites of our corpus, which are all located within 5 km linear distance. Three main morphological families: **rondel**, **cylinder** and ellipse beads, are present at all sites, with an over-representation of the former, while rarer morphological types such as the bicone beads with a circular cross-section are sometimes found at only one site. Each family is defined according to the final shape (cross section and profile) of the beads. Then, sub-category (elongated, short or extra-short) can be made depending on their morphometric ratios, which are almost identical between the sites. Each of these morphologies also shows a similar choice of raw materials, the same perforation techniques and the same stigmata of finishes such as retouching and/or multidirectional streaks associated with manual polishing on a polisher (detailed below). Indeed, the **rondel** and cylindrical beads are mainly made of hard stone with orange, red and white colours when the oversized ellipse beads can also be made of soft stone and always present green, grey or black shades regardless of the hardness of the raw material. In total, tentypes of ornamental stone beads have been identified at the three sites, using three modes of perforation and at least two shaping techniques. Thus, the hard stone used for small beads are knapped while the soft rocks used for large beads are sawn. We were also able to distinguish two polishing techniques, manual and polishing in leather bag, and one polishing technique with siliceous plant (phytoliths) material for cylindrical beads. With the leather bag technique several beads are placed together along with abrasive powder and shaken for several hours (Roux, 2000: 109). The homogeneity of these results makes it possible to assume the presence of identical *chaînes opératoires* on all our sites. Examining the evidence by site:

#### 3.1. Nyaung’gan

Nyaung’gan’s 236 beads constitute more than half of the total corpus but they are also the worst preserved: it was not possible to identify the raw material for all 82 hard stone beads as the surfaces were too eroded, maybe they are made of feldspar as some beads in this material present similar degradation.

Table 3a-c: From left to right, the distribution of raw material within the site, the colours observed and the distribution of the raw material within the burials in Nyaung'gan. N= 236.

Raw Material	Number of beads	Colours of beads	Number of beads	Burials	Raw Material	Carnelian	Biotite	Non Identified	Chlorite	Quartz	Feldspar	Talc	TT
Carnelian	138	White	5	Burial 2		7							7
Biotite	2	Grey	5	Burial 3		42				1			43
Non identified	72	Orange	103	Burial 3b		41	2		1	2			46
Quartz	16	Pink	11	Burial 6		44		72		12	4	2	134
Feldspar	5	Red	25	Burial 7		3				1			4
Talc	2	Green	4	Outside burials		1					1		2
Chlorite	1	Black	7	TT		138	2	72	1	16	5	2	236
	236	Beige	76										
			236										

Nyaung'gan also has the greatest diversity of stone types with a predominance of hard stones, opaque and homogenous, carnelian in particular with orange shades (Table 3). In order to obtain those colours, the carnelian was heated, as raw carnelian is typically rather pale. Two talc beads from burial 19 also appear to have been heated, either to reduce hardness for carving or by accident, as identified by their whitish appearance and porosity, though the majority of talc beads were not heated. The intrinsic nature of these raw materials led to necessarily different *chaînesopératoires*: the hard stones were knapped following debitage techniques; the soft, less homogeneous rocks are sawn and shaped by abrasion, as detailed further. The Nyaung'gan beads are unevenly distributed, with 70% from two tombs, S3b and S6. S3b, the burial of a disabled youth with a dog, had the particularity of unique raw materials and morphologies (Table 3, Table 4). The same disparities can be observed with the morphologies (Figure 6) as the tomb 3B present the widest scale of morphologies (Table 4).

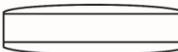
Denomination		Type						Amount
Morphological Code	Name	Elongated $L \geq 5\text{mm} \geq 1,5 \text{ } \emptyset$		Short $L \leq 5\text{mm} \geq 1,5 \text{ } \emptyset$		Extra-short $L \leq 1,5 \text{ } \emptyset$		
		Profile	Cross-section	Profile	Cross-section	Profile	Cross-section	
Rondel	Rondel							162
Cyl	Cylinder							65
Ebci	Truncated Ellipse Circular Section							4
Ebhex	Truncated Ellipse Hexagonal Section							2
Bicone	Bicone							2
Tbicone	Truncated Bicone							1
TOTAL								236

Figure 6: Observed bead typologies from NYG1-3, N=236. After Bellina (2007).

Table 4: Distribution of the different morphologies within the burials. N=236

Burials	Types of beads	Rondel	Extra-Short Tbicone	Cyl	Short Cyl	Extra - Short Cyl	Ebci	Short Ebci	Bicone	Ebhex	TT
Burial 2		7									7
Burial 3		29	1		1	10	1				42
Burial 3b		20		2	4	16	2	1	2		47
Burial 6		101		19		12				2	134
Burial 7		4									4
Outside burials		1				1					2
TT		162	1	21	5	39	3	1	2	2	236

Table 5a: Mean morphometric characteristics of the three main bead families in Nyaung'gan. N=236.

\*The standard deviation is important due to the presence of two sub-families. If we separate the short cylindrical, the standard deviation is similar to the rondel beads.

	Diameter	Standard deviation	Length	Standard deviation	Width	Standard deviation	Perforation hole	Standard deviation
Rondel	4.8	0.53	1.5	0.35	6.2	4.9	0.95	0.1
Cylinder	X	X	4.2	1.21*	3.4	0.84*	1.28	0.2
Ellipse	X	X	27.48	4.77	7.5	1.24	2	1

Table 5b: Table scoring the symmetry of the rondel beads of Nyaung'gan cemetery from 1 (bad symmetry) to 3 (good symmetry). N= 154

$\Delta$  corresponds to the difference between the two measurements of the cross-section (left/ right and up/bottom) observed on each bead to determine the degree of symmetry.

Score Symmetry	1	2	3	Amount
Rondels Nyaung'Gan	$\Delta \geq 0,5\text{mm}$	$\Delta \leq 0,5\text{mm}$	$\Delta \leq 0,2\text{mm}$	
S2	0	0	7	7
S3	1	3	26	30
S3b	0	1	12	13
S6	2	7	92	101
S7	0	1	2	3
TOTAL	3	12	139	154

Rondel beads are in the majority, with an average diameter of 5 mm and a thickness of 1.5 mm (Table 5a). They are very regular in both their dimensions with very small standard deviations (0.53 mm for diameter and 0.35 mm for thickness) and the majority of them highly symmetrical (Table 5b). These morphometric characteristics showknapping allowed a great control of the dimensions of the bead. This is confirmed by the stigma of split fracture (Figure 7a) characterized by a crushed striking platform, presence of hackles and absence of a bulb of percussion (Inizan et al., 1995), which are opposed by a slight 'reversed' characteristic of the counter-shock that stops the fracturing. They thus appear to have been detached by indirect percussion using a hammer against the tip of an anvil, and/or using a pincer (Roux, 2000). The perforation seems also standard with a mean diameter slightly <1mm

diameter and then completed by a percussion initiated by drilling on a previously abraded face (Figure 7b) and then completed by counter-drilling at about two-thirds penetration which ejects a conus flake and create a concavity on the opposite face (Figure 7a; see Figure 19 for the complete explanation). Contrary to Duhard's (2002) explanations, which presents a similar technique, Nyaung'gan beads do not show the detachment of a symmetrical cone during the perforation but rather a very irregularly-shaped cone which is torn off. As a final step, 35% of these beads are retouched by centripetal removal very probably by pressure with an antler tine or a pointed copper-base tool<sup>3</sup>, which can sometimes involve both sides (Figure 7g).

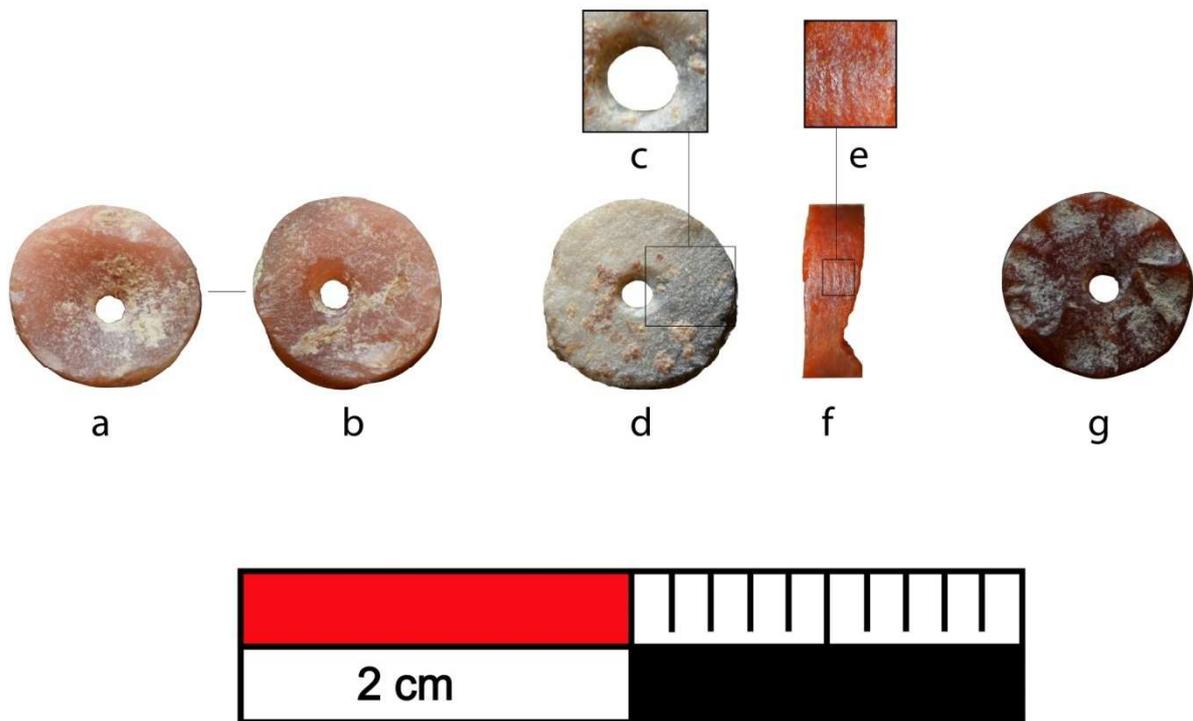


Figure 7: Technical analysis of the **rondel** carnelian or agate beads. All the samples come from the burial 3b in NYG2. From left to right.

**a&b**: Front and back of a bead showing the biconical perforation: the front (b) on the right shows a plane surface with the drilling slightly off-centre when the back (a) is concave (scar of an ejected conus).

**c**: Perforation by abrasive rotation, enhanced in the magnified section (c).

**d**: The split fracturation was optimal; the surface is rough debitage of the washer and has not been retouched. The perforation is made by abrasive rotation.

**f&e**: Front and profile of a bead showing striations transverse to the axis, probably produced at the "bâtonnet" stage.

**g**: Face of a bead with centripetal removals flattening the surface.

Nyaung'gan extra-short truncated bicone bead is characterised by exceptional dimensions, twice as large as the others ( $\text{Ø}6,95\text{mm}/\text{W}3,5\text{mm}$  vs  $\text{Ø}3\text{-}4\text{mm}/\text{W}1\text{-}1,5\text{mm}$  for the rest of the production), and a perforation by opposed pecking (Chevalier et al., 1982; Duhard, 2002; Inizan et al., 1995), where each face is pecked to obtain two opposite cones joined together to create a diabolo-shaped perforation (Figure 8). This method leaves characteristic micro-impacts that should not be confused with usewear. Other small whitish irregularities visible on the beads surface named 'granite surface' (Figure 8, centre) result from the technique of abrasion: the friction employed for the grinding leaves micro-cupula on the surface (Pelegrin, 2012: 93, Figures 5 & 6). The two inclined planes which give the bicone shape of the profile seem to be created thanks to a rotative mechanism, most likely a bow-driven lathe, to

<sup>3</sup> Ongoing zooarchaeological study shows deer were present in the area (Amanda Cook pers. comm.)

perfect the angulation, here slightly blunt. Then, a final step is performed in order to give the lustre to the bead through a polishing in a leather bag: the beads are put in the bag with an abrasive powder, which give them a shiny final appearance and can also leave micro-impacts.

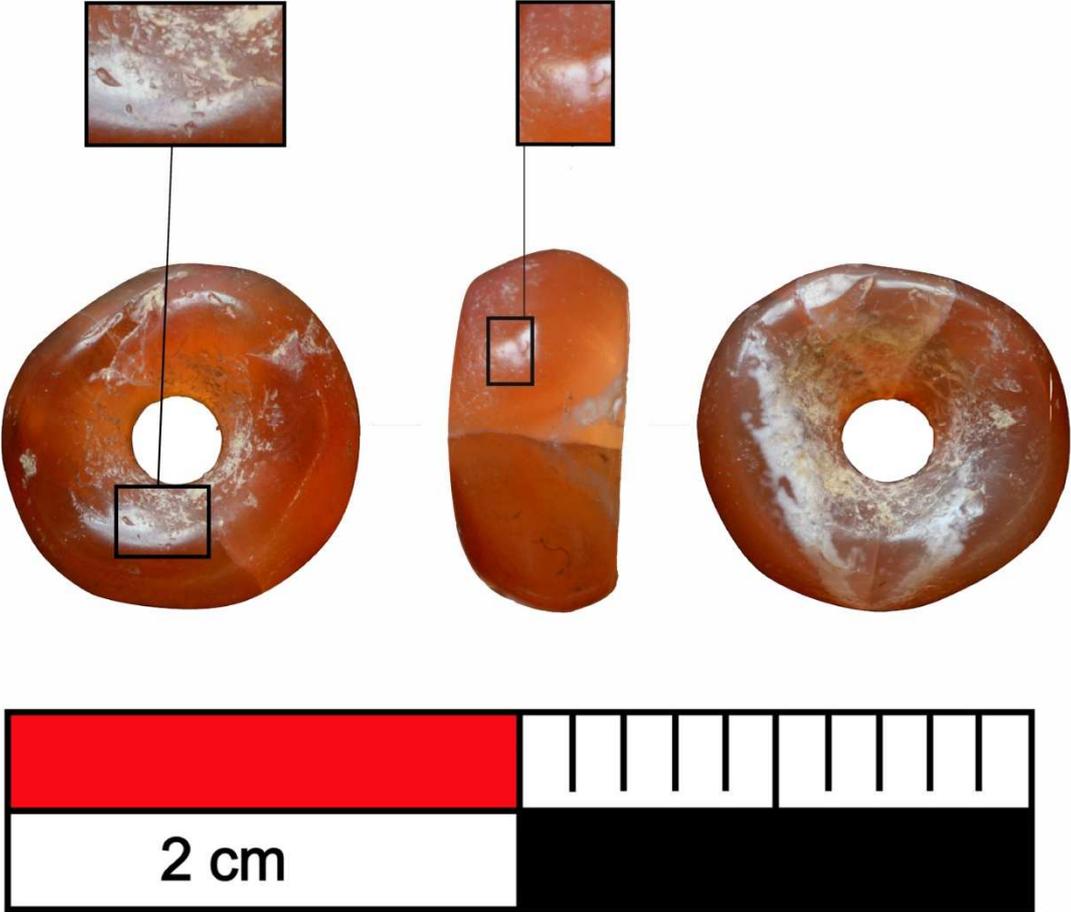


Figure 8: Technical characteristics of the short truncated bicone carnelian bead from Nyaung'Gan (S3b), face and back showing the whitish stigmata of the perforation by alternating pecking (left and right). The slice (centre) with the magnified section highlights a surface granularity, characteristic of a rough abrasion (Pelegrin, 2012: id.) reduced by further softer polishing and

the biconic profile (see figure 14 where it's more characteristic) suggest secondly a rotative mechanism in order to obtain the two inclined planes of that profile. The lustre can finally be obtained possibly by shaking the beads in a leather bag.

The cylindrical beads are less homogenous, their morphometric characteristics distinguish two main groups: elongate ellipse (length < 5 mm) and short ellipse (length < 3 mm) for a mean diameter similar to the **rondel** type (Table 5a). Their perforation however is different: using rotary abrasion technique. The perforation is bilateral, meeting at the two-thirds point of the bead (Figure 9, centre). The polishing is meticulous on all the faces, removing stigmata of shaping and some beads even have a glossy appearance (Figure 9, right) due to a lustre obtained thanks to a gentle polishing, possibly with plants rich in silica - phytoliths (Petrequin and Petrequin, 2011).

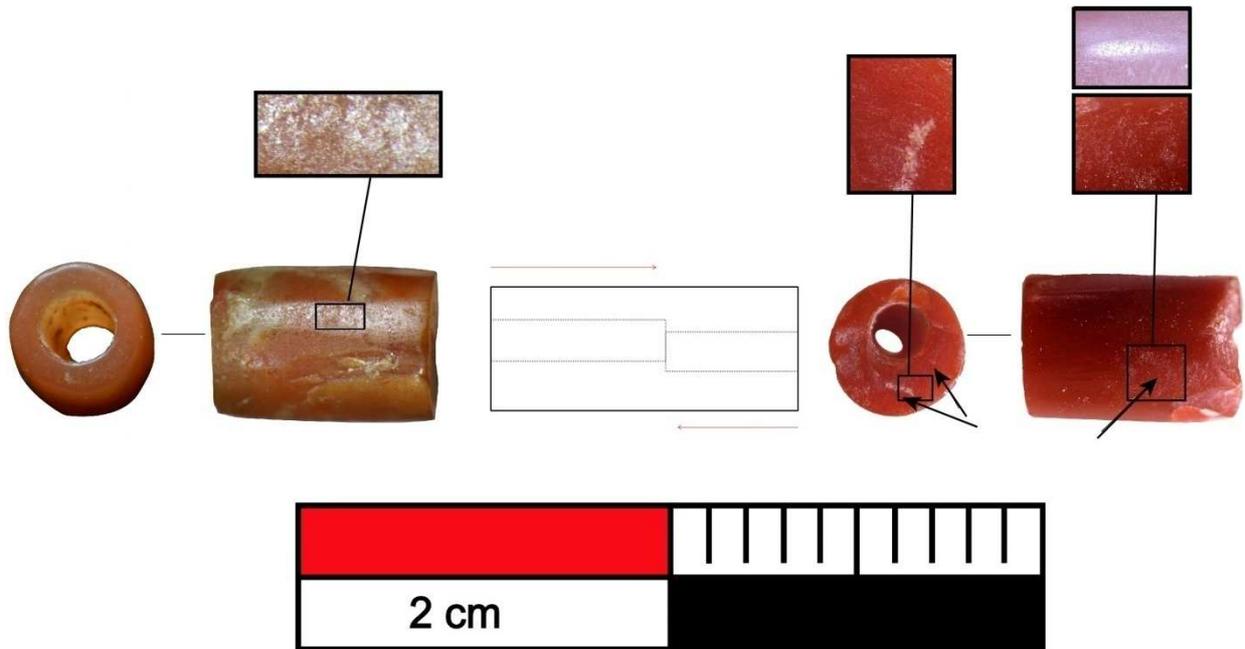


Figure 9: Technical characteristics of the **cylinder** made of carnelian, with examples from NYG3.

Left: profile and front of a bead presenting an uneven axial facet typical of manual polishing (Pelegrin, 2012) showed by the irregular shape of the shiny reflection of the polishing. The magnified section shows a typical "granite surface" from strong grinding.

Right: drilling platform and profile of bead with a bilateral perforation presenting multidirectional abrasive streaks (arrow) due to manual polishing and a glossy surface (magnified section above) obtained by a polishing with plant matter.

Finally, the ellipse beads present heterogeneous raw material and morphometric characteristics that vary, especially with length and according to their cross-section (hexagonal, circular or curved with a circular cross-section) (Table 5a). All of them present the same bilateral perforation, meeting at two-thirds depth. The finishing stages are quite different, with a rough abrasion for the beads with hexagonal section in talc (Figure 10, Up), which seems almost unfinished contrasting with the meticulous polishing of the beads with circular section also in soft and hard stone (Figure 10, Down).



Figure 10: Technical characteristics of the ellipse family made of talc.

Up, Ehex in talc, drilling platform and profile from NYG3/S6. The arrows indicate the white streaks linked to the polishing technique, magnified above.

Down, Ebc in andesite, drilling platform and profile from NYG2/S3a/3b. The magnified section highlights the streaks which can be observed on the surface.

The majority of the morphologies and *chaînes opératoires* are relatively simple and ubiquitous, with the exception of the two bicone translucent carnelian beads with a unilateral perforation; from a Neolithic burial NYG2/S3b (Figure 11).

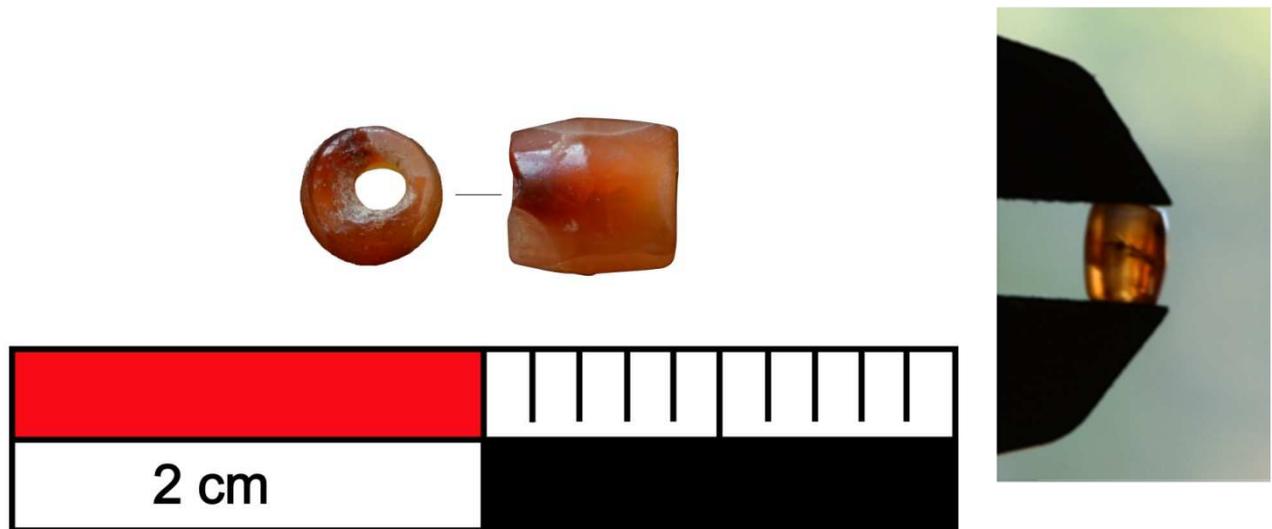


Figure 11: On the left, drilling platform and profile of a bicone carnelian bead with circular cross-section and on the right an example of unilateral perforation found on bicone beads and short cylindrical beads.

### 3.2. Oakaie 1

OAI1 beads were mainly made from homogeneous and translucent hard stone, quartz or carnelian with orange and red shades, and only five beads are from soft materials, talc, serpentinite and chlorite (Table 6). The double burial 19/19A contains the majority of the beads (N=67).

Table 6: From left to right, the distribution of raw material, the colours observed and the distribution of the raw material within the burials at OAI1 N= 129.

Raw Material	Number of beads	Colours of beads	Number of beads	Burials	Raw Material	Chalcedony	Chlorite	Nephrite	Quartz	Serpentinite	Talc	TT
Chalcedony	115	White	5	Burial 3		6						6
Chlorite	1	Grey	1	Burial 4		1	1					2
Nephrite	2	Orange	72	Burial 5		2						2
Quartz	7	Pink	13	Burial 6		11			2			13
Serpentinite	1	Red	27	Burial 7		16		1			1	18
Talc	3	Green	7	Burial 8				1				1
	129	Brown	3	Burial 15							1	1
		Purple	1	Burial 19		44			5	1	1	51
			129	Burial 19A		16						16
				Burial 21b		14						14
				Burial 21a		2						2
				Burial 26		1						1
				Burial 51		2						2
				TT		115	1	2	7	1	3	129

Four morphological families have been determined: **rondel**, which constitutes the majority, **cylinder**, ellipse of circular cross-section and sphere. None of the beads are decorated. The distribution of the morphologies within the burials is more even than at Nyaung'gan (Table 7).

Denomination		Type						Amount
Morphological Code	Name	Elongated L ≤ 5mm ≥ 1,5 Ø		Short L ≤ 5 mm ≥ 1,5 Ø		Extra-short L ≤ Ø		
		Profile	Cross-section	Profile	Cross-section	Profile	Cross-section	
Rondel	Rondel L < 1,5 Ø							114
Cyl	Cylinder							9
Ebei	Truncated Ellipse Circular Section							4
Sphe	Sphere Circular Section							1
Tbicone	Tuncated Bicone Circular Section							1
<b>TOTAL</b>								<b>129</b>

Figure 12: Observed bead morphologies at OAI1. N=236; After Bellina (2007).

Table 7: Distribution of those morphologies within the eleven bead-bearing OAI1 burials. N=129

	Rondel	Short Tbicone	Cyl	Short Cyl	Sphere	Elongated Ebei	Short Ebei	Extra-Short Ebei	TT
Burial 3	5			1					6
Burial 4	1		1						2
Burial 5	2								2
Burial 6	12			1					13
Burial 7	16				1			1	18
Burial 8						1			1
Burial 15			1						1
Burial 19	43	1		5		1	1		51
Burial 19A	16								16
Burial 21b	2								14
Burial 21a	14								2
Burial 26	1								1
Burial 51	2								2
<b>TT</b>	<b>114</b>	<b>1</b>	<b>2</b>	<b>7</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>129</b>

Table 8a: Morphometric characteristics of the three main bead families at OAI 1. N=129.

Morphometric characteristics	Diameter	standard deviation	Length	standard deviation	Width	standard deviation	Perforation hole	standard deviation
Rondel beads	4.9	0.75	1.7	0.29	4.9	0.95	0.7	0.1
Cylindrical beads	X	X	3.4	0.19	3	0.23	1.5	0.3
Ellipse beads	X	X	33.45	18	7.7	2	3.5	0.4

Table 8b. Table scoring the symmetry of the rondel beads from 1 (bad symmetry) to 3 (good symmetry).

$\Delta$  corresponds to the difference between the two measurements of the cross-section (left/ right and up/bottom) observed on each bead to determine the degree of symmetry. N= 112.

For example in the score 3 the difference between the two measures of the cross-section (left/ right and up/bottom) is inferior to 0,2m

Score Symmetry OAI1	1 $\Delta \geq 0,5\text{mm}$	2 $\Delta \leq 0,5\text{mm}$	3 $\Delta \leq 0,2\text{mm}$	Amount
S3	0	0	5	5
S5	0	0	2	2
S6	0	3	9	12
S7	2	0	14	16
S19	0	3	39	42
S19A	0	0	16	16
S21A	0	0	2	2
S21B	1	1	12	14
S26	0	0	1	1
S51	1	1	0	2
<b>Total</b>	<b>4</b>	<b>8</b>	<b>101</b>	<b>112</b>

Rondel beads are almost systematically present in the burials, only bead-poor S8 and S15 (the only definitively Bronze Age burial), do not have any. Using this point of comparison, we saw that S6, S7, S19A and S21B show almost identical rondel production, while the rondel beads in S3, S4, S26 and S51 tend to be thicker. The rondel beads have the same *chaîne opératoire* as at Nyaung'gan, presenting the same stigmata of: indirect percussion, counter-strike using split fracture, biconical perforation with pecking, drilling and counter-strike (Figure 13). Once again, the production is homogeneous (Table 8a) with a great symmetry for the majority of the production (Table 8b).

The only difference is the presence of one oversized thick rondel bead identified as chlorite by Y. Iizuka, an exceptional green colour for the morphology (Figure 13 right), which presents a different shaping as compared to others of the same typological family. That is why we classified it as a subcategory of the rondel morphology and call it "thick rondel". The perfection of its outline and regularity of the volume around the perforation does not seem feasible by holding it with the fingers to regularize the whole surface. We propose that, after its drilling perforation, the bead is first fixed by its hole at the end of a rotation drill acted with a bow, and gently rotated in a concavity of a polisher with cupula form, which will ensure the regularity of the end-faces of the bead. Then, the body could be regularized and perfectly centered around the perforation using a small turning device: the bead is fixed (glued with resin, stuck, by its perforation on a rod, and turned with a bow against the slightly concave surface of a fine sandstone. This mechanism makes it possible to abrade the bumps on the periphery of the bead (thanks to the modulation of the friction with the sandstone) while at the same time perfecting the centering of its volume around the perforation.

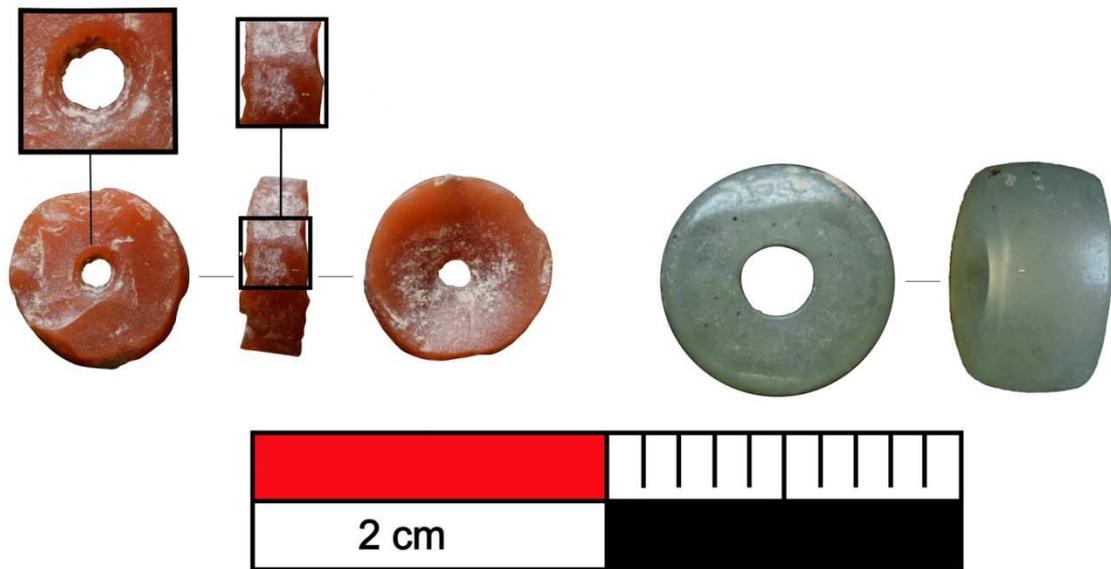


Figure 13: Technical analysis of **rondel** beads (reddish = carnelian, greenish = chlorite). From left to right.

**Left:** Front, profile and back of a **rondel** carnelian bead (S21/21a) with biconical perforation: the front on the right was slightly retouched at the circumference when the back on the left one shows the drilling process when the right face is concave as the conical ejection was as large as the surface. The stigmata on the profile enhanced in the magnified section are typical of a rough abrasion realised during the "bâtonnet" stage and are, in fact, small thermal cupula (Pelegrin 2012 p. 93).

**Right:** Front and profile of the chlorite bead. The perfectly circular profile and the perfectly centred hole evoke a rotating polishing mechanism (the bead, after perforation, would be set on a drill fixed at both ends in some device (like for wood turning) and acted by a bow against an abrasive material like sand-stone).

The extra-short truncated bicone bead, similar to the one in Nyaung'gan, presents the same characteristics as before with perforation by opposed pecking, rough shaping leaving micro thermal cupula (Pelegrin, 2012) and a finishing initiated by rotative polishing with a bow to create the two inclined plans of the biconical profile followed by a precise polishing for the lustre possibly with a leather bag similarly to the bead of the same typology in Nyaung'gan (Figure 14).

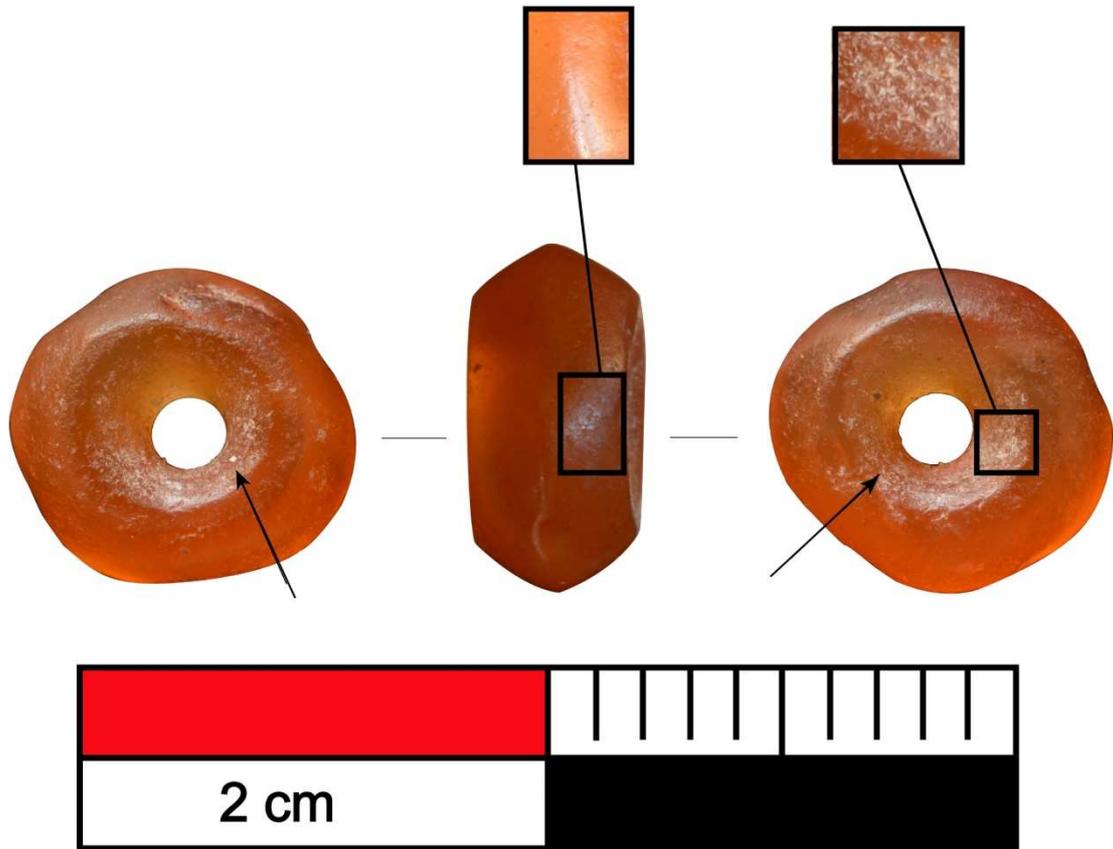


Figure 14: Face, profile and back illustrating the technical characteristics of the extra-short truncated bicone bead in carnelian, the whitish stigmata of the perforation by alternating pecking (arrows and magnified section on the right) and the slice (centre) with the magnified section highlights a “granite surface”, characteristic of a rough abrasion (Pelegrin, 2012) and the biconic profile (see figure 14 where it’s more characteristic) suggests secondly a rotative mechanism in order to obtain the two inclined planes of that profile, that intersect very well. However, compared to the chlorite bead from fig. 13, this rotation was not prolonged -as carnelian is much harder than chlorite- enough so as to regularize the volume and outline of the bead. Polishing with the leather bag leaves the glossy appearance visible in the magnified section (centre).

The spherical bead has a *chaîne opératoire* similar to cylindrical beads, with a unilateral perforation and lustre. The cylindrical beads are less numerous than at Nyaung’gan and the short type is overrepresented (Table 6). The characteristics are similar, with bilateral perforation for the elongated type and unilateral perforation for the short type and stigmata of manual polishing on all surfaces (Figure 15 Left). All are made of carnelian, except one in talc from the sole definitively Bronze Age burial, S15(Figure 15 right).

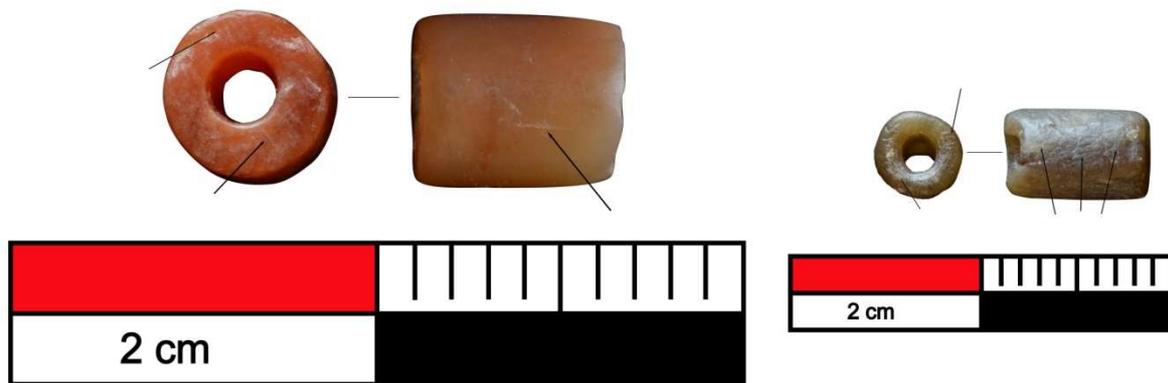


Figure 15: Technical characteristics of the cylindrical bead, from left to right.  
 Left: Drilling platform and profile of a cylindrical carnelian bead (S4) with arrows indicating oblique whitish streaks, stigmata of hand grinding, followed by softer polishing.  
 Right: Cylindrical bead in talc (S15) with deep parallel streaks from shaping and white streaks in multiple directions from manual polishing (arrows).

The ellipses remain the same as at Nyaung'gan, with heterogeneous morphometric characteristics (Table 7) and bilateral perforations. However, only the *ebci* type is present here made of hard stone with the exception of the unique short example in talc (Figure 16).

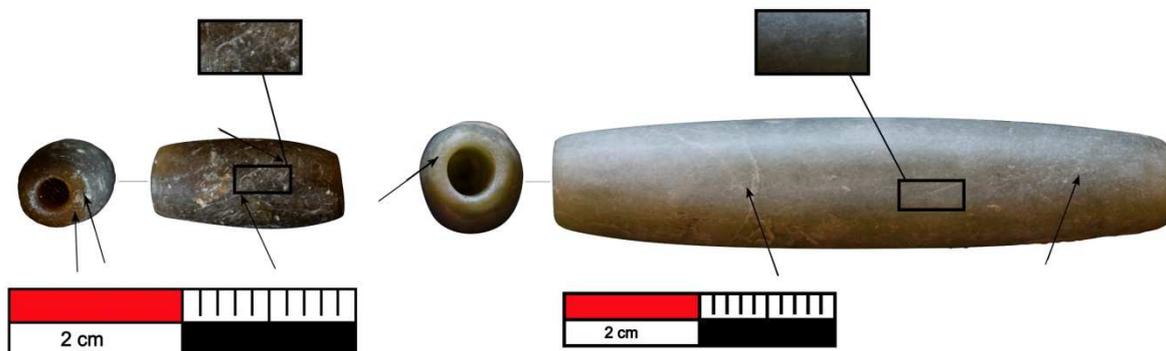


Figure 16: Technical characteristics of the ellipse beads. All present white streaks from manual polishing pointed by the arrows and presented in magnified section above.  
 Left: drilling platform and profile of the short ellipse type in talc (S7).  
 Right: drilling platform and profile of the elongated type in hard stone (S8).

Overall, the OAI1 assemblage is more carefully finished for the ellipse beads but also for the **rondel**, where 50% of the beads have centripetal retouching on one face at least and the beads are even more regular than those from NYG1-3.

### 3.3. Oakaie3 and 4

We will only mention here the three *chaînesopératoires* that have enough representative elements to be reconstructed totally or partially: the **rondel** and **cylinder** beads in hard stone and the ellipse beads with a hexagonal section in talc. However, we suspect that there are two other *chaînesopératoires* for beads with biconical profiles, especially the sphere and the truncated ellipse beads of circular section in hard stone; and at least two other main *chaînesopératoires* on the site for bangles and adze/axes

(under study). The bead types exhibit identical morphometry and technical stigmata to those discussed above, so we will not detail them again. Our analysis here is technical and qualitative but not quantitative, except for the finished beads, as only the latter represent a complete corpus.

**Cylinder** and **rondel** beads seem to have in common the early stages of their *chaînes opératoires*, based on crest-shaping and split fracturing (Figure 17a). After possible heat treatment in the case of carnelian, the block of raw material is shaped with the creation of 3 or 4 crests by series of transverse alternate removals (Inizan et al., 1995, Pelegrin in Roux, 2000: fig. 7 & 8). The edges are then minutely regularized by pressure to create a triangular or quadrangular (Figure 17b, 17c) and then quasi-cylindrical section (Figure 17d, 17e). Finally, a rough abrasion transforms the matrix into a **cylinder** (Figure 17f). This method of shaping a square-sectioned rod-like form (*bâtonnet*) volume by several (3 or 4) crests has been described in Cambay but the technique is different (there is, at present, no evidence of Cambay technique here, at the time). It also exists in different contexts (4<sup>th</sup> mill. BC southern Spain, Bronze Age Greece, and seemingly in India on late Mesolithic chalcedony pebbles (Inizan et al., 1995).

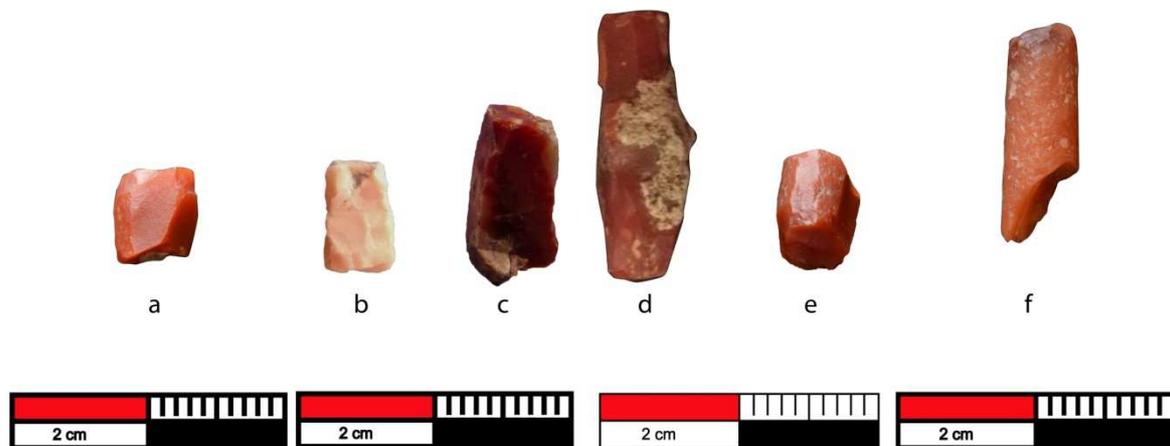


Figure 17 : **Rondel** carnelian bead chaîneopératoire: shaping the matrix. All elements are from OAI 3 TP1. From left to right: **a-b-c**: Matrix shaped with quadrangular section. **d-e**: Matrix almost cylindrical: the edges of the matrix are then extended and reshaped to create a quasi cylindrical section. **f**: Cylindrical matrix after a first rough abrasion.

At this stage, the two *chaînesopératoires* diverge. For **rondel** beads, the distal end of the matrix is arranged in a convex shape by small abrupt removals by pressure retouch, using a pointed tool, in order to facilitate the cutting in series, on parallel planes, of **rondel** 'slices', also called washers. This cutting can be carried out by squeezing the matrix placed between the obtuse wedge of an anvil opposite to the obtuse wedge of an intermediary piece that is gently stroked with a small mallet. It is probable that, at each foreseen contact of the matrix with the two wedges (the one of the anvil, and the other one of the intermediary tool), a preliminary striation was obtained by sawing with a fresh flint or agate cutting edge, so as to avoid the slipping of the matrix during percussion, which should determine a rather clean split fracture running between the two contact points (in fact striation lines), and thus detach a regular slice with the predetermined thickness (Figure 18). The washers created this way have a slightly convex profile, a mark of the removal positive. A few preforms of unequal thickness show the possible reworking of the fracture plane(s) by a tiny centripetal pressure retouch. The two main faces of the beads are then roughly abraded on a flat stone by manual action. This type of abrasion is characterized by multidirectional white streaks visible on the surface of the bead.

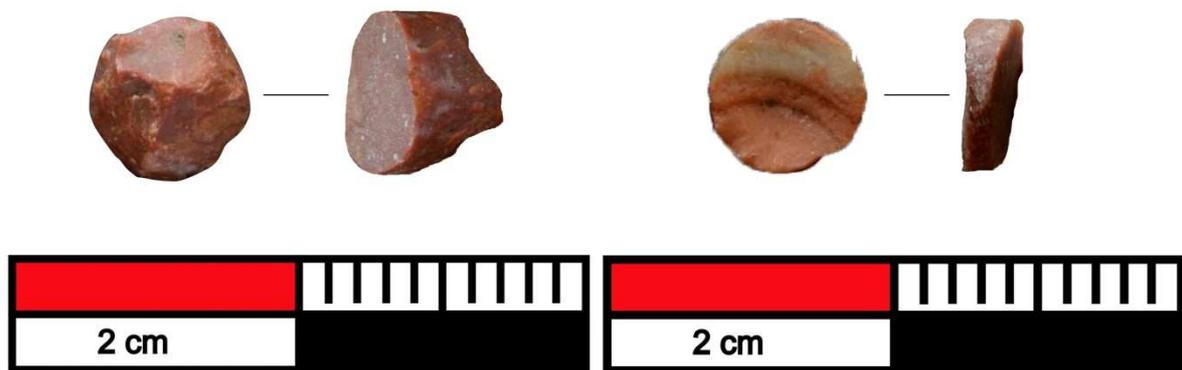


Figure 18: **Ronde** carnelian bead chaîne opératoire:  
 Left: Front and profile of a cutting starter disc characterised by a conical shape (OAI 3, L2).  
 Right: Standard preform disc slightly uneven in width (OAI3, L2).

Initially, the hole is made by pecking the area to be perforated (Figure 19d) and then a first part of the perforation is made by a drill (see Discussion) as in Figures 19e. At about two-thirds penetration, the preform is struck, which ejects the cone (Figure 19a, 19b, 19c). This is probably an indirect percussion: a mallet is used on a finely pointed punch, which ejects the Hertz cone (Figure 19f) and completes the perforation (Figure 19g, 19h, 19i). This particular technique, at least the punching of the conus, was originally described in Larsa, Iraq, and other Mesopotamian sites from the mid-3<sup>rd</sup> to mid-2<sup>nd</sup> millennia BC (Chevalier et al., 1982). The whole of this action (percussion and fracture) is demonstrated by the discovery of several conical-shaped splinters on the site with thicknesses of 0.3 to 0.5 mm, which corresponds to a third or even a half of the thickness of the beads (Figure 19f). They are characterized by the systematic presence, at the top of the cone, of a circular overcut mark with a convex hemisphere in its centre, which marks the point of impact. Because of its circular morphology and the preservation of a hemispherical raised centre, we can state that the drill bit used for the perforation was tubular (see Discussion). Finally, the beads were polished again, probably with the *entraîn* technique, whereby a series of beads are threaded on a string or wire and then displaced longitudinally within a water-lubricated grooved abrasive stone. Centripetal removals are attested on some examples as showed before.

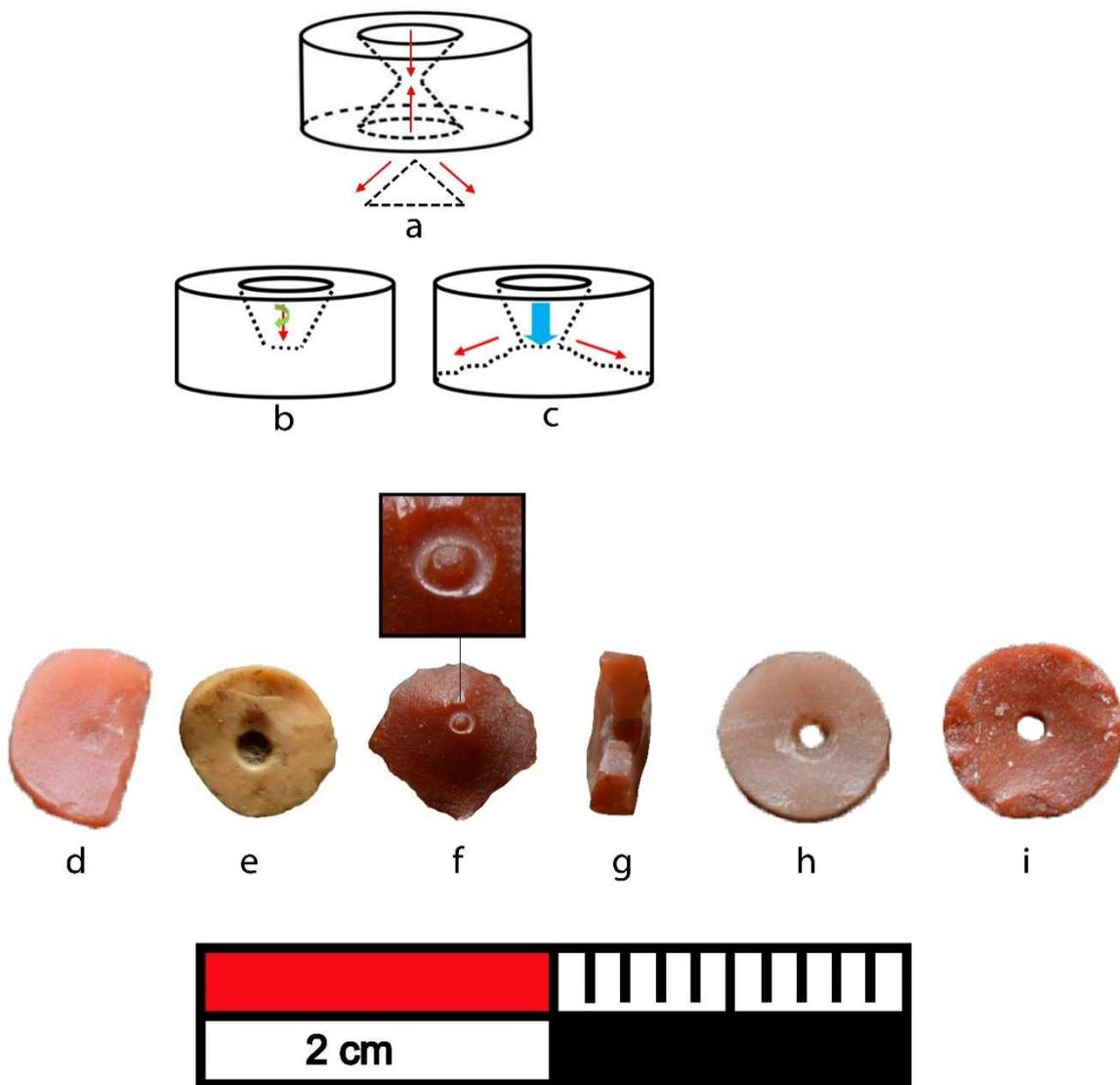


Figure 19 : Rondel carnelian bead perforation model.

Top row a-c: Schema of the perforation process: a is the theoretical demonstration when b and c are the two steps observed on the beads of our corpus.

Bottom row d-i: Examples of beads from OAI illustrating the chaîne opératoire

d: Preform staked in the centre to prepare the perforation.

e: The first step of the perforation is made by drilling the bead through half of the width.

f: Conical fragment ejected during the second step of the perforation when the preform is struck by indirect percussion. In the centre of the fragment the particular shape of the circular stigmata, rounded in the middle, proves that a tubular drill was used for the perforation.

g: Section of the perforation.

h: Front of a bead showing the corkscrew stigmata from the drilling in the first step of the perforation.

i: Back of a bead with conical depression in the centre where the conical fragment was ejected.

The shaping of the short cylindrical beads is similar, with a fragmentation technique using split fracture but here the fragments detached are small cylinders and not washer slices. Then the perforation is carried out by unilateral abrasive rotation, also prepared by pecking but completed by a drill that leaves corkscrew shaped streaks (Figure 20, centre). The perforation hole is cylindrical, sometimes tapered

due to the drill wearing out, which may also have a concave area due to a ‘bursting’ at the end of the perforation. The beads’ polishing, characterized by fine longitudinal and multidirectional striations (Figure 20, left), is also more careful and their shiny appearance is evidence of a lustre, possibly achieved with plant matter (Figure 20, right). The uneven direction of the striations associated with very fine polishing has been observed on beads polished with fine plants remains, where the naturally-present silica is the abrasive.



Figure 20: The end of the cylindrical carnelian bead chaîneopératoire. From left to right :  
 Left: Front and profile of a **cylinder** bead preform: the shaping is done, the form is abraded (magnified section) but the perforation is not achieved.  
 Centre: Profile of a cylindrical bead showing by transparency the perforation.  
 Right: Drilling platform and section of a bead illustrating the final polishing by hand with multidirectional streaks, possibly combined with plant polishing, leaving a glossy effect.

Talc beads are shaped by sawing and abrasion because the stone does not exhibit conchoidal fracture. Contrary to Nyaung'gan, the OAI3 talc has not been heated. The blocks of talc sheets are first abraded, following the structure (superposition of sheets) of the material and to achieve an approximate parallelepipedal roughout with plane and smooth surfaces (Figure 21a). These are sawn in order to obtain a rectangular preform close to the final size of the bead (Figure 21b). Four samples show sawing marks characterized by "U" shaped grooves, more regular than those of the sizing cut (Figure 21c, 21d, 21e). The verticality of the walls and the presence of longitudinal traces suggest the use of a knife (bamboo, lithic or metal) as wire cutting leaves more irregular marks (Gonthier, 2015). This putative knife, which will most often be made of hard rock, is used with water and an abrasive in a longitudinal gesture.

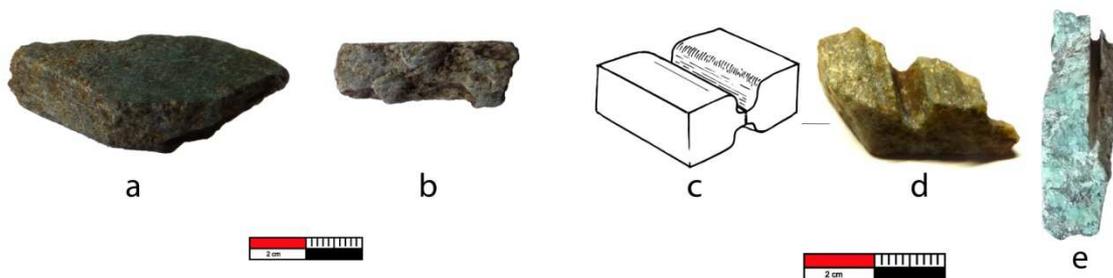


Figure 21: Chaîneopératoire of talc truncated ellipse beads of hexagonal section (OAI3, L1). From left to right:  
**a:** Sheet of talc swan in rough paralepipedal shape, polished to obtain flat and parallel surfaces.  
**b:** Achieving the rectangular preform.  
**c:** schema of the U shaped sawing marks  
**d/e:** fragment of talc presenting U shaped sawing marks.

The rectangular preforms obtained are then abraded to obtain the desired shape with six main facets and sometimes two secondary facets by grinding on a flat stone (Figure 22b). A second, finer, polishing phase, was carried out in a diagonal axis in relation to the previous stage, characterized by finer longitudinal and multidirectional striations (Figure 22a). The beads are perforated bilaterally, probably using a drill since annular stigmas are visible inside the perforation. The two perforation holes meet in the centre of the workpiece with a slight offset.



Figure 22: Chaîneopératoire of talc truncated ellipse beads of hexagonal section. From left to right:  
**b:** shaping by abrasion (OAI3, L1, U9),  
**a:** fragment of truncated ellipse bead of hexagonal section bead with polishing multidirectional streaks (OAI3L158),  
**c:** unicum **minor type with only one example in the study** unfinished bead in soft stone using sawing for shaping (arrow on the right) presenting stigmata linked to the polishing of the surface (arrow on the left) (OAI3, L1, U59).

#### 4.0 Discussion

Once the production technique is properly understood, the lack of any excessive wear, as might be expected around the perforation holes due to friction from a cord, on the Oakaie and Nyaung'gan funerary beads, suggests that they had seen little or no use prior to internment. Their location in the burials does not allow us to reconstruct their original arrangement, whether worn as bracelets, anklets or pendants, or sewn onto a garment. Nevertheless, Pradier et al.'s (2019) OAI1 funerary analyses highlight an association of beads with other grave goods, particularly bracelets (made of hard animal material [probably ivory], shell or hard stone – all under analysis), as well as bivalve shells. The presence of beads also seems to be favoured for certain forms of double burials and young individuals: NGY2/S3a&b and NYG3/S6 at Nyaung'gan, and S19/19a and S21/21b at OAI1.

Table 9: The distribution of ornaments within burials at Nyaung'gan and OAI1. After Pradier et al. (2019).

Type of Ornaments		Stone beads	Shell beads	Stone bangles	Animal Bone bangles	Bivalve Shell
Sites /Burials						
Nyaung'gan 1, 2, 3	S2	X				
	S3/3b	X	X		X	
	S6	X	X			
	S7	X				
Oakaie 1	S3	X				
	S4	X				
	S5	X			X	
	S6	X		X		
	S7	X				
	S8	X				
	S15	X				
	S19/19a	X			X	X
	S21/21b	X		X		
	S26	X				X
S51	X					

Particular care seems to have been taken with some beads, especially those made of green stone, which were rarely abandoned at the OAI3 & 4 production loci (only three fragments were found), and several specimens exhibit double perforations linked to the failure of a first attempt, and yet the bead was preserved when its integrity permitted (Figure 23). This perhaps demonstrates the effort involved in getting a bead to final form.



Figure 23: Front, profile and back of the sphere bead in nephrite found in OAI1, Late Neolithic grave S7. The front presents a double perforation from failed first attempt. This perforation is unilateral.

Denomination		Type						Sites
Morphological Code	Name	Elongated L ≥ 5mm ≥ 1,5 Ø		Short L ≤ 5mm ≥ 1,5 Ø		Extra-short L ≤ 1,5 Ø		
		Profile	Cross-section	Profile	Cross-section	Profile	Cross-section	
Rondel	Rondel							NYG OAI 1 OAI 3&4
Cyl	Cylinder							NYG OAI 1 OAI 3&4
Ebci	Truncated Ellipse Circular Section							NYG OAI 1
Ebhex	Truncated Ellipse Hexagonal Section							NYG OAI 3&
Bicone	Bicone							NYG
Tbicone	Truncated Bicone							NYG OAI 1
Sphe	Sphere							OAI 1
TOTAL								489

Figure 24: Comparison table of bead morphologies observed on all sites N =489 After Bellina (2007).

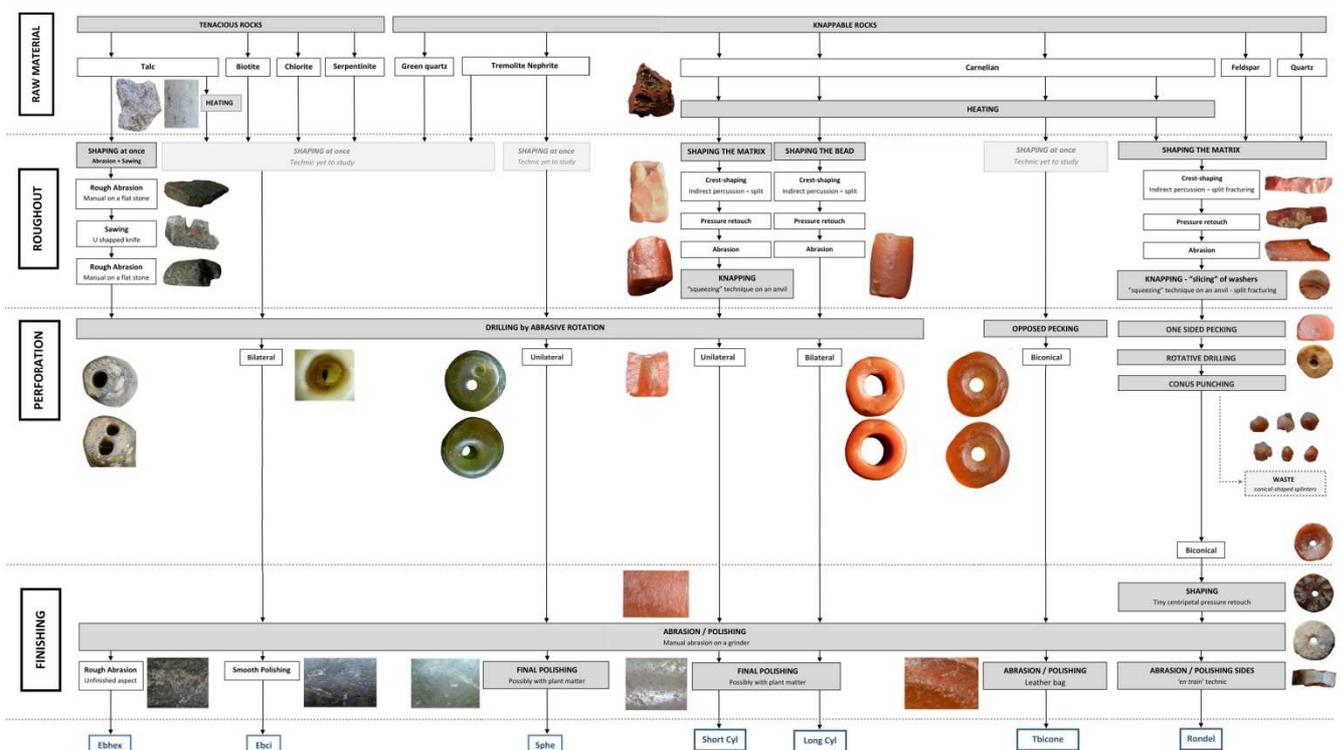


Figure 25: Graphical comparison table of chaînes opératoires between the sites.

The morphological and technical similarities thus observed on the beads make it possible to connect the chaînes opératoires evidenced in production and funerary contexts (Figures 24 and 25.). Therefore,

we can better understand technical steps that are sometimes no longer visible on the finished product. All the beads belong to the same technical tradition, which is consistent with the results of the analyses of ceramics suggesting similar *chaînes opératoires* between the sites is linked to their being populated by the same social group (Favereau et al., 2018). These material culture data maybe contrasted, however, with dental strontium isotope evidence that the OAI1 and NYG1-3 individuals did not grow up in the same area (Bentley et al., 2018), which may explain the presence of some unique (for our corpus) ornamental stones and morphologies at Nyaung'gan (Figure 28). The available aDNA data do not help here as, despite comprehensive sampling, only two OAI1 elderly ladies produced results (Lipson et al., 2018).

The **rondel** beads representing more than 80% of the corpus are, in this respect, particularly indicative as the waste sizes found on the production site helped us to partially reconstruct a *chaîneopératoire* based upon the shaping of a square section matrix by indirect percussion and pressure, the 'slicing' of washers with a particular 'squeezing' technique on an anvil and to a perforation in 3 steps: pecking, rotative drilling, and conus punching.

As far as perforation is concerned, drills have been known since the beginning of the Harappan period (e.g. Kenoyer, 2005). The technique used is that of the bow drill (Beck, 1940; Jarrige and Meadow, 1980; Rao, 1973). These drill bits (always at the same angle, 90° to 120°) are made of very hard rock in order to penetrate quartz or carnelian. These materials include flint, nephrite-jade, jadeite-jade and corundum, ernestite and copper-base drills are attested from around the 3<sup>rd</sup> millennium BC in the Middle East and elsewhere (Barthelemy de Saizieu and Casanova, 1993; Gwinnet and Gorelick, 1988, 1986; Kenoyer, 2017; Prabhakar, 2016). In spite of a lack of reference on the perforations and their diameters, **Tosi and Piperno's** (1973) study shows perforations close to one millimetre are due to these metallic tips. It is difficult to know which of these drills were used to make the perforations of the OAI3 beads, though we know secondary copper production was practiced at this locale in its final phase, and metal exchange networks extended as far as central Thailand and central Laos (Pryce et al., 2018a). However, the perforation debris of the conical **rondel** beads clearly shows evidence of the use of a tubular drill, which had previously only been shown to have been used for much larger bracelets. This technological choice is consistent with OAI3, which has also produced substantial evidence related to the manufacture of bracelets, particularly in andesite (probably local) and nephrite-jade (imported, possibly from known sources to the north in Myanmar). Bracelet production evidence was mainly found in the form of large discs, which are probably the remains of tubular perforating cuts made on bracelet blanks. The use of bamboo was likely for the much larger bracelet perforations but for the beads the drill bit could have been made of metal, or potentially very fine bones (bird) or feather shafts (calamus) (Casanova, 2013). The residual powders resulting from the perforation by abrasion would be very fine and irrecoverable without mineralogical study of soil sediments.

## 5.0 Conclusion

The technological analysis and comparison of the *chaîne opératoire* techniques used to make beads at the local production workshop of Oakaie with the beads excavated from the neighbouring cemeteries of OAI1 and Nyaung'gan demonstrated that the latter came from the production workshops of OA2-4.

In addition, Oakaie represents MSEA's first evidence for MSEA semi-precious stone ornament production. Both the techniques and the carnelian appear to be local. This study also allows us to solidly characterise a local production centre and its distribution network; a network that is securely dated from the end of the 2<sup>nd</sup> millennium BC. The techno-morphological framework now in place

constitutes a strong base for a broader study that should be extended to other sites in Myanmar and maybe further afield in Southeast Asia. This will contribute to better define Neolithic and Bronze Age material exchange and social interaction networks on a robust basis. The Halin burial sites, 80 km distant and dated to the Neolithic (HL30) and Bronze Age (HL29), are the next on our list (Pryce et al., in preparation). However, the Nyaung'gan and Oakaie sites make it possible to confirm the presence in Neolithic MSEA of semi-precious hard stone bead production, notably carnelian, with simple morphologies. In all likelihood, and as evidenced so far in metal and stone, the Late Neolithic-Early Bronze Age period in central-northern Myanmar occupied a pivotal zone, at the core of various external influences that prefigure the flourishing exchange networks of the mid-late 1<sup>st</sup> millennium BC. The question of whether this Myanmar tradition continued until the arrival of highly-skilled South Asian techniques, and potentially co-existed with them, is also an interesting avenue to pursue.

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