The Chaîne Opératoire as a Cognitive Framework for Investigating Prehistoric Textile Production: Production of Clay Textile Tools in Middle Bronze Age Crete as a ‘Troublesome’ Case Study

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ABSTRACT: In textile archaeology, the concept of the chaîne opératoire has already been widely accepted as a fundamental framework for investigating textile production within past societies. It is used to explain and illustrate the general logic of production, economic importance of textiles and the significant socio-economic involvement required for their manufacture. It facilitates recognition of potential gaps in specific archaeological evidence, as well as iconographic references to textile production in various arts. Additionally, the chaîne opératoire provides a conceptual basis for experimental textile archaeology and hands-on learning of textile technology. However, the usefulness of the chaîne opératoire concept seems to be more limited when the evidence implies a significant complexity in administrative practices, specialisation and social relations of production. Production of textile tools, specifically loom weights in Middle Bronze Age Crete, and the questions concerning by whom, how and where they were produced, are discussed as a case study illustrating this problem.

THE CHAÎNE OPÉRATOIRE APPROACH IN TEXTILE ARCHAEOLOGY

In textile archaeology, the chaîne opératoire approach has been widely accepted as a useful, if not an essential and fundamental, framework for investigating textile production in any past society (e.g. Andersson Strand 2012; Bender Jørgensen et al. 2018; Harlow and Nosch 2014: 20-22, fig. 1.2) (fig. 1). Reconstructing operational sequences in textile making—from fibre procurement, dyeing, formation of yarns, weaving and finishing, to primary and secondary use of textiles and their final discarding (fig. 2)—is helpful for understanding the general logic of production and its operational syntax, as well as the scale of textile consumption. Due to the complexity of textile technology, and the diversity of skills and knowledge required for each operational step, the analytical grid of the chaîne opératoire also illustrates the significant socio-economic involvement and investment required for textile manufacturing (fig. 2; cf. Bender Jørgensen 2018: fig. 2.1; Grömer 2016: fig. 15).

Thus, the chaîne opératoire approach demonstrates the key socio-economic importance of textile making in prehistory. However, in this general approach, the very term ‘chaîne opératoire’ does not always have to be addressed explicitly (e.g. Andresson Strand 2010, 2015; Gleba and Manning 2012; Grömer 2016). Regarding the specific archaeological evidence, using the chaîne opératoire approach, together with information from ethnographic and historical sources and experimental archaeology, is helpful for identifying gaps in the evidence.

Subsequently, we can start to fill gaps in our current understanding by reconstructing what production places, actions and tools were prerequisites for textile making, even if no tangible traces of them have been left (e.g. Andersson Strand 2012, 2015; Ulanowska 2018a, 2018b). In iconographic studies, the chaîne opératoire creates the semantic framework within which potential visual references to textile pro-
duction, such as depictions of raw materials, textile tools, tasks and specific technical gestures, may be investigated (e.g. Breniquet 2008; Gleba 2008; Nosch and Ulanowska forthcoming).

Finally, the chaîne opératoire provides the conceptual basis for experimental textile archaeology and the hands-on learning of textile technology. It facilitates understanding the rigorous interrelation of choices made at each step of production, e.g. a relationship between the choice of fibre, spindle whorl, skill-level, technique of spinning, parameters of a spun yarn and, consequently, practical and visual properties of a woven fabric (e.g. Andersson Strand and Nosch 2015a; Olofsson et al. 2015). It helps to gain further insights into the time-consumption and time-scheduling of specific actions (Andersson Strand 2012; Andersson Strand and Nosch 2015b: 377-378; Ulanowska 2016a), for example by experiencing the necessary technical breaks (such as the one separating modelling loom weights of clay from their use on the loom).

However, despite this apparent usefulness, the chaîne opératoire approach seems to be more limited when the evidence implies a significant complexity in administrative practices, specialisation and social relations of production and the culture-specific range of choices available at each step of production. Production of textile tools, specifically loom weights in Middle Bronze Age (henceforth MBA, c.2100/2050-1700/1675 BC, after Manning 2010: tab. 2.2) Crete, is discussed here as a case study illustrating this issue.

WHY DO STUDIES OF TEXTILE TOOLS MATTER?

Since textile technology is based on organic fibres and many textile tools were made of wood and bone, a significant part of the evidence is usually missing from archaeological contexts (cf. Andersson Strand 2012: tab. 4; Gleba 2008: tab. 8). In Bronze Age Greece, including Crete, the remains of excavated textiles and tools made of organic materials are rare (Andersson Strand and Nosch 2015a: Appendix B; Skals et al. 2015; Spantidaki and Moutherat 2012). The main body of evidence consists of clay textile tools: spindle whorls, loom weights and spools (e.g. Andersson Strand and Nosch 2015a). This is complemented by occasional remains of various types of textile production workplaces (e.g. Andersson Strand and Nosch 2015a; Burke 2010; Nosch and Laffineur 2012; Tzachili 1997), iconography of
textiles and textile production (e.g. Jones 2015; Nosch and Laffineur 2012; Shaw and Chapin 2016) and Linear B tablets documenting textile production controlled by the Mycenaean palaces (e.g. Burke 2010; Killen 2007).

Figure 2: Chaîne opératoire sequences in textile production (graph by M. Harlow and M-L. Nosch©; Harlow and Nosch 2014: fig. 1.2. Reproduced with permission of M. Harlow and M-L. Nosch).
Spindle whorls and loom weights attest the presence of two major operational steps in textile making: yarn production and weaving. They also imply the use of specific production techniques (for example, spinning with high, middle and low spindle whorl, drop-spindle spinning, supported spinning and weaving on a warp-weighted loom). As a result of recent experimental studies, the geometric form of spindle whorls and loom weights, as well as related properties of weight, height, diameter or thickness, have been shown to constitute functional parameters that influence the properties of yarns and fabrics made using them (Andersson Strand and Nosch 2015a; Grömer 2016; Mårtensson et al. 2009). The number of tools, their distribution and variety or homogeneity of forms, can inform us about the scale and diversification of production at a specific location.

PRODUCTION OF TEXTILE TOOLS AS AN OPERATIONAL SEQUENCE

Since the majority of spindle whorls and loom weights in Bronze Age Crete were made of clay, their manufacturing partly follows the steps of the chaîne opératoire for clay processing and firing. Similar procedural steps would have especially applied to the production of textile tools made of medium- to fine-quality processed clays that were fired. However, there were also tools (although fewer in MBA Crete) made of coarse, roughly procured clays that were air-dried or fired very poorly.1

Regarding the skills required for tool making, spindle whorls and loom weights could have been modelled by people inexperienced in clay processing, since the forms of these implements are simple (figs 3-4, see below; cf. Boertien 2009; Cheval 2008; Ulanowska 2016a, Ulanowska 2019). Therefore, production of textile tools may have been performed by potters, spinners and weavers themselves, or perhaps by craft-people’s helpers such as apprentices or children. In the first case, some practical knowledge of the functional parameters of textile tools or tool templates might have been required to ensure that the forms and weight clusters fitted the expected functionality of the implements. In the latter case, the production of tools could have been entirely maintained within a household or a textile working area, as well as using certain facilities of a potter’s workshop; for example, well procured clay or a kiln for firing. Therefore, the mere analysis of an operational syntax of textile tools’ procurement cannot conclusively answer the question of who produced these tools.

TOWARDS IDENTIFYING TEXTILE TOOLS PRODUCERS

Locations where textile tools were made are rarely preserved in the archaeological record, thus archaeological evidence only occasionally allows us to identify the tool makers (cf. Quercia and Foxhall 2014). In Minoan Crete, textile tools are very exceptionally found in situ. Usually they are found as fallen from upper storeys of buildings where the warp-weighted loom(s) might have been placed (cf. Andersson Strand and Nosch 2015). The author was not aware of finds of loom weights in potters’ workshops or in potters’ kilns, except for the Potter’s Workshop from Malia, where 33 loom weights were found scattered, as they had fallen from rooms above rooms VIII 1 and VIII 5 (Cutler et al. 2013: 112; Poursat 1996: 23-43; Poursat et al. 2015: 237-238).

1: Cf. Firth 2015: 158, 167; for the statistics of the production quality of tools recorded in the textile tools database of the Centre for Textile Research in Copenhagen.
However, as Siennicka (2020: 28-30) argues, even when no workshops are recognised, the use of good quality clays and uniformity of forms and weights (as observed in the spindle whorls from Early Bronze Age II mainland Greece, c.2650-2200 BC) may suggest that the implements were produced in a potter’s workshop.

Conversely, poorly procured clays, greater irregularity in forms, and less careful manufacture may imply that tools were made by textile manufacturers within working areas of their households.

**REPRODUCING CLAY TEXTILE TOOLS**

The author’s hands-on experience in modelling copies of clay textile tools and monitoring their production by students results from eight years’ practice in academic teaching about textile technology in Bronze Age Greece in the Institute of Archaeology, University of Warsaw. Tool reproduction has two goals: to provide copies for experimental spinning and weaving and to enable better understanding of time-scheduling for operational sequences in textile production, e.g. the time required for drying tools before they may be used on a loom or sent for firing.

Altogether, the production of 324 clay tools has been monitored over this period: 17 spindle whorls and 307 loom weights. From these, 200 loom weights are copies of different types of loom weights from Crete, such as discoid, cuboid, spherical and pyramidal truncated (tab. 2, figs 3-4). All tools are made of modern, commercial clays (cf. Ulanowska
2016b: 322-324, 2019). Usually, tools are formed by hand from previously weighed lumps of wet clay, using 1:1 drawings or pictures of the original finds as templates. Flat rectangular surfaces are achieved by pressing lumps of clay on a flat surface or using modern wooden tools for clay working (fig. 3b). Observations have shown that making cubes and truncated pyramids required more time and care than making spheres and discoid weights.

Two sets of discoid weights were made using a method reconstructed by Cheval (2008: 20-21). This method facilitates production of entire sets of discoid loom weights of similar parameters (cf. Ulanowska 2019: 746-750, tab. 1). In this method, clay slices of a width corresponding to the width of each loom weight are sliced with a string from a roll of clay of a diameter corresponding to the diameter designed for the set of loom weights (fig. 3a, cf. Ulanowska 2019: 746-750). The raw slices require piercing and finishing by smoothing the surface and edges.

Making textile tools from clay was evaluated by students as a pleasant and easy task. A lack of previous experience in clay working did not directly affect the quality of reproduced tools. However, students tended to leave their tools before completing the final surface smoothing, unless they were instructed to do so. Several tools were spontaneously personalised, by incising marks and impressing personal items on them, in order to identify the tools produced by an individual afterwards (fig. 4c).

**ORGANISATION AND SCALE OF TEXTILE PRODUCTION IN MIDDLE BRONZE AGE CRETE—THE EVIDENCE FROM TOOLS**

In the MBA, especially during the Protopalatial period (MBA IB-MBA IIB), Crete witnessed several developments in textile technology and, presumably, an increase in scale of production and complexity of the production modes (cf. Ulanowska 2018b; Ulanowska and Siennicka 2018).

MBA textile tools were found in larger concentrations at newly formed socio-political centres (the so-called ‘palaces’) and several town buildings, including large public buildings, for example as at Knossos, Malia, Petras and Phaistos (Andersson Strand and Nosch 2015; Burke 2010; Cutler 2011; Cutler and Andersson Strand 2018). Finds of spindle whorls are significantly rarer than loom weights, and thus do not correspond to the scale of weaving suggested by the latter (Tzachili 1997: 126, cf. Andersson Strand and Nosch 2015a; Cutler 2011).

This apparent discrepancy in the evidence has been explained by factors that might have occurred together. Firstly, the use of spindle whorls made of perishable materials. Secondly, the use of spindle whorls that are not recognised as such. Thirdly, the use of alternative techniques for making yarn. Finally, spatial organisation of textile production in which spinning was located elsewhere, perhaps in small settlements invisible in the known archaeological record but close to sources of raw materials (Burke 2010: 50; Rahmstorf 2015: 6; Tzachili 1997: 128-129).

The parallel use of several forms of loom weights—for example, discoid, spherical, cuboid, cylindrical and pyramidal truncated (fig. 4)—might possibly imply different regional weaving traditions or local preferences for fabrics of certain qualities.
and appearance (cf. Cutler 2016a: 177-178; Cutler and Andersson Strand 2018: 54, for the CTR method of estimating what kind of fabrics might have been made using specific loom weights, see Andersson Strand and Nosch 2015; Mårtensson et al. 2009).

The observed preferences for specific types of tools (and presumably fabrics) in specific contexts at Knossos, Malia, Petras and Phaistos (cf. Andersson Strand and Nosch 2015; Burke 2016, 2010; Cutler 2016b; Cutler and Andersson Strand 2018; Cutler et al. 2013, Poursat 2012) may also suggest a degree of specialisation in weaving and, perhaps, certain specialisation in tool manufacture. Whilst the use of spherical, cylindrical and cuboid weights was almost exclusively restricted to Crete, the discoid loom weights, perhaps together with the entire warp-weighted loom technology, were transmitted from Crete to the southern Aegean (Cutler 2012, 2016a, 2019; Gorogianni et al. 2015).

A framework for the organisation of textile production in MBA Crete and the specific production modes may be hypothesised by examining several organisational components of production (tab. 1; cf. Costin 1991, 2005: 1056-1069; Ulanowska and Siennicka 2018). They comprise such elements as location and intensity of production, specialisation of production manifested by standardisation of tools and products, presence of administrative practices, complexity of social relations of production and potential cross-craft-interactions. In MBA Crete, concentrations of standardised loom weights within the palatial centres and important town buildings, as well as administrative practices reflected by seal-stamping, marking

Table 1: Organisational components of textile production (after Costin 1991, 2005: 1056-1069; Ulanowska and Siennicka 2018, fig. 1).

<table>
<thead>
<tr>
<th>Organisational components</th>
<th>Characteristics</th>
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</thead>
<tbody>
<tr>
<td>Types of production loci</td>
<td>general location</td>
</tr>
<tr>
<td>Scale and concentration of production</td>
<td>concentration of workshops</td>
</tr>
<tr>
<td>Specialisation of production</td>
<td>standardisation of tools</td>
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<tr>
<td>Social relations of production</td>
<td>social status of textile workers and producers</td>
</tr>
<tr>
<td>Labour division</td>
<td>gendered division of work</td>
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<tr>
<td>Administration of textile production</td>
<td>control over raw materials and their processing</td>
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<tr>
<td>Administrative practices</td>
<td>weighing of raw materials</td>
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</tbody>
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Table 2: Types of Cretan loom weights reproduced by students of the Institute of Archaeology, University of Warsaw, and the number of copies.

<table>
<thead>
<tr>
<th>Type of loom weight</th>
<th>Discoid</th>
<th>Cuboid</th>
<th>Spherical</th>
<th>Prismatical truncated</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Copies</td>
<td>12</td>
<td>60</td>
<td>66</td>
<td>16</td>
</tr>
</tbody>
</table>
and writing on textile tools (cf. Godart and Poursat 1978: 100-106; Karnava 2019; Nosch and Ulanowska forthcoming), imply more complex modes of production. However, alongside these more complex modes, the household production for individual needs must have continued (cf. Cutler and Andersson Strand 2018: 52; Ulanowska and Siennicka 2018).²

**LOOM WEIGHTS THAT TRAVELLED FROM CRETE**

Recent macro- and microscopic analyses of clay fabrics have demonstrated that not only the discoid type of the loom weight and the related weaving technique(s) were transmitted from Crete to the southern Aegean. A small number of actual tools made of non-local, most likely Cretan, clays (c.15 % of the number of recovered tools) were also transferred, for example to Miletos, Ayia Irini on Kea and Akrotiri on Thera (cf. Cutler 2012: 149-150; 2016a; 2019; Gorogianni et al. 2015; Karnava 2019; Vakirtzi 2019). At Ayia Irini, non-local fabrics have also been recognised in spindle-whorls and pierced spools, recovered from various contexts (Gorogianni et al. 2015).

At Akrotiri, the majority of the MBA discoid loom weights (62 examples) was made of local fabric, however the two-holed implements (17 examples) were exclusively made of non-local, probably Cretan, clays (Vakirtzi 2019: 485-500). One of these tools was inscribed in Linear A script (Karnava 2019). One locally made loom weight was marked by a string impression, running from a perforation to the lower edge of the tool (Vakirtzi 2019: 489, 494). According to Vakirtzi (2019: 492), it is possible that the string was used as a measure, helping to transfer a specific dimension to other tools produced as a set.

The phenomenon of the adoption of the new discoidal loom weights suggests horizontal transfer of knowledge and skills that must have resulted from the mobility of craftspeople (Cutler 2016a; 2019). Textile tools might have travelled with weavers—most probably females—as suggested first by Cutler, as templates for making similar weights in a new place, or perhaps as a part of their dowries (Cutler 2012: 150; Gorogianni et al. 2015). The desire for “fashioning the new identity” (Cutler 2016a: 177, 180-181) by an adoption of Cretan weaving techniques and dress, has been seen as a distinctive part of the Minoanisation process (cf. Cutler 2016a; Davis 1984). However, an alternative explanation, based on the MBA finds from Akrotiri, links the diffusion of discoid loom weights to the adoption of new naval technology and production of sails (Vakirtzi 2019: 499-500).

**SEAL-IMPRESSED AND MARKED LOOM WEIGHTS**

The practice of seal-impressing and incising clay loom weights may be observed throughout the entire Bronze Age of Greece (cf. the ‘Gewicht’ form of a seal-impressed object in the CMS Arachne database;³ Burke 2010: 43-44; Godart and Poursat 1978: 100-103; Krzyszowska 2005; Poursat 2001). Although never

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²: In the Aegean Bronze Age, there is no evidence suggesting that all needs of an individual ‘common’ household could have ever been fulfilled with textile production organised within more complex modes of production.

particularly frequent, the practice of stamping tools is the most common in MBA Prepalatial Crete, e.g. at Malia, Petras, Phaistos and Palaikastro (cf. Karnava 2019: 503). Impressing seals and incising marks was performed when the tools had been formed and the clay was still leather-hard.

It is argued that both types of marking might have had a similar administrative meaning, possibly related to a specific function of the marked loom weights in weaving, such as denoting a set for a loom (e.g. Burke 2010: 43-44; Militello et al. 2015: 222; Poursat 2001: 28-29). Occasionally, different notation systems could have been combined for one tool, as demonstrated by a discoid loom weight from Palaikastro (inv. no. HMp 4875) which is stamped by a seal (CMS II,6 no.245) that bears an inscription in the Cretan Hieroglyphic script (CHIC #174: CHIC 044-{065}-005) and is also marked by an incised labrys sign.

More insights into the apparent complexity of these notation practices come from Malia Quartier Mu, where clay analyses suggest specific patterns of production and distribution of the marked tools (Poursat 2001). At Malia, at least 13 loom weights were incised and another 12 were seal-impressed, which constitutes c.4% of the entire assemblage of tools (fig. 5; CMS Arachne database; Godart and Poursat 1978: 100-103; Poursat 2001). According to Poursat (2001: 28), the forms of incisions were different from contemporary potters’ marks on vases, although the marks on loom weights might also have been made by the potters. Tools incised with the same mark, resembling an inverted letter ‘Z’, were recovered in different buildings of the Quartier Mu.

Interestingly, all of them were made of a different clay compared to the rest of the loom weights they were found alongside (Poursat 2001: 28). According to Poursat, the marked implements, if found in situ, denoted sets of weights ranging from 32 to 38 tools each. In building D, room VII 3, an assemblage of 145 loom weights (according to Poursat 2001: 29, or 119 according to Poursat et al. 2015: 235) included four ‘Z’-incised weights and thus, according to Poursat (2001), enough sets for four warp-weighted looms. The suggested numbers of weights in a set seem generally plausible for the warp-weighted loom set-up. However, the metrical analysis of these tools cannot further support this estimation, since the functional uniformity of many implements would allow them to be used in various combinations on the loom (cf. Cutler et al. 2013: 110-112; Poursat et al. 2015: 235-237). It is not confirmed whether the clay fabrics of the seal-impressed loom weights at Malia differed from the fabrics of non-marked or incised implements.

However, the seal-impressed loom weights were also distributed in different locations. The same seal (CMS II,6 no. 213) was impressed on three spherical weights found in the palace, room 3.3 (inv. nos 81/0613-002, φ 4.05 cm; 83/E 0368-003, φ 5.8 cm; 83/E 0369-002, φ 4.1 cm), and on a spherical loom weight from building A in Quartier Mu (fig. 5b; CMS II,6 no. 203, inv. no. 67/E 31, φ 4.1 cm). The weight of these spherical weights is not known, but the diameters of three of them (two from the palace and one from building A) show striking uniformity.

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4: See Weingarten 2000 for a unique LBA set comprised of 17 seal-impressed loom weights from Palaikastro
Although the practice of marking loom weights possibly reflects a certain administrative rule, the meaning of the incised signs and impressed images remains obscure. The author is aware of at least three examples—all dated to the MBA—where the meaning of the impressed/incised images or marks may be related to textile production. The first example is the inscription on a loom weight from Akrotiri, transcribed as AB 164a AB 53 AB 01, where sign AB 164a resembles the Linear B logogram TELA—graphic forms of these both signs allude to a piece of textile (Karnava 2019). The second one is a spoon-like tool from the Quartier Mu, Malia (inv. no. 69 M 1662), impressed five times on each side by a seal bearing a depiction of two spiders (fig 5c; CMS II,6 no. 192). In this case, spiders could be seen as a symbolic reference to textile production. The third is a seal-impressed spindle whorl from MBA Chamalevri (inv. no. II 13247), stamped 39 times by a seal that possibly shows an iris flower (CMS VS3 323), perhaps alluding to a precious nature of the dye itself (Vlazaki 2010).

A pair of loom weights from Enkomi (Late Cypriot IIIA), impressed by the same ring possibly bearing a depiction of a loom weights motif (Smith 2002: 292), is a later non-Cretan example, suggesting that a symbolic relation between the function of a tool and the meaning of the impressed image may, sometimes, be suggested.

**CONCLUDING REMARKS**

The discussed evidence from MBA Crete cannot allow us to unambiguously determine by whom and where textile tools, specifically loom weights, were actually made. The mere analysis of the operational syntax of tool production is also inconclusive on this matter. The loom weights were part of complex practices related to their production, allocation and use; they were marked, stamped, inscribed, redistributed and transferred far away from the place of production. All these practices reveal socio-economic, and perhaps symbolic, aspects of textile production which cannot be easily incorporated into a specific operational sequence.

However, given the scale of MBA textile production on Crete, the chaîne opératoire may be used indirectly to explain the logic of tool production. It seems that hundreds of functionally uniform loom weights, found across the main socio-economic and
political centres of Crete, must have been made by ‘professional’ potters, perhaps as mass-produced items, rather than by individual spinners and weavers. The impression of a string on one of the locally manufactured discoid loom weights from Akrotiri may be seen as a possible measure undertaken to produce a large series of highly uniform tools. Moreover, the author’s hands-on experience in tool making suggests that the widely transmitted discoid loom weights were the type that might have been easily replicated in large series of nearly identical copies.

The evidence of travelling tools that could have served as templates for making new tools in a new place seems to support the view that MBA textile tools, in this case the discoid loom weights, were produced by potters. The re-occurring evidence of tools made of non-local clays, yet forming functionally uniform assemblages, implies that not all of the travelling tools were copied in a new place. The example of the two-holed discoid loom weights from MBA Akrotiri suggests that they came to the island of Thera over a longer period of time, possibly together with the weavers themselves, but they were never locally imitated. Only the inscribed tools, such as the discoid weight from Akrotiri, “could very well travel on their own” (Karnava 2019: 503).

Finally, the complex notation practices observed on textile tools—such as impressing seals, incising marks and writing—suggests a certain level of craft-peoples’ involvement, if not control, over the manufacture of textile tools. Several aspects of the notation practices related to textile tools, such as differences in clay between the marked and unmarked loom weights, cannot at present be explained. Hopefully, further macro- and microscopic examination of clays used to produce the loom weights used in different locations may shed more light on this issue in the future.

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