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Mold-making technology at architectural compound 60 (CA-60): A newly discovered ceramic workshop at Huacas de Moche, Peru

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ABSTRACT

Ceramic molding is often addressed as a simple, repetitive, and standardized technique. Similarly, mold-making, though much less studied than molding itself, is frequently viewed as equally straightforward. Yet what specific gestures, techniques, and tools are involved in mold-making? Does internal technical variability exist behind apparent external standardization? What insights into ancient craft production can mold-making evidence provide? This paper addresses these questions through a technological study of molds from a recently discovered ceramic workshop at Huacas de Moche (Trujillo, Peru). Our study reveals that mold-making comprises multiple complex sequential steps with significant technological variation. We suggest that local Moche artisans maintained autonomy in their mold production methods, employing diverse technological approaches while sharing a common artistic repertoire, meanwhile elite oversight ensured quality standards in final products.

1. Introduction

Scholars have extensively studied molding technology and its role in specialized craft production across ancient societies (Rice 2015; Rye 1981; Shepard 1974). Molds enable increased standardization, efficiency, and mass manufacturing capabilities through economies of scale (Rice 2015; Arnold 1988:202). One key advantage is the ability to scale up production by employing unskilled or semiskilled workers while maintaining consistent product quality and design (Arnold 1994:488-489; 1999:63-66). In systems of attached production, molding technology allowed elites to directly control ceramic production and regulate the replication of important iconographic elements (Costin 2005:212). In middle-range societies, since ideology could be materialized (see DeMarrais et al. 1996), control over the production and distribution of ideologically charged crafts became a crucial source of power, as emerging elites used material culture to spread state ideology (see Goldstein 2000; Vaughn 2004, 2006, for Andean cases).

Besides these advantages, molding technology has notable limitations and complexities. The mere adoption of this technology does not automatically lead to improved efficiency, standardization, or production rates (Costin 2005:1067-1068). Molding requires significant time and resources, as artisans need multiple sets of molds for mass production and additional space for drying and storage (Arnold 1999:66-70). Molds might be used only for specific occasions, like the death of a high-status individual or during calendrical events, to produce limited sets of sacred images (Shimada 2016, 2022). Societies may adopt molding technology primarily to ensure consistent iconographic messages across vessels, preserving their symbolic and sacred value, rather than to increase production efficiency (Cummins 1994). Moreover, mold use alone does not guarantee complete standardization, as artisans can still decorate and modify vessels in ways that create significant variations (Costin 2018:175). These insights challenge simplistic assumptions about the relationship between molding technology, mass production, standardization, and efficiency, highlighting the need for a contextual historical approach.

While researchers have extensively studied molding technology's relationship to craft specialization by analyzing molds' physical traits, usage patterns, workshop features, and item distribution, they have largely overlooked the specific techniques and gestures used to create the molds themselves. Like other ceramic technologies, mold-making demands precise techniques, deep material understanding, and careful execution to produce high-quality ceramic products (Donnan 2004:23; Mosna 2024). In societies with some form of attached production (see Costin 1991, 2005), mold-making can be viewed as an intermediary stage in the production process, bridging artisans' technical expertise, identity, and creative autonomy with elite demands for standardized

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production. Understanding the specific techniques of mold production can provide valuable insights into skill development, knowledge transmission, and social organization in workshop settings, enhancing our understanding of ancient craft production systems.

1.1. Molding technology on Peru's north coast

Molding technology developed on Peru's north coast during the first centuries A.D., achieving a sophistication unmatched in most other regions of the Western Hemisphere before European contact (Donnan 1997:30). Molding, alongside coiling, formed the foundation of Moche ceramic technology (Espinosa et al. 2019, Espinosa 2023). Coiling was used for producing undecorated utilitarian items such as jars, cooking pots, and bowls, while molds were reserved for manufacturing fine-ware pieces like stirrup spout bottles, portrait vessels, flaring vases or *floreros*, and dippers or *cancheros* (Espinosa et al. 2024:685-687). The extensive adoption of molding by Moche potters is evidenced by hundreds of molds found in workshops throughout the Moche Valley (Bawden 1982; Chiguala et al. 2007; Rengifo and Rojas 2008:328-329; Uceda and Armas 1997), Chicama Valley (Jackson 2000, 2002; Russell et al. 1994), Santa Valley (Chapdelaine et al. 2009; Gamboa 2013), Nepeña Valley (Rengifo 2016) and Lambayeque Valley (Shimada 1994). While two-piece molds were predominant, artisans also employed one-piece and multiple-piece molds depending on the vessel's shape and complexity (Donnan 1965:118-119; 2004:21-35; Jackson 2000). Later North Coast Peruvian cultures, particularly the Sican or Lambayeque (A.D. 800–1375) and Chimú (A.D. 900–1470), widely adopted molding technology to mass-produce standardized ceramic vessels (Tschauner 2006, 2009; Wauters 2016, Shimada and Wagner 2019). During the Inka occupation (CE 1470–1532), mold-making technology remained widely used in state-sponsored workshops, alongside other technological innovations and aesthetic preferences (Hayashida 1999, 2019).

Andean archaeologists have analyzed mold technology through several lenses: as a tool for mass-producing ceramics (Tschauner 2006, 2009) or creating ritual objects for specific occasions (Shimada 2016, 2022); as evidence of elite control over production (Russell et al. 1994); as a marker of technological identity distinguishing local from foreign ceramic traditions (Hayashida 1999) and different potter communities within workshops (Shimada and Wagner 2019); and as a symbolic communication system serving as a proto or semasiographic writing (Jackson 2000, 2002, 2011). Chemical analyses of molds have also revealed information about raw material sources (Chapdelaine et al. 2009) and how ceramic production was organized in imperial workshops (Hayashida 2019). This archaeological evidence is complemented by ethnographic studies of modern Andean potter communities that combine mold use with other traditional techniques (e.g., Druc 2011, Lara and Ramón 2020; Sillar and Ramón 2016). As stated previously, no systematic analysis has been conducted on the specific techniques and knowledge required for mold creation in pre-Columbian Andean contexts. The only attempt to reconstruct this process was conducted by Christopher Donnan (2004:23, see Fig. 15a-f), who focused on Moche portrait vessels. His research, while groundbreaking, covered only one specific vessel type and did not explore the full range of technological variations present in ancient Moche workshops.

Building upon Donnan's work, this study aims to expand our understanding of mold-making's technological complexities while analyzing the social dimensions of craft production through the lens of mold-making practices. We address three key questions: What specific gestures, techniques, and tools are involved in mold-making? Does internal technical variability exist behind apparent external standardization? What insights into ancient craft production can mold-making evidence provide? To answer these questions, we analyze a sample of molds from a newly discovered ceramic workshop at the site of Huacas de Moche, as described in the following section.

2. Area of study

2.1. The archaeological complex of Huacas de Moche

The Moche or Mochica (AD 100–850) are considered one of the most complex cultural developments in the Central Andes (Castillo and Uceda 2008; Castillo and Quilter 2010; Uceda et al. 2021). Its material culture is widely spread along a narrow littoral desert strip stretching between the Piura Valley and the Nepeña Valley on the north coast of Peru (Fig. 1a). The nature of the Moche phenomenon has long been debated. An early view that emphasized the existence of a single, centralized, expansionist state based at Huacas de Moche has been gradually challenged by models that conceive the Moche as a religious system that realigned north coast societies around a shared set of deities and ritual practices (Bawden 1995; Donnan 2010; Quilter 2010; Quilter and Koons 2012).

Moche craft production exhibited significant technological diversity across regions, with workshops showing varying levels of organization and technical sophistication (see Chapdelaine 2011:207-208; Costin 2004; Vaughn 2006:329-331 for a complete review of Moche craft organization). Artisans' social status varied from commoners to lower elites, and their production encompassed everything from elite ceremonial vessels to everyday utilitarian wares. These craftspeople worked in both household settings and specialized facilities, operating under different levels of elite supervision. Despite these organizational differences, all workshops sourced their raw materials locally (Chapdelaine et al. 1995; Del Solar 2015; Koons 2015; Rohfritsch 2010; Russell et al. 1998).

The site of Huacas de Moche, a center of primary importance within the Moche polity, lies five kilometers east of Trujillo on Peru's Pacific coast in the Department of La Libertad (Fig. 1b). The 60-hectare archaeological complex features two monumental mud-brick platforms —Huaca del Sol and Huaca de la Luna— alongside an extensive urban sector. A long-term archaeological project was initiated in 1991 and continues to the present (Morales and Rengifo 2021; Uceda et al. 2017). The site's occupation spans from four centuries before the Common Era through the Spanish conquest in 1532 (Rengifo et al. 2022). The Moche occupation can be divided into two periods: the Theocratic Period (AD 100–600), when priest-elites governed the urban population from the Old Temple of Huaca de la Luna, and the Secularization Period (AD 600–850), marked by the rise of urban leaders, the construction of the New Temple of Huaca de la Luna, and Huaca del Sol's final construction phase (Uceda 2010a; Uceda et al. 2021).

The urban area was largely associated with the Moche phase IV ceramic style (AD 450–850), though earlier occupations remain poorly understood. The area comprised well-defined architectural blocks connected by streets running along north-south and east-west axes (Chapdelaine 2001) (Fig. 2). The main avenue, known as Avenida 1, ran from south to north, separating public buildings from architectural compounds (Chapdelaine 2002:56). The architectural blocks contained multi-functional compounds that served as family living spaces, craft production areas, storage facilities, administrative areas, food preparation zones, and public spaces for feasts and ritual activities (Bernier 2009, 2010; Castillo et al. 2015). Excavations uncovered workshops dedicated to producing ceramics, metals, textiles, and semiprecious stones (Gayoso 2011, 2016; Rengifo and Rojas 2008; Uceda 2010b; Uceda and Rengifo 2006). Narrower streets (*callejones*) ran both east-west and north-south, defining large blocks of rooms and connecting public spaces in domestic quarters to other areas of the city (Zavaleta et al. 2009:275). The city was home to an urban elite, with each residential block likely overseen by a leader who held authority over lineages and corporate groups (Bernier 2010; Uceda 2010a; Van Gijseghem 2001).

At Huacas de Moche, production control operated through various mechanisms that reflected different levels of artisan attachment and expertise. Full-time specialists carried out craft activities at small to

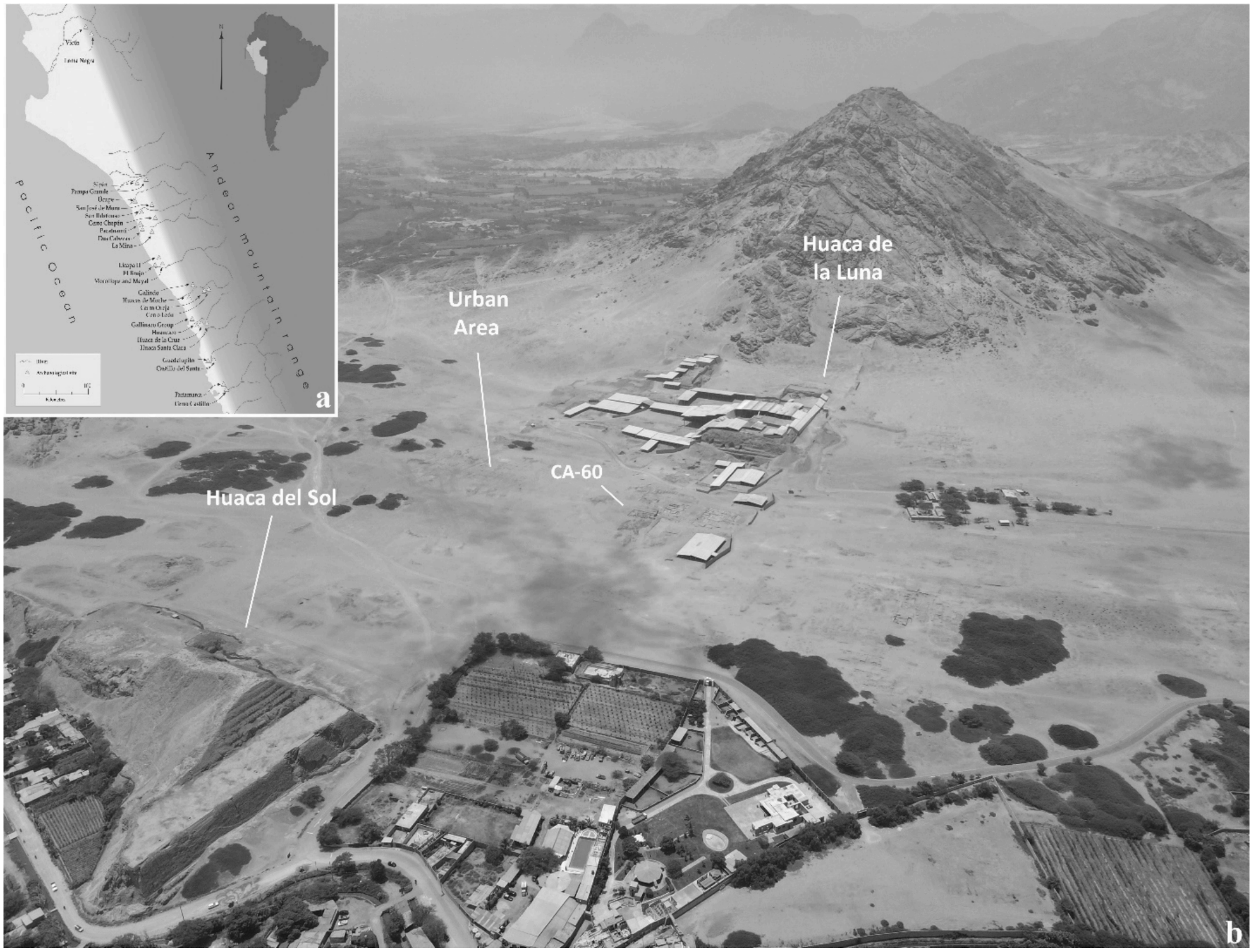


Fig. 1. (a) Map of the Moche territory. (b) Aerial view of the Huacas de Moche archaeological complex. The location of the ceramic workshop at CA-60 is indicated.

medium scales of production (Bernier 2010:15). Highly skilled craft specialists maintained close ties to the ruling elite, producing luxury goods directly for the state while enjoying elevated social status in Moche society (Rengifo and Rojas 2008; Uceda and Rengifo 2006). Meanwhile, the production of intermediate goods (feminine figurines, stirrup spout bottles, trumpets, pendants, etc.) operated under urban leaders' supervision, occupying a middle ground between elite attachment and independence (Bernier 2010:11-13). These items, reflecting state ideology, were not only used by elite members but also exchanged among urban leaders and the population to maintain social connections and alliances. The presence of such "embedded specialists" —whose production is neither strictly independent nor strictly attached— has been documented across various middle-range societies in the Western Hemisphere (Ames 1995; Janusek 1999). In contrast, domestic pottery production at Moche occurred outside the urban sector and was likely operated independently by commoners (Bernier 2009:169-170).

2.2. *Ceramic workshops at Huacas de Moche*

Three key criteria are generally used to identify manufacturing locations in the archaeological record: the presence of raw materials, manufacturing facilities and tools, and production by-products (Costin 1991; Feinman 1982; Stark 1985). At Huacas de Moche, specialized production workshops are distinguished by their permanent structures and dense concentrations of craft-related materials, contrasting with the rest of the urban sector where evidence primarily indicates consumption activities (Bernier 2010:4).

Before this study, two specialized ceramic workshops dedicated to fine ware production had been identified at the site. The first one, excavated in 1994-1995 and located in the southern part of the urban complex, was called TAM (Taller Alfarero Moche) (Fig. 2). This workshop produced fine clay items including figurines, musical instruments, decorated vessels, and necklace elements (Uceda and Armas 1997, 1998). Composed of 15 rooms, it underwent three renovations and expanded from 64 m^2 to over 300 m^2. The workshop contained production equipment including kilns, grinding stones, molds, and tools for shaping and finishing vessels. Evidence indicates that all production stages took place *in situ*.

A second workshop, excavated in 2008-2009, was discovered in the central portion of the urban sector within Architectural Compound 21 (CA-21) (Fig. 2). This complex served both residential and production purposes, with areas for cooking, storage, patios, and living quarters (Chiguala et al. 2007). Three occupations were identified, each associated with different remodeling episodes (Gayoso 2011:102-104). Manufacturing activities took place in the western portion of the complex. Archaeological evidence included two open kilns, production tools, manufacturing by-products, and a water drainage canal used in ceramic production. This workshop specialized in producing body ornaments, ritual objects, and musical instruments.

A third workshop, located outside the urban area at the base of Cerro Blanco, focused exclusively on utilitarian vessel production (Bernier 2010:5; Gayoso 2016:312-313). Although unexcavated, surface findings indicate the production of cooking pots, storage jars, and other domestic items. Evidence of manufacturing includes ash deposits, production waste, potter's tools, and abundant pottery fragments (Bernier 2009:163).

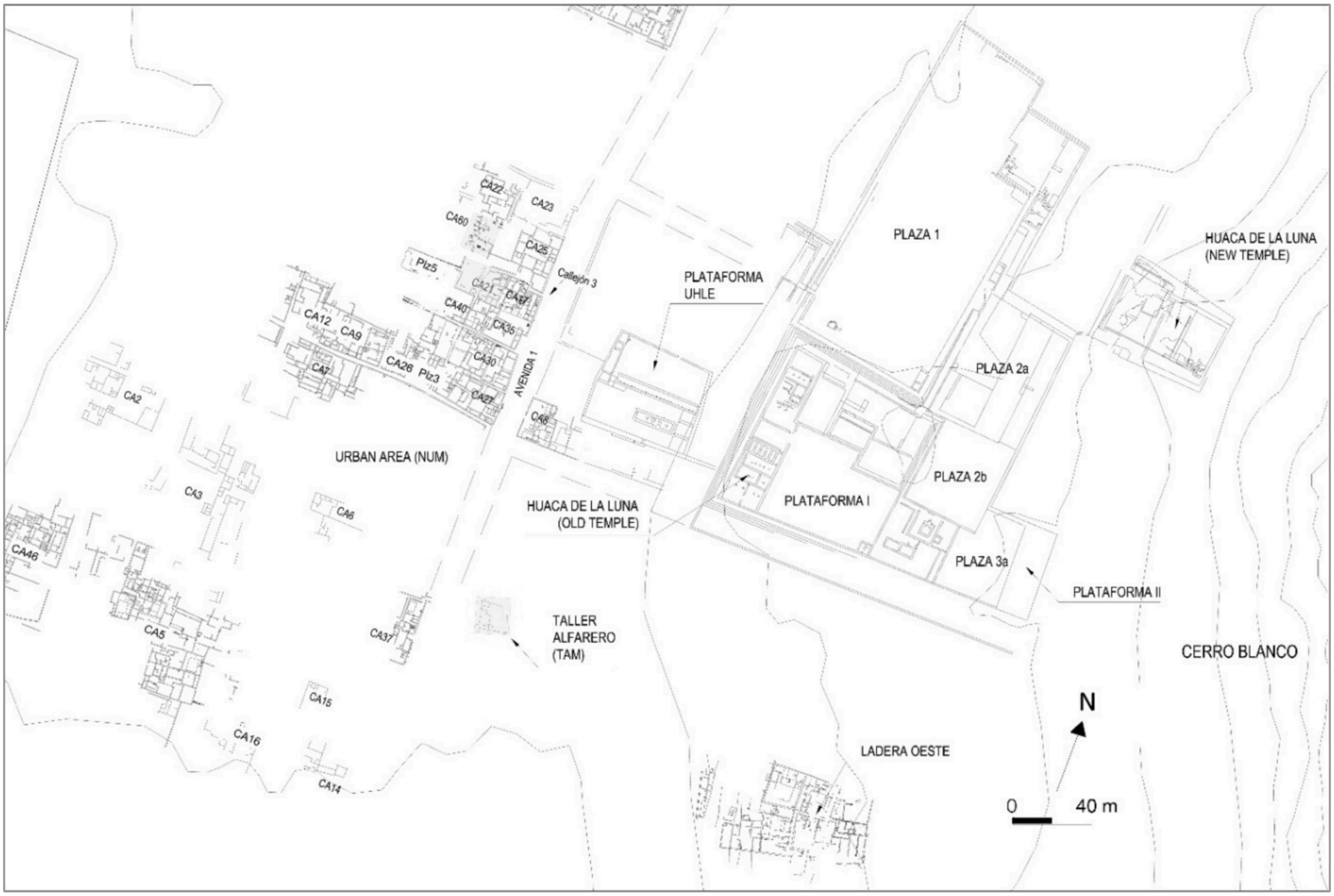


Fig. 2. Map of the central part of the Moche urban sector showing the ceramic workshops mentioned in the text.

2.3. The ceramic workshop at architectural compound 60 (CA-60)

During the field season of 2021, a fourth ceramic workshop was found at Huacas de Moche within Architectural Compound 60 (CA-60), a newly discovered complex in the urban sector's central area (Mosna 2024; Rengifo 2022; Zavaleta et al. 2022) (Figs. 2 and 3). CA-60 bordered architectural compounds CA-21 to the southwest, CA-25 to the southeast, and CA-22 to the northeast (Fig. 2). While the exact entrance location of CA-60 remains unclear, the architectural block likely connected to the main avenue through a narrow street known as Callejón 3 (Fig. 2). This 1.5-meter passage ran east to west for over 30 m, facilitating access and movement within this sector of the urban complex (Zavaleta et al. 2009:278).

Two excavation units were opened: Unit 1, measuring 20 m by 16 m in surface area (320 m^2), and Unit 2, a trench of 3 m by 5 m (15 m^2) located southwest of Unit 1, designed to identify the southern limit of the architectural compound (Fig. 3b). Stratigraphy of Unit 1 was composed of seven layers — superficial, A, B, C (Floor 1), D (Floor 2), E (Floor 3), and F (Fig. 4). Layers C, D, E and F are associated with Moche IV phase (AD 450–850). Upper layers (Superficial, A, B) are post-Moche deposits. The excavated area had suffered extensive damage from recent looting activities and Chimú-period agricultural land use. Layer C contained the best-preserved architectural features, including fourteen rooms bounded by eighteen walls associated with a single occupational floor (Floor 1) (Fig. 3b). The walls were constructed using rectangular adobe bricks joined with mud mortar— a traditional construction technique common throughout Peru's North Coast (Tsai 2012). However, extensive damage to wall sections in the central-northern sector made it difficult to fully understand the compound's spatial organization and its exact limits.

Archaeological evidence reveals that CA-60 served multiple functions. The southern sector—comprising rooms 60-9, 60-10, and 60-11—functioned as a ceramic workshop during two occupation phases, corresponding to Floors 2 (Layer D) and 1 (Layer C). A variant of a type F kiln (see Castillo et al. 2015) was discovered in room 60-11 and was associated with both occupational floors (Fig. 3c). The kiln was bounded by three walls (W-13, W-14, W-15) and occupied a 9 m^2 area (Fig. 3b). Its southern side remained open to take advantage of the area's prevailing south-to-north winds. The internal walls showed a reddish coloration, indicating exposure to high temperatures and direct flames. The kiln contained a thick layer of ash, charcoal, organic matter, and manufacturing waste, including unfired, underfired, and overfired ceramic sherds. The southern part of the complex contained extensive evidence of ceramic production, including grinding stones, concentrations of tempering material (gravel), polishers, scrapers, and numerous fragmented molds (Fig. 5). This assemblage suggests that all stages of ceramic production took place in this space.

Ceramic production at CA-60 focused on "intermediate goods" (see Bernier 2010:9-10) specifically figurines, musical instruments, ritual vessels, and ornaments, following patterns similar to those observed in TAM and CA-21. Local craftsmen primarily used vertical half-molding or two-piece molding techniques, with one-piece and multiple-piece molding as secondary methods (Mosna 2024:27-40). The workshop area yielded 718 molds, used to produce figurines (31.2%), open and closed vessels (28.1%), musical instruments (22.4%), and ornaments (18.3%). While CA-60 primarily produced "intermediate goods" through molding, some utilitarian vessels found in the workshop—such as cooking pots (*ollas*), neck jars (*cántaros*), and large storage jars (*tinajas*)—may have also been manufactured *in situ* using either molds or modeling techniques (Gamarra and Gayoso 2008).

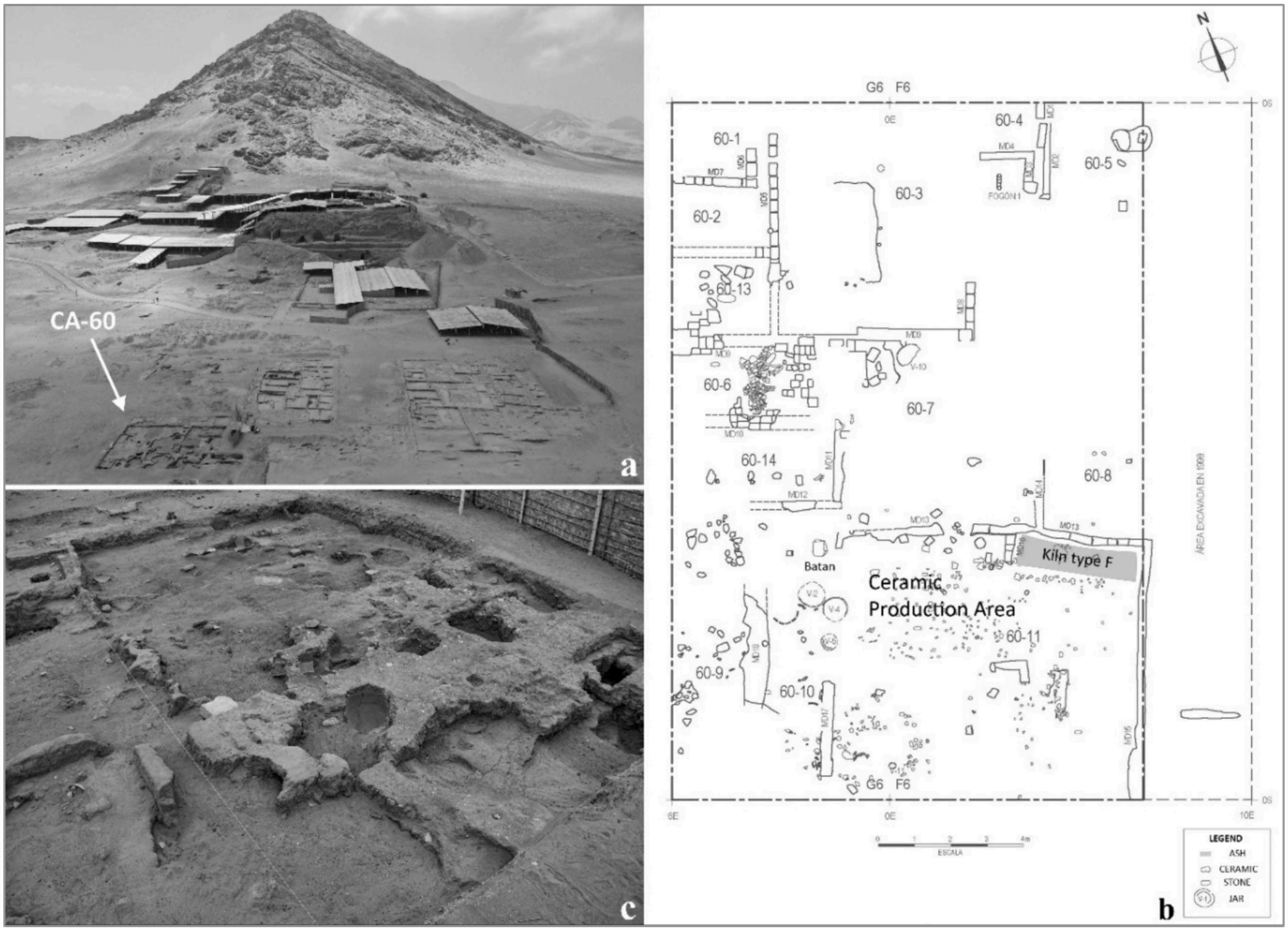


Fig. 3. (a) Panoramic view of the Huacas de Moche archaeological complex, showing the location of CA-60. (b) Plan of Unit 1 (Layer C) at CA-60 (c) View of the southern portion of the compound that functioned as a ceramic workshop.

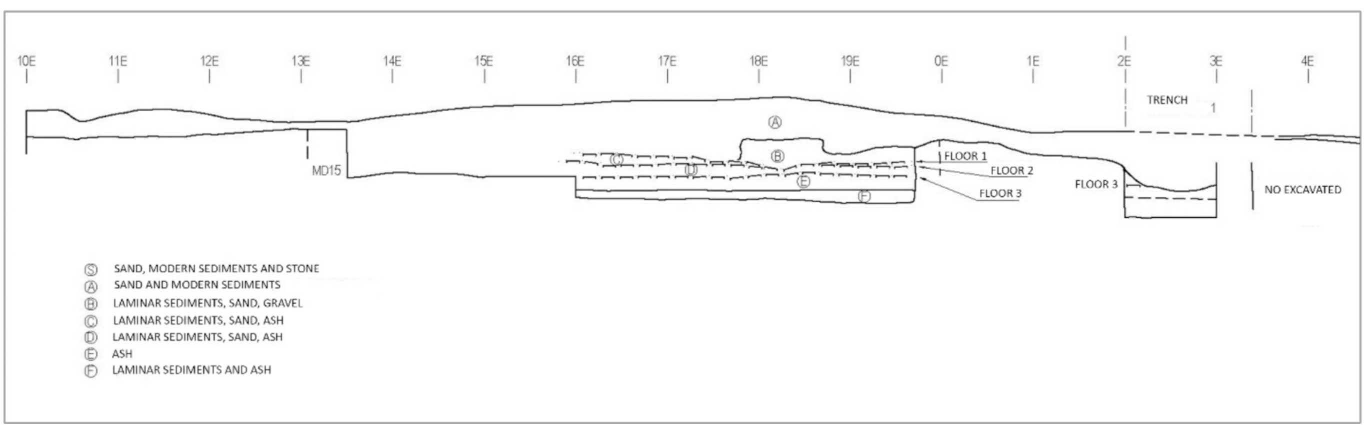


Fig. 4. Profile view showing the south side of Unit 1 and the trench of Unit 2.

Excavation units at CA-60 yielded 4,735 ceramic fragments, comprising 4,640 diagnostic pieces and 91 complete vessels, associated with consumption, processing, and storage activities (Table 1). The assemblage comprised several categories, with vessel parts being the largest group at 34.11% (spouts, handles, decorated bodies, bases, lids). Closed vessels made up 27.98% (crucibles, dippers, bottles, cooking pots, neck jars, storage jars), followed by production tools at 16% (spindle whorls, molds, potter's plates), and open vessels at 8.53% (flaring bowls, bowls, cups, plates). Lesser quantities included ritual objects at 4.94% (hollow and solid figurines), ornaments at 2.70% (pendants, beads, architectural decorations), musical instruments at 2.68% (trumpets, ceramic shell *pututos*, rattles, ocarinas, whistles), and utensils at 1.1% (spoons). The remaining 1.97% of fragments were unidentifiable. Activity at CA-60 showed significant growth over time. Floor 1 (Layer C) contained 1,766 sherds, more than double the amount found in Floor 2 (748 sherds) and far exceeding Floor 3 (70 sherds).

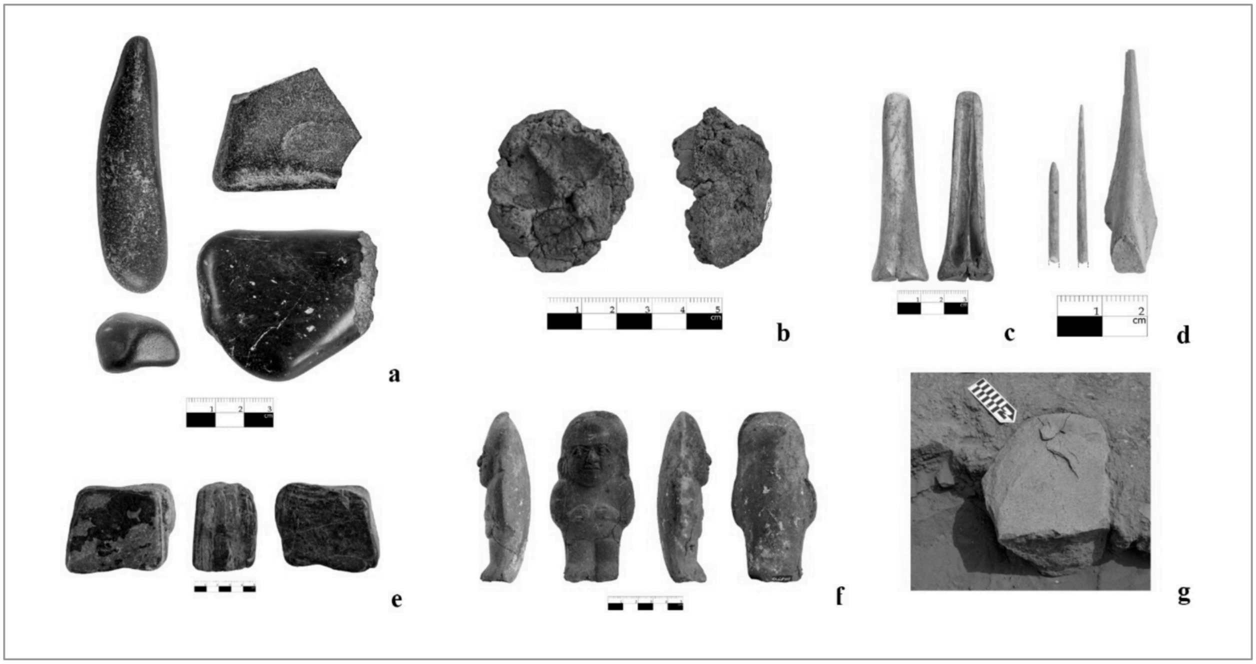
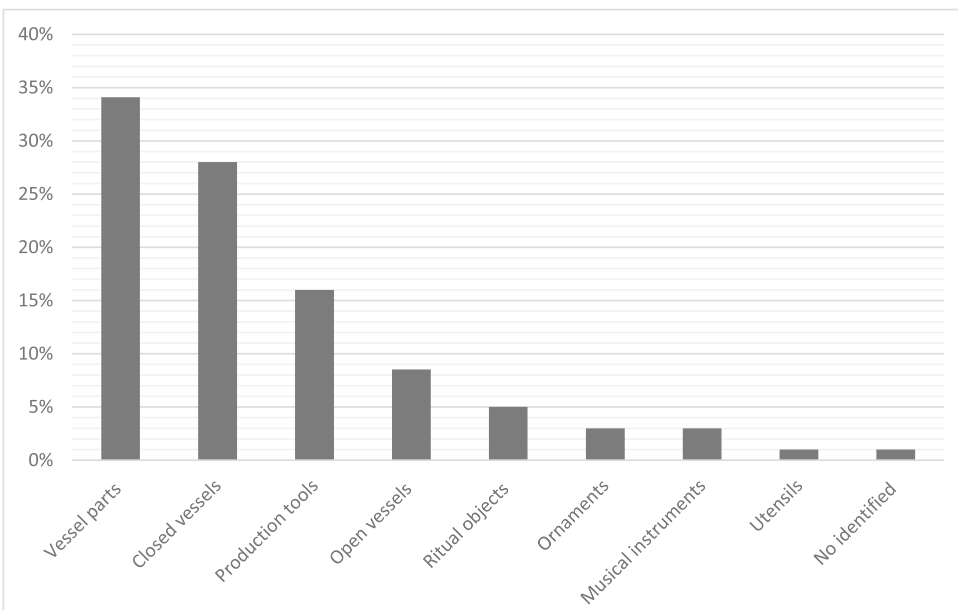


Fig. 5. Evidence of ceramic production at CA-60: (a-e) polishers; (b) manufacturing waste; (c-d) bone tools; (f) overfired ceramic pieces, and (g) grinding stone or "batán" likely used to process the tempering material (gravel) found in concentrated deposits inside room 60-11.

Table 1
Distribution of ceramic categories at CA-60.



Several indicators beyond ceramic types point to food-related activities at CA-60: domestic vessels with use marks (particularly soot), concentrated food remains (mainly shells, camelid and fish bones), domestic kilns containing ash and charcoal deposits, and large storage jars (*tinajas*) set into the floors. The southern sector also revealed evidence of small-scale stone ornament production, including cutting debris, stone tools (polishers and blades), unfinished or broken pieces, and finished items comprising 45 beads and 3 spindle whorls. CA-60 functioned as a multi-functional residential complex that merged specialized ceramic production with domestic activities. This arrangement mirrors other architectural compounds at Huacas de Moche, where artisans combined their living and working spaces, integrating craft production with household activities (Bernier 2010; Gayoso 2011; Uceda 2010b; Van Gijseghem 2001).

3. Material and methods

3.1. Sample

The sample comprised 167 molds found in room 60-11, layer C

(Floor 1), the area with the highest concentration of pottery production evidence within CA-60. We classified the molds into six main morphological groups: figurines (62%), adornments (6%, including earplugs, pendants, and beads), jars and bottles (6%), musical instruments (4%, including rattles, whistles, and trumpets), portrait vessels (2%), and one miniature (see Gayoso 2016, for a complete description of each category at Huacas de Moche) (Fig. 6). Due to extensive fragmentation, 29 molds remained unclassifiable. Following Margaret Jackson's (2000:120-137) classification from Cerro Mayal, we categorized the molds by type (Fig. 7). Multiple-piece molds dominated the sample (62%), followed by one-piece press molds (14%) and stamp molds (1%). The remaining 38 sherds (23%) were too fragmented for identification.

3.2. Method

As previously discussed, the manufacturing process of pre-Columbian molds remains poorly understood. Our research addresses the fundamental question: How were molds made? To reconstruct the manufacturing processes, we conducted both macroscopic and microscopic analyses. We documented surface features through detailed photography and sketching, while examining internal structures using a digital microscope (Dino-Lite AF4115ZT) at magnifications ranging from 30× to 130×. We carefully documented cross-sections to reveal layering patterns, inclusion distributions, and evidence of joining methods.

Our analysis employs ceramic technology as a methodological framework through the *chaîne opératoire* concept (see Roux 2019, for a complete description of the methodology). Ceramic production follows six sequential stages: raw material procurement and preparation, shaping, finishing, surface treatment, decoration, and firing (Rice 2015; Roux 2017; Shepard 1974). By examining diagnostic features on archaeological artifacts, we identified specific gestures, techniques, and tools used by ancient potters (see Espinosa 2023; Espinosa et al. 2019; Espinosa et al. 2021; Espinosa et al. 2024; Lara 2017; Lara 2020; Lara and Bray 2025, for applications of this methodology in Andean contexts). This approach enabled us to reconstruct the mold-making process, uncovering previously unknown technical complexities.

A second point of study focused on the social sphere of mold producers. How can evidence from molds provide insights into the organization of ancient potters' craft production? One of the strengths of the *chaîne opératoire* approach lies in its potential to reveal social groupings and their cultural choices (Gosselain 1992; Lemonnier 1993). The specific techniques used to make vessels represent culturally learned skills that endure over time and can be linked to distinct regions, pottery-making communities, or individual craftspeople (Dietler and Herbich 1994; Roux 2020; Stark 1998:5-7). By identifying non-functional variations in the *chaînes opératoires*, we can distinguish between different groups of producers (Espinosa et al. 2024; Lara and Bray 2025; Roux 2017).

Like other ceramic technologies, mold-making requires specific physical movements and learned sequences of actions (Donnan 2004: 23-25; Mosna 2024). We take this as one of the starting points of our discussion. The presence of distinct operational sequences within the same mold categories indicates that artisans from varied social backgrounds worked in the same workshop. Conversely, functional variability—where one specific recipe is used exclusively for one mold category—suggests that certain techniques were specifically adapted for practical requirements rather than reflecting social differences.

To address mold variability, we followed three sequential stages: (1) classification by morphological groups (see Section 3.1); (2) compositional analysis, where freshly cut cross-sections of 82 representative sherds were examined under a digital microscope at 30× and 130× magnification, including qualitative, granulometric, and quantitative analyses; and (3) techno-morphological grouping to identify correlations between mold categories and their specific manufacturing sequences, revealing functional or social patterns.

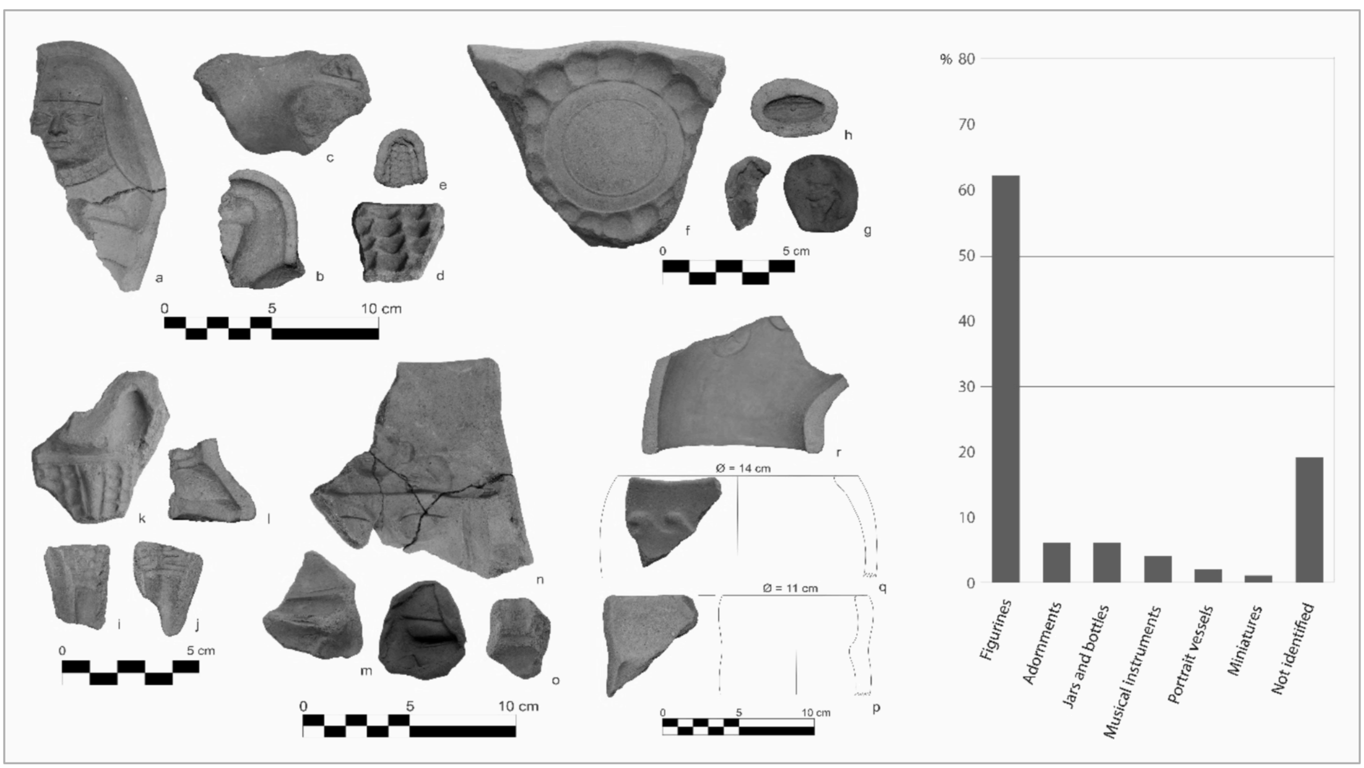


Fig. 6. Morphological groups of molds and their percentages: figurines with (a) anthropomorphic, (b-c) zoomorphic, and (d-e) phytomorphic designs; adornments, including (f) earplug, (g) pendant, and (h) necklace; musical instruments, comprising (i-k) rattles and (l) bird-shaped whistle; (m-n) portrait vessels; (o) miniature; and vessels, including (p-q) jars and (r) a bottle depicting a sea lion's snout.

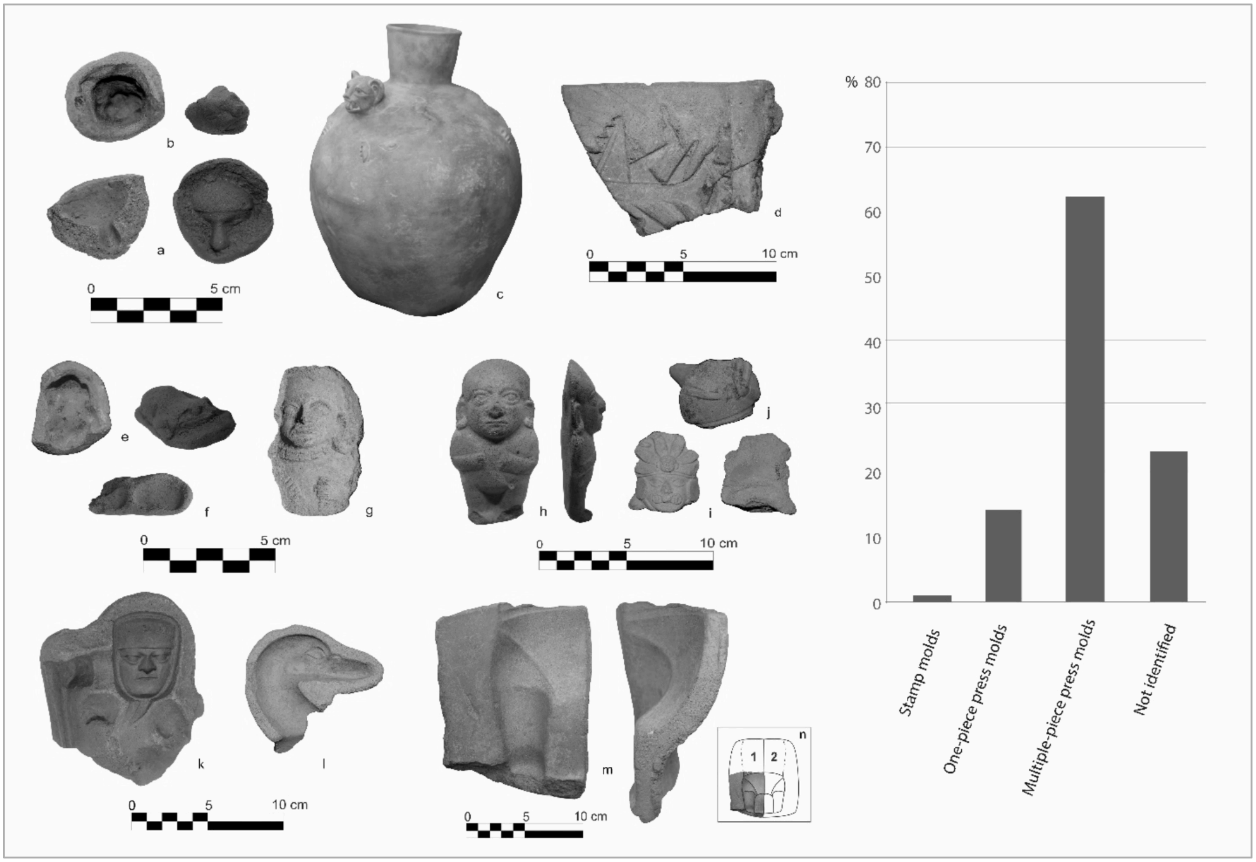


Fig. 7. Mold types and their percentages. (a-b) Stamp molds and (c) their application in decorating a jar at Huacas de Moche. (d) "Intaglio Mold" found during surface collection near Huaca de la Luna. One-piece Press Molds: (e) pendant; (f) bead; (g) figurine. Artifacts made with this method at CA-60: (h) figurine; (i-j) whistle. Multiple-piece molds: (k-l) two-piece molds; (m) front and side views of one part of a four-piece mold. This part covered only one half (n1) of the back face of a sculptural vessel representing a standing individual.

Analysis of the molds also provided insights into the degree of elite oversight and control over ceramic production. We ask: Did urban leaders provide artisans with standardized raw materials and production tools, or did artisans maintain autonomy in their craft techniques and material choices? The presence of distinct technological choices within the same workshop could indicate artisan autonomy in production methods. Conversely, highly standardized techniques and materials would suggest stronger elite oversight of the manufacturing process. At Huacas de Moche, the homogeneous composition of molded fine ware ceramics compared to the heterogeneous composition of domestic wares suggests similar patterns may have existed in mold production (Bernier 2009; Chapdelaine et al. 1995; Vaughn 2006:331).

4. Results

Our microscopic and macroscopic analysis revealed the key characteristics of the Moche mold-making ceramic tradition by identifying specific gestures, methods, techniques, and tools used by ancient potters (see Tables 3 and 4). Significant variability has been documented in clay composition, forming techniques, and surface treatments.

4.1. Raw material procurement and preparation

4.1.1. Clay recipes

Vessels exhibit significant variability in raw material selection. Analysis revealed four main compositional groups, four subgroups, and six distinct clay types (Fig. 8). Table 2 presents the detailed results. It should be stressed that this preliminary classification relies on paste variations observed through digital microscopy, clustering samples with similar compositional profiles (see Druc and Chavez 2014; Rey de Castro 2019). Future petrographic and chemical analyses will be necessary to confirm these initial findings and fully understand the samples' compositional diversity.

4.1.2. Paste preparation

Preliminary observations can also be drawn about paste preparation. This stage can include multiple steps: drying, pounding, sorting, hydrating, adding temper, and wedging (Druc 1996:27-30; Roux 2017:4). In our sample, the even distribution of inclusions, absence of voids, and high compaction levels observed at macroscopic scale (see, for example, Groups 2,3, and 4) suggest careful paste preparation through thorough kneading (Druc and Chavez 2014:72-73). However, further petrographic analysis is needed to reveal more detailed insights, particularly regarding paste refinement and temper addition (Druc et al. 2020:2).

4.1.3. Local geology and possible origin of raw materials

Identifying the source areas for raw materials used in mold-making is challenging, primarily due to the lack of comprehensive geochemical analysis of clay sources from the Moche Valley (Arrelucea 2019:56; Espinosa 2023:263-266). This challenge is further complicated by the high degree of geochemical similarity among valleys of Peru's central-north coast (Druc et al. 2020:8). Nevertheless, some preliminary observations can be drawn. The sample reflects the geological environment of the lower and middle Moche Valley, containing Casma-type rocky outcrops and elements such as biotites, feldspars, quartz, iron, and pyroxenes (see Regional Geological Map 17-f). Both Neutron Activation Analysis (Chapdelaine et al. 1995) and petrographic studies (Espinosa 2023:266) indicate that artisans at Huacas de Moche used locally

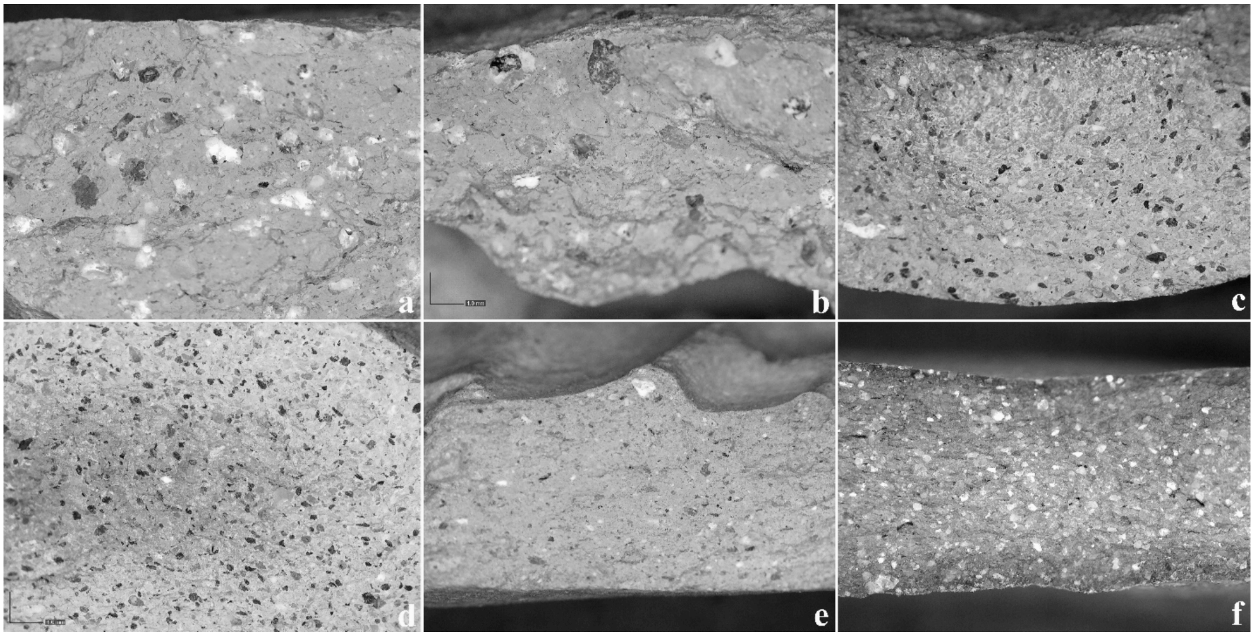


Fig. 8. Compositional groups identified in the sample: (a) subgroup 1A; (b) subgroup 1B; (c) subgroup 2A; (d) subgroup 2B; (e) group 3; (f) group 4.

sourced raw materials to produce fine wares and figurines. A similar pattern can be reasonably expected for the molds. This practice of local sourcing is well-documented across the Moche valleys (Del Solar 2015; Espinosa et al. 2021; Koons 2015; Rohfritsch 2010) and aligns with ethnographic studies showing that raw materials were typically collected within a 2-3 km radius, rarely extending beyond 5-7 km (Arnold 1988:32-57; Druc 1996, 2013).

4.2. *Shaping*

Shaping techniques for mold production at CA-60 consist of two distinct stages: (a) *roughout* – the initial hollow form that lacks the container's final geometric characteristics; and (b) *preform* – the container with its final geometric shape but before any surface finishing techniques are applied (Roux 2017:5).

Table 2
Summary of compositional analysis (based on Orton and Hughes 2013:275-285).

Groups	Paste color	Type of clay	Mineralogical composition of the inclusions	Inclusions scale of roundness	Inclusions scale of sorting	Percentage of silt	Samples
Group 1 Subgroup 1.A	Reddish/ orange /brown	1/3	Mafic rocks (53 %) Felsic rocks (35 %) Lithoclasts (12 %)	Angular-Subangular	Poor	Medium-low	181C, 252, 254E, 257C, 204A, 214A
Subgroup 1.B	Orange/ brown/gray	1/3	Mafic rocks (56 %) Felsic rocks (34 %) Lithoclasts (10 %)	Angular-Subangular	Poor	Medium-low	154A, 159, 170A, 170B, 171B, 179, 210H, 301
Group 2 Subgroup 2.A	Orange/ brown/gray	2/5	Mafic rocks (64 %) Felsic rocks (25 %) Lithoclasts (11 %)	Angular-Subangular	Fair	Low	172A, 172C, 187, 188B, 192B, 192C, 196I, 206A, 206C, 207A, 216A, 221A, 235, 244B, 244C, 253A, 253 J
Subgroup 2.B	Orange/ beige	2/5	Mafic rocks (66 %) Felsic rocks (23 %) Lithoclasts (11 %)	Angular-Subangular	Fair	Low	204B, 210G, 249B, 251, 261C, 272D, 272E, 277A, 290A, 307, 318
Group 3	Orange/ brown	2/4/5	Mafic rocks (65 %) Felsic rocks (25 %) Lithoclasts (10 %)	Angular-Subangular	Fair-good	Medium-low	178C, 182I, 190, 192A, 247C, 249A, 257A, 268, 274B
Group 4	Orange/ brown/gray	2/6	Mafic rocks (61 %) Felsic rocks (29 %) Lithoclasts (10 %)	Angular-Subangular	Good	Medium-high	175A, 178A, 178B, 182B, 182C, 182H, 184A, 184B, 184C, 188A, 193A, 193C, 195A, 196B, 201A, 206E, 210B, 216B, 217, 221B, 224, 232, 236A, 247A, 247B, 247D, 253B, 265, 274C, 290B

Type of clay	Groups	Description
1	1.A/1.B	Clay of ferruginous type that presents subangular and angular minerals, with a medium concentration of lithics
2	2.A/2.B/3/4	Clay of ferruginous type, but highly pyroxenic, with a medium to low concentration of angular and subangular type minerals
3	1.A/1.B	Clay slightly ferruginous with medium to low silt concentration, with medium and small lithics of angular and subangular type
4	3	Clay characterized by the presence of carbonates
5	2.A/2.B/3	Clay strongly ferruginous, with a medium to low level of silt, and few lithics of angular and subangular type
6	4	Clay of ferruginous type with high to medium silt concentration, and medium to low lithics of angular and subangular type

Table 3
Main diagnostic traits of the ceramic mold assemblage from CA-60 at Huacas de Moche (Quinn 2013; Rice 2015; Roux 2019).

Chaîne Opératoire steps						
Shaping			**Finishing**		**Decoration**	
Technique	Diagnostic features		Technique	Diagnostic features	Technique	Diagnostic features
	Macroscopic scale	Microscopic scale		Macroscopic scale		Macroscopic scale
Discontinuous pressure and scraping on wet clay (roughout)	Rounded depressions, fingerprints,irregular topography of the inner walls, bumpy walls and fissures, deep grooves	Irregular micro-topography; horizontal, elongated, subparallel voids	Smoothing on wet clay with fingers/soft tool	Fluidified micro-topography ribbed and threaded striations	Painting	Color difference (white/red) between the painting and ceramic body
Coiling of the rim (preform)	Horizontal fissures on the surfaces and overthicknesses on the rim, uneven walls, visibility of segment coil junctures	Random and oblique voids, presence of relic coils			Negative relief - Incisions on wet clay / leather-hard clay	Thin grooves (0.5–1.5 mm width), cross-sectional shape of a “U” or “V”, ribbed striations and protruding grains (microscopic scale)

4.2.1. *Discontinuous pressure and scraping*

When forming a mold, a solid item, either a pottery matrix or an actual object, is required to rough out the body (Donnan 1965:118). Discontinuous pressure was one of the primary techniques used at this stage. Fingerprints are commonly visible to the naked eye on the external surface of the molds (Fig. 9a). Their orientation varies, indicating multidirectional movements. As with mold usage (see Arnold 1999:62), artisans possibly applied powder temper, ash, or another release agent to prevent clay from adhering to the matrix. Additionally, scraping was another technique performed alongside pressure, as evidenced by the presence of grooves on molds’ exterior surfaces.

4.2.2. *Coiling*

In 20% of the molds, artisans added a peripheral coil to the outer edge of the rim during the preforming stage. It typically measures between 0.5 and 1.5 cm in width and protrudes approximately 2-5 mm, forming a slight bulge (Fig. 9b,d). The coil structure is also evidenced macroscopically by the presence of concentric marks (Fig. 9c). Since the rim is the most fragile part and susceptible to breakage or deformation during firing, this additional clay strip served as reinforcement, strengthening the mold’s most vulnerable section. The coil was applied using pressure and scraping techniques.

4.2.3. *Cut marks*

Cut marks appear on the flat surface of the lip in 44 molds (26%) (Fig. 9e-h). These thin grooves, ranging from 0.5-1.5 mm wide, form clusters of irregularly distributed marks along the lip. Their visibility varies: being easily noticeable to the naked eye in some sections, while nearly imperceptible or completely absent in others. The marks show a curvilinear orientation, suggesting they were made through repeated brief oblique movements with a rotary motion toward the exterior, likely using a cutting tool. As discussed later, this feature provides crucial insight into the mold-making sequence, indicating that artisans produced mold halves independently rather than cutting them from a single clay piece (see Table 4 and Fig. 15).

4.3. *Finishing*

Smoothing is a finishing technique used to even out the surfaces of clay vessels (Ionescu et al. 2015). At CA-60, artisans applied this technique almost exclusively to the internal surface of molds while the clay remained wet, using either soft tools or their hands. Diagnostic features include: fluidified micro-topography and ribbed striations (Fig. 10a-b). Artisans made multidirectional movements, primarily horizontal strokes along the vessel’s rim. In one instance, evidence suggests that potters used cloth to homogenize the internal surface or to wrap up moist clay before use (Fig. 10c-d).

4.4. *Surface treatments*

No surface treatments, such as burnishing or coating, were identified either macroscopically or under magnification.

4.5. *Decoration*

Two types of decorative techniques were identified: low relief or one-dimensional decoration (painting) and negative relief or recessed decoration (incised-simple). Painting was very rare, appearing in only 1% of cases. White paint was found along the internal rim of an earring mold (Fig. 11a), while traces of red pigment were identified on the

Table 4
The principal steps in fabricating a two-part mold (adapted from Arnold 1999:62, Table 5.I.).

1. Make the mold matrix
2. Flatten a lump of clay with the hands
3. Apply wood ash or another release agent to the matrix surface to prevent the clay from adhering to the mold
4. Press and shape the flattened clay against the first half of the matrix
5. Add a reinforcing peripheral coil to the outer edge of the rim
6. Smooth and even out the lip surface using a cutting tool and/or fingers while the clay is still moist
7. Apply a separating material, such as sand, to the lip surface to prevent the two halves from sticking together
8. Flatten a lump of clay with the hands
9. Press and shape the flattened clay against the second half of the matrix
10. Smooth the outer surface of the molds with moistened hands
11. Apply exterior marks on moist or leather-hard clay for functional and/or symbolic purposes (pictorial alignments/register marks/pictorial notations)
12. Set the mold halves aside to dry (the matrix still in place)
13. Remove the matrix from the mold halves
14. Firing the mold halves

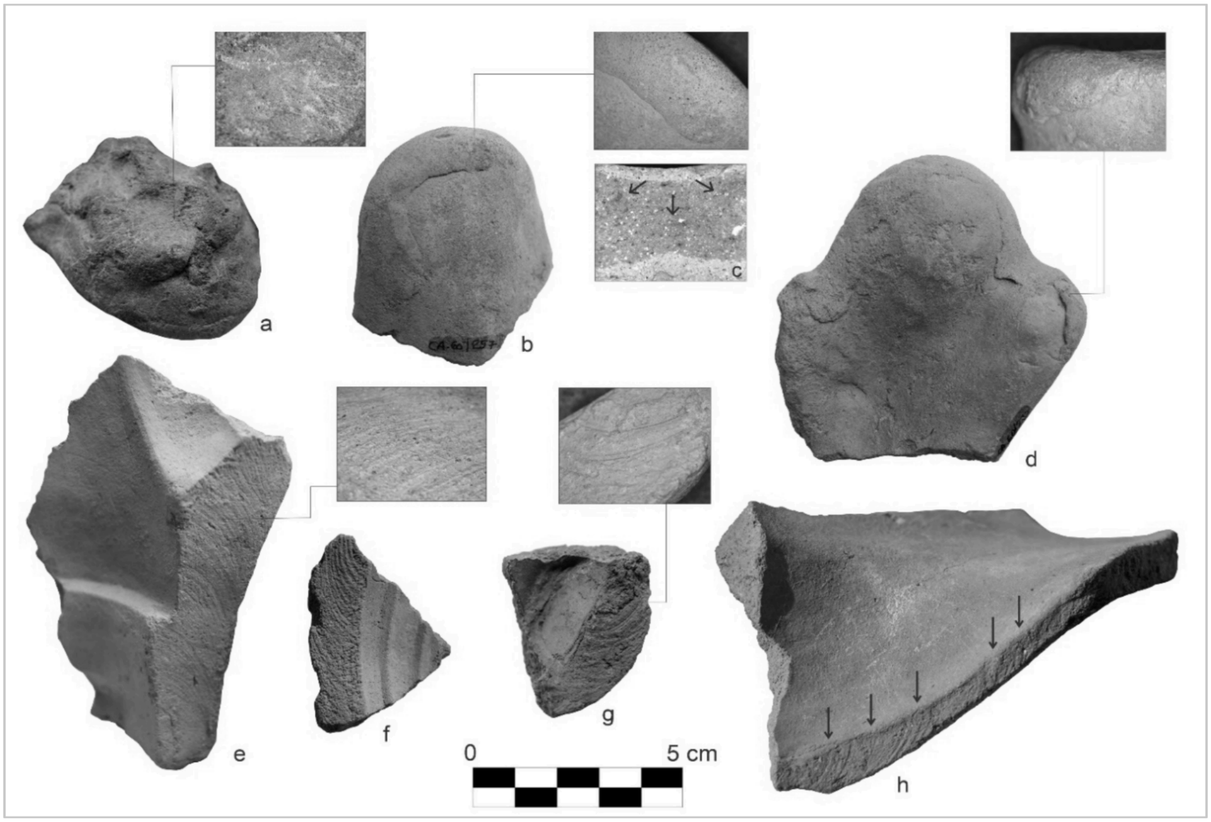


Fig. 9. Diagnostic features of the fashioning step of the manufacturing process. (a) Fingerprints indicating discontinuous pressure; (b,d) coils applied along the rim and (c) visible at microscopic scale; (e-h) cut marks.

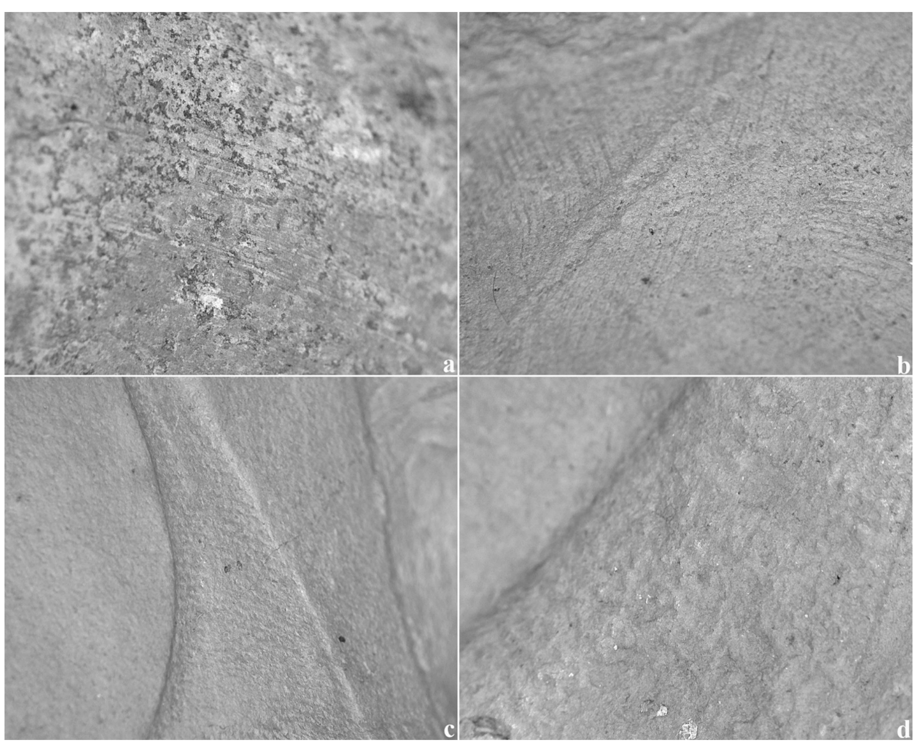


Fig. 10. Diagnostic traits indicative of finishing techniques. (a-b) fluidified micro-topography and ribbed striations made with a soft tool or hands. (c-d) cross-hatched striations suggesting the use of a piece of cloth.

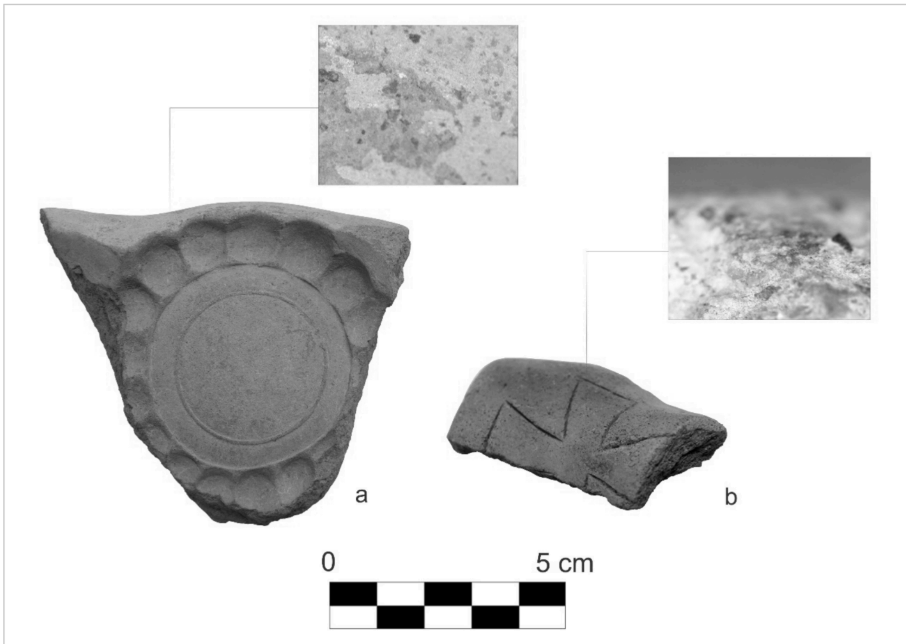


Fig. 11. Molds showing evidence of (a) white and (b) red paint usage. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

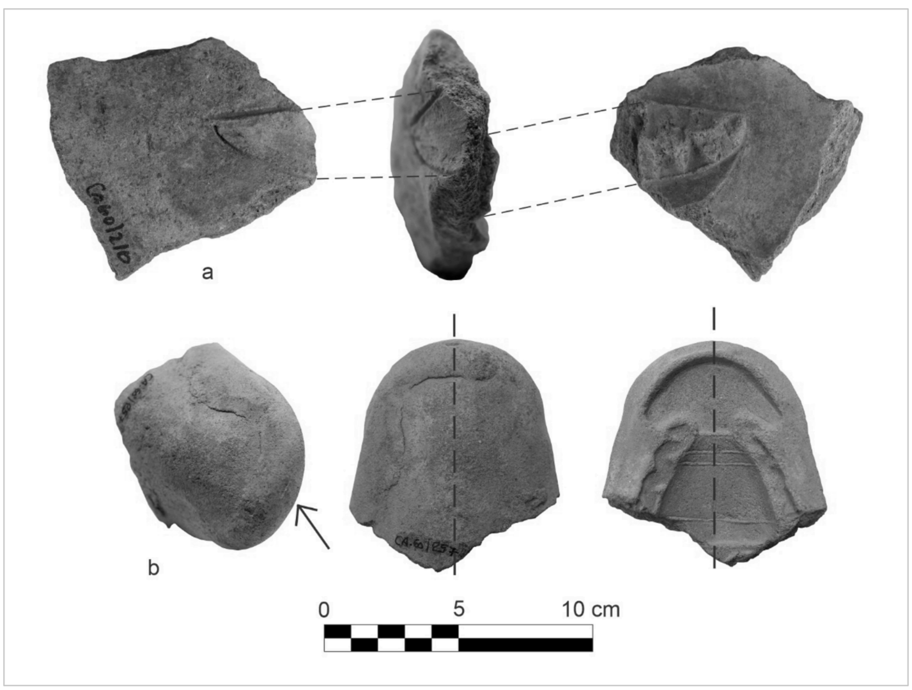


Fig. 12. Molds with evidence of (a) "pictorial alignments" and (b) "register marks".

external surface of a figurine mold (Fig. 11b). Although uncommon, the use of post-firing painting suggests that some molds were valued not only for their functional purpose but also for their aesthetic qualities.

Incisions on the external surface of molds are far more common. Following Jackson's (2000, 2002) classification, we identified three types of exterior marks: pictorial alignments (three sherds), register marks (four sherds), and pictorial notations (42 sherds). Pictorial alignments (1%) are stylized images sketched on the mold's exterior surface that roughly mirror the motif inside. These markings served as references for correctly aligning multiple-piece molds, depicting features such as eyes, nose, mouth, and snout of human or animal imagery (Fig. 12a). Similarly, register marks (1%) are small lines placed at key points on the vessels (axes of symmetry and/or junction points) to guide alignment (Fig. 12b).

Pictorial notations (25%) are by far the most common type of exterior marks. These abstract markings neither match the imagery inside the mold nor relate to the manufacturing process. The identified symbols include six *porras* (war-clubs) and six crosses (Fig. 13a-f). The widespread use of pictorial notations suggests an intricate interplay between practical and symbolic aspects of mold-making. Microscopic

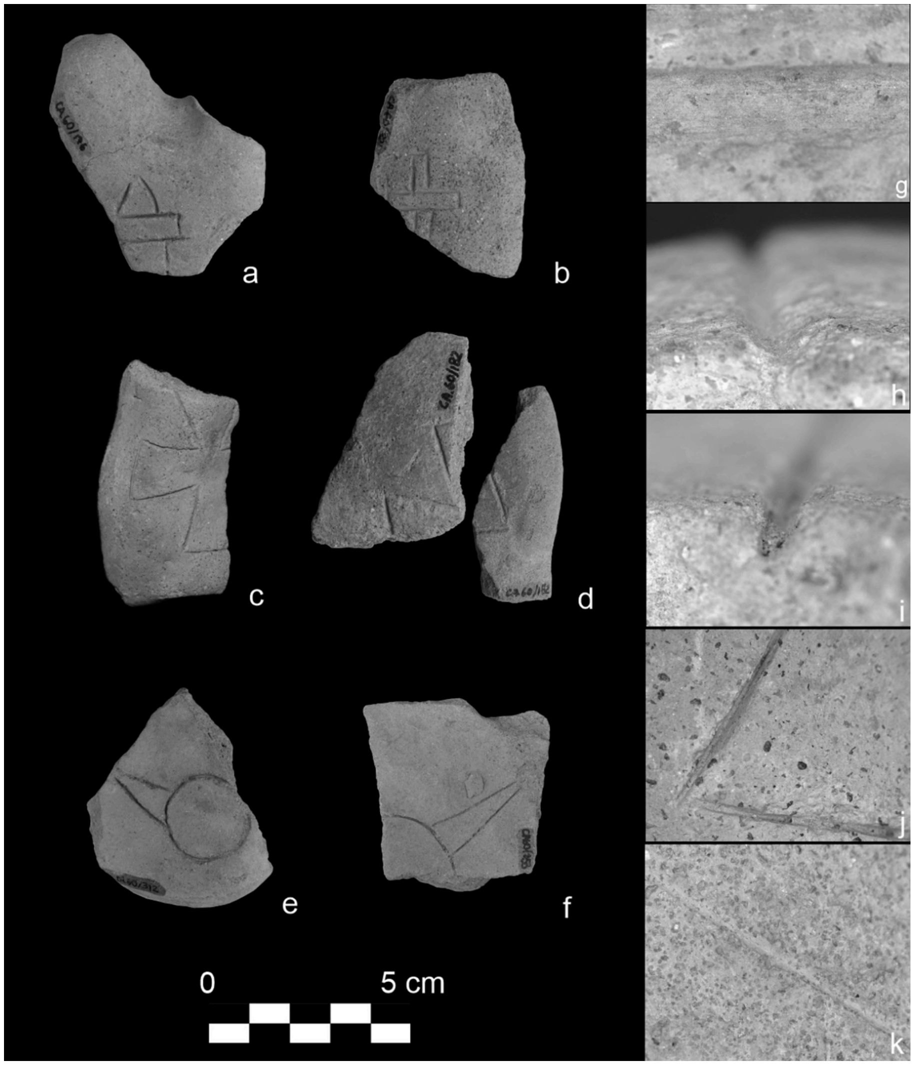


Fig. 13. Molds showing different types of pictorial notations: (a-b) “porras” or war clubs, (c-d) crosses, and (e-f) geometric motifs. (g) Ribbed striations and protruding grains visible at microscopic scale. Incisions with (h) “U” shape and (i) “V” shape suggesting the use of different tools. Incisions made on (j) moist clay and (k) leather-hard clay.

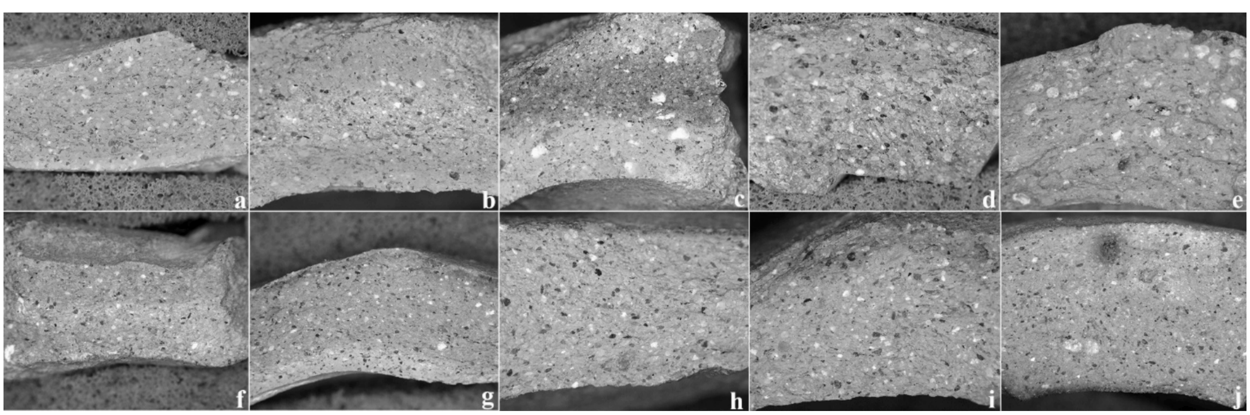


Fig. 14. Radial section of sherds showing different firing conditions: (a) complete oxidation; (b) partial oxidation (margins); (c) partial oxidation (inner margin); (d) partial oxidation (outer margin); (e) complete reduction; (f) partial reduction (margins); (g) partial reduction (final oxidation margins); (h) partial reduction (final internal oxidation); (i) partial reduction (final external oxidation); (j) incomplete reduction on a different scale.

examination of the grooves reveals additional manufacturing details. Ribbed striations and protruding grains indicate the use of a wet tool on wet clay, possibly a feather shaft or wooden stick (Fig. 13g). The incisions exhibit either “U” or “V” shaped profiles, with widths of 1-2 mm and typical depths of 1 mm (Fig. 13h-i). While most markings were made on moist clay (Fig. 13j), some were created on leather-hard clay

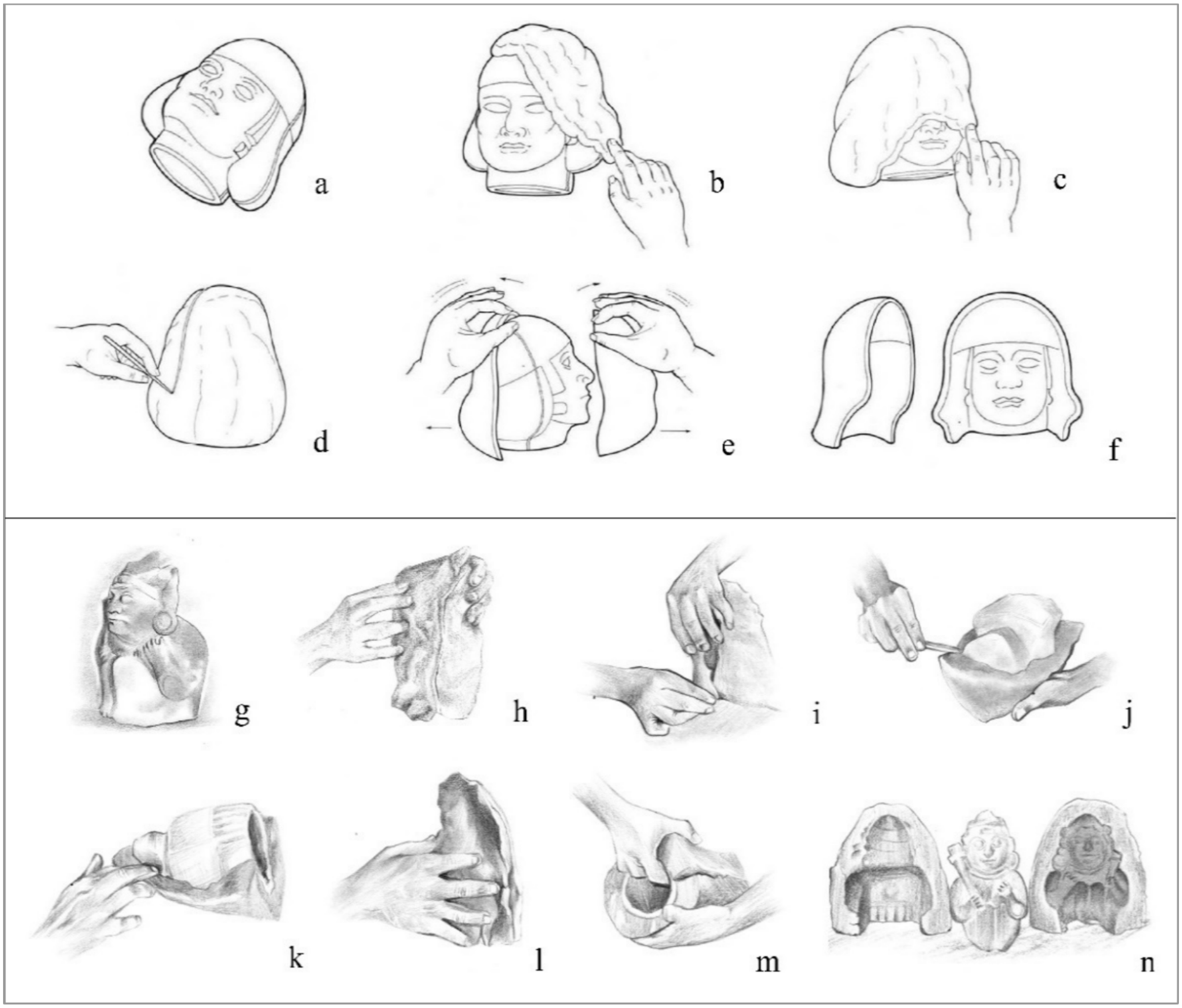


Fig. 15. (a-f) Donnan's scheme illustrating the steps in manufacturing a two-part mold for a portrait vessel (adapted from Donnan 2004:24, Fig. 3.2). (g-n) An alternative model derived from macro- and microscopic analysis applicable to different categories of multiple-piece molds.

(Fig. 13k).

Digital microscope analysis of war clubs (*porras*) grooves also revealed distinct sequences of gestures in creating these drawings, showing different modalities while maintaining a shared symbolic language (see Mosna 2024:53-55).

4.6. Firing

Most molds (78%) were fired in an oxidizing environment (Fig. 14a-d). The radial sections of these sherds typically displayed a "sandwich" coloration—a grey core with reddish margins—indicating incomplete oxidation. This variation in oxidation is common in open firing kilns (Roux 2019). The remaining 22% of ceramics showed evidence of reduced firing conditions, characterized by a greyish core (Fig. 14e-j). Complete reduction firing was rare. The reduced molds also exhibited considerable variation in their firing conditions.

5. Discussion

5.1. The technological complexity of mold-making

Arnold (1994, 1999) showed that vertical-half molding technology, despite its apparent simplicity, involves multiple complex sequential steps. As our results suggest, a similar argument can be made for the production of the molds themselves. The fabrication of a two-piece or bivalve mold involves up to 14 distinct steps (Table 4).

The complexity of mold-making manifests in several key aspects: careful paste preparation to ensure even distribution of inclusions and high compaction; specialized forming techniques like coiling; diverse finishing methods such as smoothing with soft tools or hands; and deliberate use of decorative elements, from painting to the more common incised markings that serve both practical and symbolic functions. Modern potters at Campiña de Moche, near the archaeological complex, employ similar techniques to those identified in the archaeological record, including careful clay preparation, the addition of reinforcing coils, the use of a cutting tool to separate mold halves, and controlled drying and firing processes (Mosna 2024:78-98).

5.1.1. *Alternative method of two-piece mold production*

To date, Donnan's (2004:24) operational sequence for Moche portrait vessels remains the only documented manufacturing process for two-piece molds. In his proposal, the artisan first covers the matrix's exterior completely with a layer of moist clay (Fig. 15a-c). Then, cuts the clay into two parts with a pointed tool (Fig. 15d). Once the clay begins to dry, the halves are carefully removed, allowed to dry completely, and then fired (Fig. 15e-f). Our results suggest an alternative, possibly complementary model. Rather than fully coating the matrix with clay, the artisan first presses clay onto the front half up to the vertical axis (Fig. 15g-h). The edge can be reinforced with a clay strip (Fig. 15i). The lip's plain surface is made uniform by removing any protruding grains with a cutting tool or fingers (Fig. 15j-k). Notably, cutting moist clay as described by Donnan would not produce the same marks we observed at the microscopic level (see Fig. 9e-h). The opposite valve is formed using the same procedure but without smoothing the lip's surface, after which the two pieces are joined together (Fig. 15l). Once the clay begins to dry, the halves are carefully removed from the matrix, allowed to dry completely, and fired (Fig. 15m-n). This method is applicable to the production of various types of multiple-piece molds. It also offers the advantage of constantly monitoring the joint lines between the parts, a key aspect when manufacturing sculpture forms with pronounced angles. Indeed, both methods can coexist within the same assemblage, representing different approaches to mold-making.

5.2. *Social dimensions of pottery production at CA-60: Insights from mold analysis*

5.2.1. *Craft organization at CA-60*

The technological analysis of mold-making can offer additional insight into the social organization of ceramic production in ancient societies. Without doubt, this represents just one piece of complementary evidence that must be considered alongside other primary sources, including finished products, production waste, workshop architectural features, and other archaeological indicators (see Costin 1991, 2005). Unlike the routine use of molds in pottery production, their manufacturing was not an everyday activity. The technological choices in mold-making could be easily influenced by circumstantial factors (e.g., the availability of raw materials, energy, and time) rather than being strictly tied to artisans' social circles and learned practices within communities (Sillar 2000; Sillar and Tite 2000). Nevertheless, since molds are objects closely tied to production processes and potters' social spheres, they can provide valuable perspectives on the organization of pottery production.

The evidence presented in this paper indicates that Moche leaders did not supply craftsmen at CA-60 with production tools like molds or raw materials to make them. Instead, local potters operated independently, exercising autonomy in both sourcing materials and crafting molds according to their own standards. Yet their autonomy was balanced with oversight mechanisms. While potters maintained independence in their craft techniques and material choices, they still needed to meet quality standards and production quotas set by urban elites. Molds produced at CA-60 were primarily used to create "intermediate goods"—a class of objects consumed by the general urban population under the supervision of urban leaders—within a model of controlled yet semi-autonomous production (Bernier 2009, 2010). Though the mold creation process allowed for artisan autonomy, mold usage had to meet state requirements, ensuring consistent quality in the final products, as evidenced by quality control measures in the finished fine ceramic vessels (e.g., Donnan 1978, 2004, 2011; Quilter 2021).

The workshop's location within the urban core reinforces this oversight arrangement (see Fig. 2). Its easy access from the main street suggests that artisans engaged in direct transactions with urban leaders, who could walk over to commission pieces and inspect both finished objects and production tools. While this location enabled oversight, craftsmen at CA-60 maintained their specialized practices within a household setting, as shown by abundant domestic refuse and architectural features typical of Moche residential spaces. The integration of craft and living spaces indicates household-level production organization, where family units likely participated in various manufacturing processes (Bernier 2010; Uceda 2010b; Van Gijseghem 2001). This arrangement allowed craftsmen at CA-60 to maintain their specialized techniques while meeting broader production requirements. The mold-making process itself exemplifies this dynamic, with artisans exercising creative freedom in their manufacturing methods while ensuring their products met established standards.

The findings reveal a more nuanced picture of social complexity within craft production systems, where artisans successfully maintained creative autonomy while meeting established quality standards and output requirements. This dynamic balance between individual craftsmanship and institutional oversight created a system where technical innovation could flourish within established parameters, allowing for both creativity and consistency. The relationship between technological diversification and standardization emerges in this study as complementary aspects of craft production, combining personal expertise with collective production goals. This diversity in mold production methods, rather than indicating a lack of organization, demonstrates how multiple approaches and methodologies could coexist effectively within a structured production system. Further insights into craft organization patterns emerge from analyzing the technological variability of molds in the following section.

Table 5
Chaîne opératoire stages in the Moche mold-making process (adapted from Lara and Bray 2025:Table 2).

Provenance of clay material	Moche Valley (based on paste compositional analysis in the absence of petrographic data)
Shaping (Roughing-out)	Discontinuous pressure / scraping (wet clay) (Mold body)
Shaping (Pre-forming)	Coiling / discontinuous pressure / scraping (wet clay) (Mold rim)
Finishing	Smoothing on wet clay with fingers or soft tools / absent (Inner and/or external surface)
Surface treatment	Absent
Decorative techniques	Painting / incisions on wet-leather-hard clay / undecorated
Firing	Oxidizing firing conditions characterized by incomplete combustion (Reducing firing also present but less common)

5.2.2. *Assessing technological variability in Moche mold production*

As discussed earlier, the *chaîne opératoire* approach provides a valuable framework for analyzing the social background of craftspeople. Technological choices are deeply rooted in social learning networks and communities of practice where knowledge passes through apprenticeship. These choices become routinized and embodied in the craftsperson's habitus, reflecting both individual agency and collective traditions. By identifying variations in *chaînes opératoires* that are not related to function, we can distinguish different groups of producers (Espinosa et al. 2024; Lara and Bray 2025; Roux 2017).

When examining the Moche mold-making tradition at CA-60 through this lens, we observe significant variations in paste recipes, shaping techniques, decoration, and firing methods within each morphological group (Table 5). No clear correlation exists between specific *chaîne opératoire* sequences and particular mold categories. Rattles (Fig. 6i-k) may represent the only exception, showing notable standardization despite the small sample size (n=5). They feature high-quality clay paste (compositional group 3), pictorial notations (4/5), and complete oxidized firing (4/5). As Moche's only percussion instrument (Gayoso 2011:158), rattles held ritual significance for priests and healers (Scullin and Boyd 2014:19-25). The molds themselves may have carried symbolic meanings tied to their produced objects, though additional samples are needed to verify this pattern.

Among other mold categories, significant technological variability—especially in the shaping stage which constitutes the "hard core" of the *chaînes opératoires* (Espinosa et al. 2024:679; Lara and Bray 2025:2; Roux 2020:19)—suggests multiple mold-making traditions coexisted at the CA-60 workshop. Within the same morphological category—particularly in figurines, which comprise 62% of the sample—artisans employed multidirectional discontinuous pressure and scraping as basic techniques for *roughing-out* the vessel form. At the subsequent *preforming* stage, they used different techniques: some artisans added coils to the rims, while others simply smoothed and shaped the edges through scraping and discontinuous pressure. Beyond these variations in rim shaping, artisans apparently used diverse methods for *roughing-out* the body, as evidenced by cut marks on the lip's surface (see Section 5.1.1.). These manufacturing variations suggest that multiple mold-craft traditions coexisted within the workshop, where individual artisans maintained their specialized techniques while operating within broader workshop conventions.

The way artisans shaped and combined valves during the *roughing-out* stage to create multiple-piece molds may provide another valuable indicator for identifying distinct potter communities through mold analysis (see Shimada and Wagner 2019, for the case of stirrup spout bottle molds at the Lambayeque workshop of Huaca Sialupe). Portrait vessels in our sample illustrate this well. In the Moche Valley, artisans typically used two-part molds (Fig. 6n and 16a). At Cerro Mayal in Chicama, however, craftspeople employed three-part molds—two for the face and one for the back of the head (Fig. 16b). Interestingly, modern potters from "Campiña de Moche" use yet another configuration: two pieces for the backside and one for the front (Fig. 16c). This technical choice lies at the heart of the *chaîne opératoire*, revealing deep differences in how objects are conceptualized and manufactured. These differences influence all other stages of production and likely reflect distinct technical traditions passed down through generations of potters.

While variations in manufacturing techniques suggest individual artisans maintained their own specialized knowledge and techniques, the shared repertoire of pictorial notations on molds' external surfaces indicates common practices and conventions across the workshop. These symbols likely served multiple purposes: identifying individual craftsmen's work, tracking production quotas, incorporating symbolic elements in craft, and functioning as a proto-writing or semasiographic system (Jackson 2000, 2002; Johnson 2021:156-157; Young and Cook 2023:19). The geographic distribution of these markings across Moche regions in the North Coast reveals compelling patterns. Specific symbols, including the "porra" (war-club) and "florero" (flaring vase), appear across ceramic workshops in the Moche (Jackson 2000), Nepeña (Rengifo 2016:380, Fig. 12.12b), and Chicama Valleys (Jackson 2002:124, Fig. 410). Potter communities along the North Coast may have shared values, beliefs, and social identities, visually depicted on the molds' exterior, reinforcing their cultural identity and cohesion. The molds thus transcended their practical function, becoming artifacts imbued with sacred and symbolic meaning that reflected the intricate relationship between technology, religion, and politics in Mochica culture, opening up a fascinating area for further research (Shimada 2016, 2022).

6. Conclusions

Although molding technology has long been recognized as a cornerstone of pre-Columbian ceramic production, previous research has focused primarily on the molding process and its products. This study breaks new ground by systematically reconstructing the mold-making process itself, revealing both its technological complexity and social implications. Through analysis of samples from CA-60, a newly discovered ceramic workshop at Huacas de Moche, this research provides novel insights into the specialized craft production and technological sophistication of local artisans. Our findings show that mold-

Fig. 16. Molds of portrait vessels from: (a) private collection (Donnan 2004:24, Fig. 3.3b and 3.3c) and (b) Cerro Mayal (Jackson, 2000:253, Fig. 2.3c). (c) Matrix of a portrait vessel used by modern potters at "Campiña de Moche" (Mosna 2024). The entry and exit points of the molds are indicated.

making involved up to 14 distinct steps and specialized knowledge to ensure quality and functionality—a technical complexity previously overlooked. We also identify an alternative operational sequence for two-piece mold production, complementing previously documented techniques.

This research also uses mold-making evidence, alongside other archaeological indicators, to explore the social organization of craft production. Such evidence suggests that, at CA-60, Moche leaders did not supply craftsmen with molds or raw materials, allowing artisans to maintain independence in tool manufacturing while operating under broader production oversight. Although artisans maintained autonomy in material choices and mold-making techniques, they operated within a system of elite supervision that ensured molds were used to meet quality standards and production quotas through a controlled, yet semi-autonomous system. The considerable variation within mold categories —particularly in paste recipes, shaping techniques, decoration, and firing methods— suggests that potters from distinct technical traditions shared the workspace. Meanwhile, the widespread use of pictorial markings on molds' exterior surfaces demonstrates a cultural and ideological connection among local craftsmen, though their recurrence along the North Coast illuminates the shared cultural background of Moche communities.

These findings offer valuable insights into how technical knowledge, social organization, and political control intertwined in ancient specialized craft production systems. The workshop evidence shows that social complexity manifested itself not through simple top-down hierarchies, but through sophisticated networks of relationships where elite supervision and craftsman independence found a delicate yet productive balance. Through the lens of mold-making, we found that technological diversity and standardization were not mutually exclusive but rather operated as complementary facets within a sophisticated production system. The technological choices of individual artisans simultaneously served as expressions of their cultural identity and technical expertise while fulfilling broader societal and economic needs. This nuanced interplay shows that standardization and individual technical expression functioned not as competing forces, but as complementary elements that enhanced both social cohesion and economic productivity.

The mold-making process emerges in this study as a fascinating dimension where artisans expressed their individual technical traditions and creativity while operating within a controlled craft production system. This dual nature of molds —as both standardized production tools and expressions of artisanal identity— provides valuable insights into the complex social dynamics of pre-Columbian craft production.

CRediT authorship contribution statement

Federico Mosna: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Carlos Rengifo:** Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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