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A MULTI-DISCIPLINARY APPROACH TO THE STUDY OF AN ASSEMBLAGE OF COPPER-BASED FINDS ASSIGNED TO THE PREHISTORY AND PROTO-HISTORY OF FUCINO, ABRUZZO, ITALY

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Abstract

The project aims to characterize, through a body of archaeometric analyses, an assemblage of copper-based finds known as 'Fucino bronzes', most of which lack any finding data. The Fucino bronzes include artefacts that emerged during the drainage of Lake Fucino at the end of the XIX century, as well as bronzes acquired locally or dug out later by several collectors on behalf of the various Italian museums where finds are currently distributed.

Our work explores the dynamics related to the objects assembled and relationships between production centres, local workshops, and the emergence of iron.

This study proceeds concurrently with the following research and cataloguing procedures: quantification, portable ED-XRF analysis, metallography, and the development of a database.

The finds are grouped into three main categories: ornaments and accessories, instruments, and weapons. The quantification is also classed in terms of typology, technology, chronology, and territory whenever possible, in order to establish customized models for the interpretation of data.

Metallographic analysis is carried out using optical microscope (OM) and SEM.

On this occasion we report the results of selected materials, such as 'Kardiophylakes' that make up about one-third of the known samples in the assemblage, thirty eight of which have a reported provenance from specific Fucino sites.

Keywords: *Copper-based finds; Archaeometric analysis; Fucino bronzes*

1. Introduction

The project aims to characterize, through a body of archaeometric analyses, an

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assemblage of prehistoric and proto-historic copper-based finds known as 'Fucino bronzes', most of which lack data regarding context or specific provenance. This body of Fucino bronzes includes artefacts which emerged during the drainage of Lake Fucino at the end of the XIX century, as well as bronzes acquired locally or dug out later by several collectors on behalf of the various Italian museums where finds are currently distributed. Contextual and provenance information is sometimes found in varying degrees of completeness.

Currently the Fucino bronzes are scattered throughout Italy: Roma, L. Pigorini Pre-historic and Ethnographic Museum; Perugia, National Archaeological Museum of Umbria; Chieti, National Archaeological Museum; Sulmona, Civic Museum; Avezzano, Permanent Exhibition of Farming and Pastoral Culture at Torlonia Palace; and Firenze, Archaeological Museum. The bronzes in the Chieti Archaeological Museum have already been analysed in a similar project and have therefore been excluded from the analytical phase of this study.

In a long-term, this research extends its analysis to those finds emerging from current and regular excavations for bronzes, vitrified material, and smithing pottery.

This study is part of the current description of updates on the development of ancient metallurgy and proposes a broader re-evaluation of all the resources available for the interpretation of metal finds, particularly as most of these are out of context. This work explores the dynamics related to the production of objects and their assemblage, alongside relationships between production centres, local workshops, and technological change from bronze to iron.

The study proceeds concurrently with various research and cataloguing phases:

- Quantification of finds
- Chemical characterization of materials by ED-XRF
- Metallographic examination of samples by OM and SEM
- Development of a database

For the moment, only the Roma and Perugia inventories have been included and quantified in the database. When possible the finds have been dated typologically. The following is a brief outline of the artefact typologies (fig.1): among the razors we note a double-edge style with a reported Menaforno provenance and a double axe Celtic motif [6], which is unique to this assemblage and the area; among the knives, the Matrei [3], Baiedorf and Halstatt are common throughout Central Europe, but other types such as the Ortucchio or the Celano [4] are specific to Fucino and hardly occur outside Central Italy; among the daggers [12], we see extremely ancient shapes common to Central Europe and the Mediterranean basin, as well as in the swords [9]; among the ornaments and accessories there are the usual pre-historic and proto-historic inventories [1-5], however the small bronze figurines from Fucino are mainly in quadrupedal form [2] and sometimes face backwards, which emphasizes the importance that hunting played for these communities; there are beads and spirals [10]; and lastly, a class of objects referred to in classical terms as 'kardiophylakes' [7,8], which are bronze or bronze/iron discs used for three centuries across the 'medio-Adriatic' proto-historic horizon which included the Fucino cultures.

Fig. 1. The materials

2. Experimental

For the quantification of these materials each object is grouped according to function in both classes and categories. At the same time, finds are also grouped typologically, technologically, chronologically, and territorially as appropriate, to derive customized models for data interpretetion. This methodology aims to deduce the socio-technological conditions from the materials themselves, using theoretical constructs so that data can be ordered and examined from various perspectives. The procedure provides part and parcel analyses that facilitate the development of a workable database.

Chemical analysis is carried out using a portable ED-XRF, which provides quantitative results that are comparable to the data produced by similar bronze characterization projects, such as the San Francesco hoard in Bologna [6] and the Chieti Archaeological Museum [in press], the latter also includes a number of the aforementioned Fucino bronzes..

The portable fluorescent X-ray system has the following technical features (Figs. 2, 3): Tube: Tungsten anode, Hv max 38 kV anode, Power anode, max 0.5 mA, air cooled; Size: 60(W)x200(D)x100(H)mm, Weight 2kg; Collimator diametre: 1mm. The tube avails of 35 kV tension and 0.2 mA power.

Detector characteristics: SDD (Silicon Drift Detector) cooled by a Peltier cell. Resolution from 150 eV to 6.4 keV. A multi-channel: 1,024 channels. Pointing system: laser diode. A portable ACER computer with a self-appointed spectrum management program.

All the analysis points have been registered on the reverse side or the least visible points of the objects and whenever possible the patinas have been removed. XRF-ED is a popular choice as chemical analysis methodology for cultural goods,

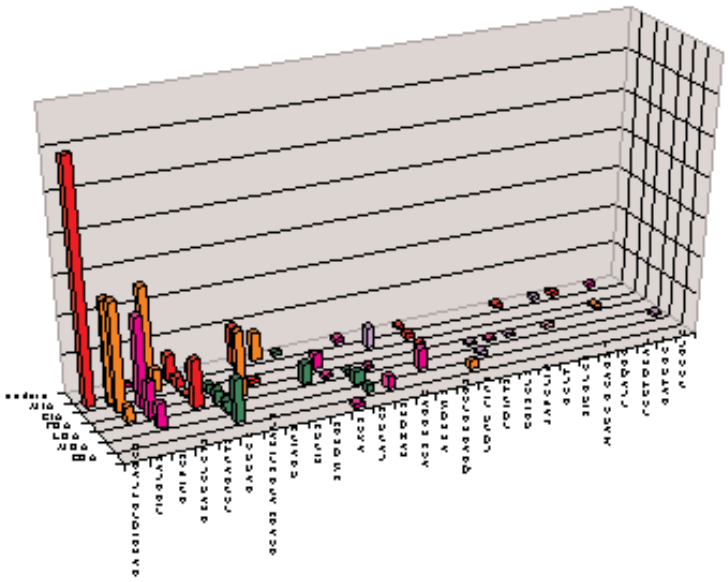

Fig. 2. Chronological quantification of functional classes of objects

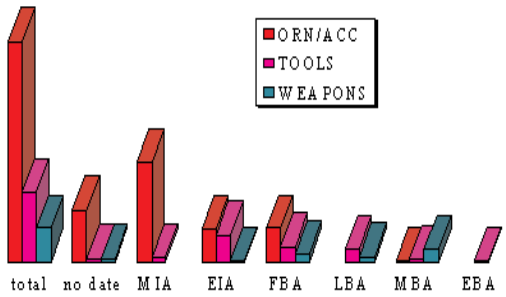

Fig. 3. Chronological quantification of categories of objects

because it can be completely non-invasive as well as portable. However, in this form XRF-ED analyses are influenced by problems associated with the irregular forms of the objects, protection windows, and a lack of emptiness. These problems strongly limit the penetration depth and the detection capacity of the equipment. In the case of a typical XRF system, the photons emitted by the X-ray source are absorbed in the first 10–100 μm of the object surface, depending on the density of the material and the X-ray beam energy. The penetration depth of a portable XRF-ED in unprepared samples cannot be estimated. Moreover, the removal of the patina is not always uniform and frequently uncovers metal layers where alloy composition varies based on many factors, such as environmental change or cooling methods used in the manufacturing process of an object [14].

For this research, the choice of XRF-ED firstly depends on museum requiements, but at same time responds to the necessity of providing a general view of the chemistry of these objects.

Both the Roma and Perugia museums, where most of the finds are located, do not permit the application of chemical agents for micro-structural analysis of the materials. On the other hand, the operational chains related to the production of objects, such as those in this assemblage, are applicable [9,10,12,13, 15]. In which case, metallographic analysis aims to collect data on assemblage, maintenance and the reparation of objects. This could therefore be defined as macro-metallography, although this kind of definition is not universally recognised.

Metallographic analysis of finds is carried out with a stereo optical microscope (80x) and a SEM whenever possible.

So far metallographic analysis has been carried out on all the materials in the Pigorini Museum, while analysis of the Perugia inventory is still underway. All the objects are weighted and sized, and a descriptive label with all the technical data on each has been drawn up for the publication of the database.

Given the large number of finds involved with the Fucino bronzes complex, only 316 of which are from the Roma and Perugia museum inventories, the chemical analysis and metallographic examination of these finds requires the following cross-sectional models:

- Analysis of functional classes
- Analysis of technological classes
- Analysis of selected territories

3. Results and Discussion

These objects are functionally grouped into 27 classes and 3 categories (Figs. 2, 3): tools, ornaments and accessories, and weapons, which are narrowly defined as objects intended to harm others.

Chronological graphics illustrate the common tendency of Bronze/Iron Age inventories, which generally include larger groups of weapons and tools from early periods and ornaments and accessories from more recent times. The Middle Iron Age in Italy reports a steady increase in the ornaments/accessories category, given the use of precious gifts in the burial rituals of the rising IA communities.

Among the most interesting classes in the ornaments/accessories category are the kardiophylakes, bronze, or bronze iron discs, which form the major group in the functional classes and the most representative material classified in terms of technology. With 60 units, 26 in Roma and 34 in Perugia, kardiophylakes in this assemblage comprise one-third of the known samples. They have for a long time been interpreted as components of armour, but currently they are more widely linked to an expression of social and cultural belongings and associated with both genders. Chronologically, geometrical discs of bronze (Figs. 1:7) are considered the earliest ones and dated to the VIII century BC while figurative discs of bronze back supported by iron sheets (Figs. 1:8) are considered the latest ones and dated to the VI century BC. The earliest samples are –conical or slightly convex thick sheets of bronze with strictly geometric decorations and with bronze or lead constitutive elements. Patinas suggest that no iron constitutive elements were used until the emergence of the ‘orientalizzante’ style in its earliest form by geometrical patterns of figurative elements. As iron use increased, the bronze sheets became thinner and flatter and the latest ones are systematically back supported by iron sheets, attached at the front with studded nails or folded along the entire rim. In the later case, a solitary figure fills the space, free from any form or constriction. Certainly, the iron revolution was not just a dramatic technological change.

Since most of these objects appear to have been frequently repaired, as products for consumption with the addition of different metals and alloys, technological classes are based on their affinities in terms of constitutive elements or the degree and types of maintenance and reparation. Particular attention is given to determining the chemical compositions and technologies of

the various constituent elements of the artefacts or parts of reparation, in order to compare data both in the same artefact and among objects showing similar interventions.

Regarding the kardiophylakes, the most frequent secondary interventions are shown on fractures along the rim or around the concave centre of the disc, with small plates supported by two or more rivets. This kind of reparation may have occurred using mainly bronze plates and rivets, iron plates and bronze and/or iron rivets, or whole iron intervention, which powerfully corroded the objects. This allows us to recognize technological sequences related to the widespread use of iron in the area and suggests integrated chronologies for the objects and eventual links among the workshops or -throughout the line- metalwork traditions.

Kardiophylakes plentifully document the chronological passage from bronze to iron technology in terms of production centres and particular local metal workshops. In fact, most of the discs, including the earliest samples, show frequent repairs with the addition of iron elements long before iron was in use as a constitutive element.

In table 1 and figure 4, the quantitative chemical results of 6 discs and their relative elements are reported.

Tab.1. XRF results of 6 discs from the Pigorini Museum

n inv	point*	Cu	Sn	Pb	As	Fe	Ag	Sb
54072	nail	85.6	12.2	1.2				1
83114	nail	81.5	11.9	2.5		3.1	0.1	0.9
72490	nail	94.4	5.6					
83114	sheet	89.3	6.9	2.4		1.4		
72491	sheet	81.5	12.3	4.8	0.5			0.9
72490	sheet	87.9	9	2.1				0.9
54072	sheet	87.7	8.7	2.2		0.7		0.8
80335	sheet	99.1	0.9					
70925 - 2	sheet	93.6	2.7	2.8	0.4			0.6
70925 - 1	sheet	76.6	21.1	1.6		0.6		
70925 - 3	sheet	89.3	8.6	1.2				0.8
70925	plate	86.4	12	1				0.7
72491	plate	87.6	8	3.2				1.2
80335	rivet	73.4	8.4	1.1		16.4		0.8
70925	rivet	88.6	10.2	0.7	0.4			
72491	rivet	88.4	8.4	2.1				1.1

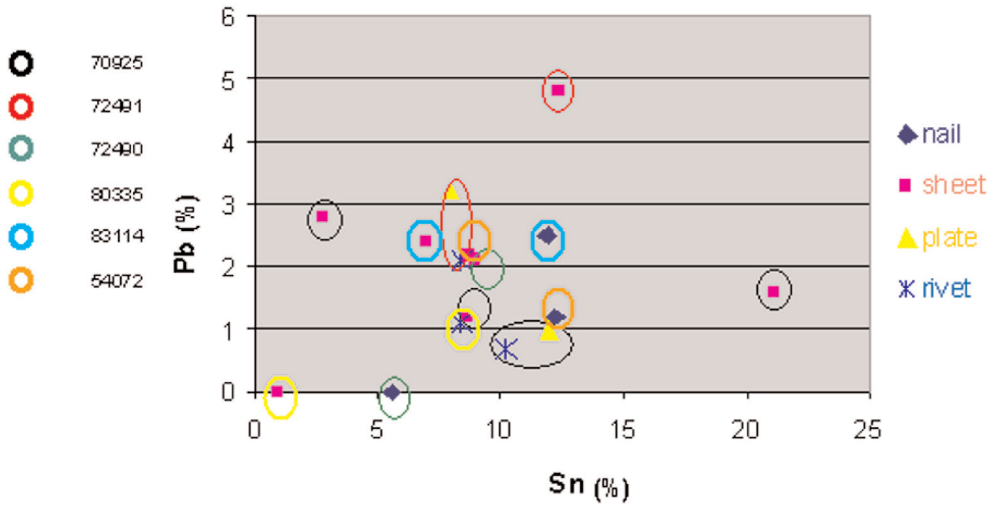

Fig. 4. Legenda and scatter plot diagram (Pb vs Sn related to Cu as mayor component) of 6 discs of the Pigorini Museum

In the discs numbered 54072, 83114 and 72490, respectively geometric, orientalizzante and figurative samples, two analysis points have been registered on each: one on the sheet and one on the studded nails involved in the support system and constitutive elements of the objects.

Disk number 80335, a geometric sample, has been analysed in two points, on the sheet and on one of the 2 bronze rivets still in situ that originally maintained an iron plate that has now disappeared. Intervention repaired a fracture running between two nail holes and the rim (Fig.5-left). In this point, the patina was left to preserve the secondary feature formed by the rivets and the oxidation layer. The amount of iron in this point documents the oxidation fingerprint left by the plate; the rivets show their bronze nature on the front of the disc (Fig.5-right).

Fig. 5. Disc number 80335

Disc number 72941 is particularly interesting (Fig. 6). The sample, as well as number 72490 , comprises a thin bronze sheet with figurative decoration back supported by a thick iron sheet that is completely oxidated and partly removed. This iron sheet is attached to the front with studded nails. In antiquity in the area where the iron sheet was removed, a trapezoidal plate was installed supported by a new studded nail serving as a rim consolidation intervention. On the front side, a difference in patina of the new stud is quite evident . All the elements in this intervention are of bronze, representing a radical change of

Fig. 6. Disc number 72941

direction: iron was removed in order to intervene with bronze. Also in this case local workshops appear to have been quite precocious in monitoring technological changes and their consequences

Finally, disc number 70925 with a very archaic geometric decoration was analysed on five points, three on the rim, centre and middle of the sheet, and two on a heavy consolidation feature formed by a bronze trapezoidal plate, which is attached to the disc by 6 rivets of which at least one was in iron. Analysis points on the feature were registered on the plate and on the unique bronze rivet still in situ.

The chemical composition of the three analysis points on the sheet refers to superficial and probably individually different visual layers of materials, suffering the effects of the segregation of metals. The compositions of points 2 and 3 have antimony in common, however they are substantially different, especially in point 1 where even the oxidation of the rim was registered despite the removal of the patina.

In one case (54072), the constitutive elements of the disc, sheet and nail, show a relatively homogeneous composition, but in other cases (83114, 72490) they appear to be the products of different manufactures. The nail composition of number 83114 contains a

higher percentage of Sn compared to the sheet and also considerable traces of Sb and Ag. On the contrary, the nail composition of number 72490 is a Cu/Sn bronze, while the sheet composition contains lead and antimony.

Secondary elements, such as plates and rivets show similar compositions within the same artefact, but not amongst each other. This suggests that local workshops used their own production strategies with spare parts probably available through metal recycling and smithing. This is entirely different to what was considered the organizational structure of large production centres, Etruscan, or campane for example, to which kardiophylakes production is attributed [5,7, 13,15].

In thi report, we also discuss the results of a preliminary test of XRF-ED analysis on 6 kardiophylakes, the group of 5 aes rudae, 1 pendant, and 7 beads and 1 spiral in the bead/spiral group (Table 2. and Fig. 7). Results of disc number 83114 are already discussed.

As previously mentioned, all the samples are copper-based products with Cu percentages ranging from 100% of one of the aes rudae to 65.3% in one of the beads. Compositions of the 5 aes rudae are nearly pure copper, except one reporting iron and zinc with percentages of 7.2% and 2.8% respectively.

All the other samples are ternary bronze alloys (copper, tin and lead) with variable compositions, but for the moment they are

Tab.2. XRF results of 20 objects from the Pigorini Museum

ogg	n inv	Cu	Sn	As	Pb	Sb	Ag	Fe	Zn	Ni	Bi
Disc	53832	85,3	13,1		1,5						
Disc	85251	85,1	10,1	0,5	3,9			0,5			
Disc	85250	89,6	5,2		5,2						
Disc patina	85253	87,5	10,9		1,6						
Disc sheet	85253	87,7	10,1		2,2						
Disc rivet	83114	81,5	11,9		2,5	0,9	0,1	3,1			
Disc	53833	85,4	9,4		2,9		0,1	2,2			
Disc sheet	83114	89,3	6,9		2,4			1,4			
Pendant	36458	70,7	7,0	2,1	14,9	2,7	0,1			2,5	
Aes rudae	36465-5	88,8	0,2		1,0			7,2	2,8		
Aes rudae	36465-2	98,4	0,2				0,1		1,3		
Aes rudae	36465-3	100,0									
Aes rudae	36465-1	99,3	0,1	0,1							0,4
Aes rudae	36465-4	99,5						0,4			
Spiral	36466-10	87,3	7,8		4,8		0,1				
Bead	36466-2	72,2	6,0		21,8						
Bead	36466-7	71,3	5,6		23,1						
Bead	36466-6	74,7	4,5		20,8						
Bead	36466-5	69,0	5,4		25,6						
Bead	36466-3	72,3	5,9		21,0	0,7	0,1				
Bead	36466-4	65,3	8,0		26,7						
Bead	36466-1	71,9	6,4		21,7		0,1				

Fig. 7. Disc number 70925

consistent with the functional classes of the objects (Fig.8). Spiral composition is more consistent with composition of the kardiophylakes than with the beads composition, however the spirals are associated with the beads for inventory reasons and no other data indicates any further association, except perhaps deposition. Moreover, the beads come from smithing operation chains that are very different from spirals or kardiophylakes. The beads were made by one single casting operation, while the spirals and the discs required long cold working and annealing. Of course, too much Pb made such objects too fragile to be worked intensely. By adding a massive quantity of lead, as in the case of the beads with more than 20% of Pb in all of the samples, ancient workers firstly obtained better fluidity for casting and then saved copper and tin, both of which were more expensive and much more difficult to recover than lead. In any case, it is worth adding that tin bronzes with high percentages of lead are usually found in proto-historic continental Italy, demonstrating the occurrence of common metalwork traditions of the production centres.

What are referred to as ‘aes rudae' are unrefined bronze lumps involved with the exchange systems of Italic proto-history. Their value was related only to their weight. The five lumps in the assemblage have been purchased as stock and inventoried as slag. They are unusually light and cannot be clearly interpreted as aes rudae, the heaviest weighting only 16g, however the chemical composition of number five perfectly matches other aes rudae compositions: rich in iron and zinc and with moderate percentages of lead and tin [11]. The five lumps show very similar patinas, which at least indicate their common deposition. Since in antiquity, ‘quite pure copper’ lumps were rarely lost, they were eventually hoard for recycling..

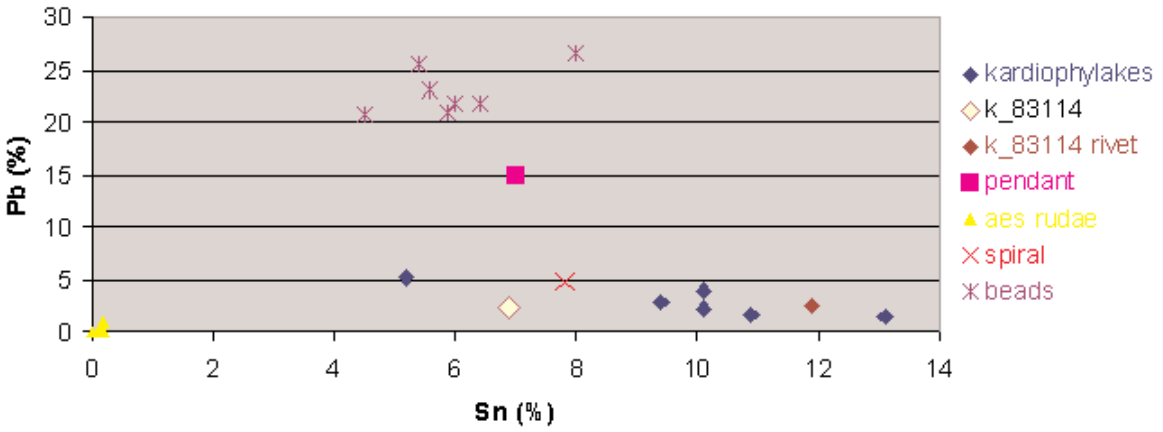

Fig. 8. Scatter plot diagram (Pb vs Sn related to Cu as mayor component) of 20 objects of the Pigorini Museum

For the territorial quantification of objects two areas have been identified as operational models: Ortucchio and Celano. Both archaeological areas lie on the dry lake bed and include several sites from the Mesolithic Age to the Early Iron Age, when they were both abandoned due to frequent flooding. Both areas have been recently excavated and report traces of substantial industrial activity.

All the 47 samples report Ortucchio provenance and belong to the Bellucci Collection. Bellucci personally collected and acquired these at the beginning of the XX century, but hardly documented their provenance. The bronzes show the general tendency of pre-historic and proto-historic inventories and the IA ornaments and accessories comprise a large group, but in total the major group is made up of tools.

The nine samples reporting Celano provenance have been acquired in different stocks by the Pigorini museum. Tools are the main group, such as the Ortucchio case.

Both inventories appear to support the relevance of considerable industrial activity recently observed in the sites. Unfortunately, many of the possible pyrotechnological contexts observed lie under water and in swamps where features can barely be observed [4].

4. Notes and proceedings

An assemblage of recent contextual finds from the Ortucchio and Celano sites will be analysed in order to be compared for data interpretation. This assemblage includes bronzes, one lump of working slag and some fragments of pottery, perhaps involved with some smelting or casting processes of domestic size.

Fucino prehistoric and proto-historic archaeology did not provide clear contexts associated with metallurgic processes, but on the other hand the difficulty of finding such contexts earlier than the true Iron Age is well known. Moreover, the Abruzzo region does not have significant mining resources that suggest independent metallurgical traditions. However, there is no reason to exclude a priori the possibility that local workshops existed and that they probably used their own strategies.

For the development of the database, the chemical, technological and traceological parametres are considered in the same way as the classical data in order to build a framework able to support crossed relationships among materials.

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