TECHNICAL AND DIAGNOSTIC INVESTIGATION ON SOME METALLIC OBJECTS COMING FROM THE ISIAO EXCAVATIONS AT THE SITE OF BARIKOT (SWAT, PAKISTAN)

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1. Introduction

The aim of this text is to present the technical and diagnostic analyses made on some metallic samples found in Barikot (Bir-kot-ghwandai), an archaeological site which is long the course of the Swat river in the North-Western Frontier Province in Pakistan (fig. 1). These enquiries, whose main aim was to collect information about the metallurgic industry and the composition of the copper alloy used, were carried out thanks to the cooperation between the Missione Archeologica Italiana dell'IsIAO in Pakistan – MAIP (IsIAO Italian Archaeological Mission in Pakistan), directed by P. Callieri, and the Laboratorio

Figure 1. Geographical setting of the Swat Valley (image from Google Earth).

Diagnostico del Dipartimento di Storie e Metodi per la Conservazione dei Beni Culturali, Alma Mater Studiorum Università di Bologna, sede di Ravenna, directed by S. Lorusso. The intention of the authors is to make this research only be the first step for a more detailed study on the metallic objects coming from the Barikot site. The achieved results and the hypothesis made here must be considered as preliminary, not only since the excavations of the MAIP are still being carried out, but also because the quantity of the analysed samples unfortunately is limited.

2. The Swat Valley

The Swat, which is known as Uddiyana in the Sanskrit sources, is a valley in the mountain area to the North of the Peshawar plain and at the foot of the mountain chain linking the Hindu Kush and the Karakorum.

Figure 2. The Swat Valley, view form Barikot Hill (photo L. Colliva).

The name Swat identifies the main valley of the high course of the homonymous river, which is 200 km long from the source to the gorges from which the river goes down to the plain, and the lateral valleys of its tributaries (fig. 2).

The enviable position of the valley, which is a passing point between the Gandharic plain and the mountain valleys going to Central Asia, allowed the region to flourish and become a centre of blooming trades but it also made it a privileged goal of the many conquerors which followed one another during the centuries.

Alexander the Great conquered the region in 327 BC, but through this valley also passed the Indo-Greek kings, the Saka and Parthian populations, the Kuṣ̄āṇa, the Sasanians, the Ephthtalites and the Muslim Ghaznavids during the 11th century [1].

The richness of this valley is likely to be one of the factors allowing, as from the first century BC, the extraordinary development of Buddhism and the building of the many monasteries which made it famous and it also made it become later on a fundamental stage of the travels of the Chinese pilgrims looking for sacred texts (Faxian during the 5th century AD, Songyun during the 6th century, Xuanzang during the 7th century, Huizhao during the 8th century). Between the beginning of the 6th and the beginning of the 7th century AD the region seemed to be struck by a heavy economic crisis; nevertheless, despite this decadence, it remained an important transit place not only for goods but also for ideas [2].

During the 8th century, Padmasambhava, one of the fathers of Tibetan Buddhism, left from this region and it is following backwards his path that Giuseppe Tucci in 1955 arrived in the Swat valley.

The archaeological research in the valley had started in 1926 with a first visit by Aurel Stein, who took advance of the fact that the government of the Wali Miangul Badshah Saheb created a unitary state, by reconciling and unifying the Yusufzai never crushed by the British Empire [3]. In 1938 another recognition campaign, much more superficial, directed by P. Barger and E. Wright for the Archaeological Survey of India, followed the Stein expedition. In 1955 Giuseppe Tucci, president of the IsMEO, directed a fundamental archaeological survey thanks to the support of the Wali of the Swat. The following year the activity of the IsMEO (now IsIAO) Archaeological Mission in Pakistan started and which Giuseppe Tucci entrusted to the lead of Domenico Faccenna (fig. 3).

Figure 3. F.A. Khan (Director General, Dept. of Archaeology & Museums, Govt. of Pakistan), G. Tucci, D. Faccenna, Villa d'Este (Tivoli, Italy), c. 1962 (photo IsIAO).

During these last years the mission consecrated many of its energies to the study of the pre-Islamic settlements and, in particular, to the extensive excavation of the Barikot (Bir-kot-ghwandai) site.

3. The Barikot Site

After the visit of Tucci, the Barikot site was the subject of research by the MAIP as from 1978, when G. Stacul, the person in charge of the prehistoric sector, started to investigate on the plain area in the South of the hill.

The studies carried out by Stacul gave proof of human presence as from the 2nd millennium BC [4-5]. This date is confirmed also by the excavations made on the top of the hill by L.M. Olivieri [6].

Nevertheless, the excavations made by Stacul brought to light also important architectonic remains of a big historic settlement which is the subject of a series of excavations directed by P. Callieri (fig. 4) as from 1984.

The research carried out showed the importance of the urban site, which is in a strategic position from where it is possible to dominate the roads leading to the high Swat valley, to the low river valley and then to Afghanistan, Buner and Indu.

Figure 4. Barikot (Pakistan): general view of the fortified town founded by the Indo-Greeks (photo P. Callieri).

Moreover, it was possible to find clear confirmation of the identification of this site, already proposed by A. Stein [3, 7] and G. Tucci [8], with the city called by the classical historians (Curtius Rufus, VIII, 34 and Arrianus, Anabasis, IV, 27) with the name of Bazira and conquered by Alexander in 327 BC. The name used nowadays seems to come from the old Bajira [7].

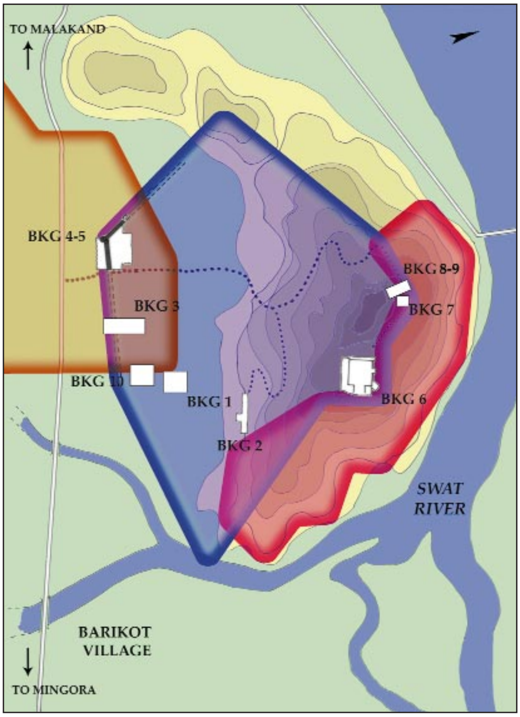

Figure 5. The Archaeological area of Barikot (in brown: the proto-historical settlement and grave yard; in blue: the Historic city; in red: the Late Historic settlement; in white the excavated areas).

The ancient city, on the Western side of the modern village, is on an area of 10 ha and is closed on the northern part by a crescent shaped hill touched by the Swat rive and on the southern part by the Kandak and Karakar rivers.

As from 1984 the excavations went on, despite some interruptions due to the not always easy international situation, till today. A topographic survey of the site and of all of the emerging structures came before the excavation campaigns leading to the opening of ten trenches on the alluvial plain at the bottom of the hill or on the two artificial terraces (eastern and western terrace) dominating the hill [9] (fig. 5).

In the first phase, from 1984 to 1990, four trenches were opened (BKG 1, BKG 2, BKG 3 and BKG 4-5) through which it was possible to build up stratigraphic sequences going from the 2nd century BC until the beginning of the 6th century AD and which go on, as regards the area of the slope of the hill, until the Islamic period (13th-14th century AD).

In the plateau were discovered the remains of important defensive works belonging to the Indo-Greek period (BKG 3 and BKG 4-5) containing the level area of the city: up until now a long part of the city walls heading to E-W and a shorter part which, starting from the south-western corner heads to NNW have been indentified. Both these walls

Figure 6. Barikot Temple, the East side: with the monumental staircase (photo Colliva).

have rectangular ramparts at 27-28 metres from one another. There is also a pentagonal angular rampart, on the south-western corner (trench BKG 4-5); even if there are some hypotheses [10], the precise perimeter of the city walls is not certain.

As from 1998 the excavations were also made in the hill protecting, thanks to its crescent shape, the ancient city area and on which other trenches were opened (BKG 6, BKG 7, BKG 8, BKG 9). The most ancient materials found date back to 2nd millennium BC, even if the first structures preserved long to the 1st-2nd century AD (BKG 7) and then to the Shahi period, 7^{th}-11^{th} century AD (BKG 6) [6]. The most important discovery in this area is without any doubt the sacred indu building, partially brought to light during the 1999 and 2000 campaigns: the eastern terrace, supported by a high substructure wall, is almost entirely taken by the remains of this imposing religious building, with a rectangular plan (25 x 12.5 metres), embellished with architectural elements and figured decorations in stucco (fig. 6). During the excavations the remains of the stucco decoration and the fragments of a cult marble image dating back, from the stylistic point of view, to the art of the Shahi period [11] (fig. 7) were brought to light.

After a forced stop of the works, due to the dramatic events of 2001, in 2006 the mission could restart the excavation in the site and, while waiting to reopen the trenches on the hill, it was decided to work once again in the plain. A new trench (BKG 10) was opened trying to find out useful elements for the reconstruction of the orientation of the eastern section of the perimeter wall. Unfortunately no part of the walls was found but the finding of what seems to be a canalisation out of the walls gave new elements useful for an hypothetical reconstruction.

The high number of trenches and their position made extremely difficult to made a unitary chronological sequence of the site. The problems due to the lack of physical links between the trenches and, in some cases, also inside the trenches themselves (BKG 3 BKG 4-5)[1] sum up to the high complexity of a stratigraphic situation spreading for almost four millenniums of history.

Figure 7. Barikot Temple: fragment of a marble statue representing Gadadevi (photo Primangeli).

Many times it was underlined how a similar operation is difficult [12], and only an attentive analysis of the found material, along with the study of the architectural techniques found out thanks to the excavations will allow to arrive to a final dating. In particular, much hope is placed in the study of the ceramic material, which is being carried on at the moment, and which promises to solve many problems still unsolved thanks to the richness and the volume of the data which can provide [13-14].

Despite the difficulties underlined in this necessary introduction, in the past at least two partial attempts were made in order to find a connection among the different periods identified in the trenches [9-10]. On the basis of these precedents, the authors of this article proposed a new periodization including in an exhaustive way all of the trenches studied up until now, all of the periods and the phases identified inside them[2].

In this proposal (table 1) the author hypothesises ten big periods identified by the acronym BKGCS (Bir-kot-ghwandai Cultural Sequence). This periodization, which is not final, wants to be a work base to use during the study, still in progress, of the materials found during excavations.

Table 1. Chonological sequence of the Barikot Site.

	BKG 1	BKG 2	BKG 3	BKG 3 c.w.i.a[4]	BKG 4-5	BKG 4-5 c.w.e.a.[5]	BKG 6	BKG 7	BKG 8	BKG 9	Absolute chronology
BKGCS X			Period VII	Phase 5							15th-20th cent AD
	Period X										
					Period X						
					Period XI						
BKGCS IX							Period VI		Period VII?		First Islamic Period, from 11th cent AD.
							Period V				
							Period IV	Period VII	Period VI?	Period VIII ?	
							Period III	Period VI			
			Period VI	Phase 4			Period II		Period V	Period VII	
		Period VI									
BKGCS VIII	Period IX	Period V					Period IB	Period V ?			Shahi Period, 7th-11th cent. AD.
		Period IV					Period IA	Period IV	Period IV	Period VI	
		Period III									
BKGCS VII			Period V?	Phase 3	Period VIII	Phase 8					4th-5th cent. AD.
	Period VIII ?		Period IVB	Phase 2b	Period VII	Phase 7					
BKGCS VI	Period VII		Period IVA	Phase 2a	Period VI	Phase 6				Period V	2nd-3rd cent. AD.
								Period III		Period IV	
BKGCS V	Period VI			Phase 1b?	Period V	Phase 5					1st-2nd cent. AD.
	Period V	Per II									
		Per I ?	Period III	Phase 1a	Period IV						
BKGCS IV	Period IV?		Period IIB			Phase 4?					1st cent. AD.
BKGCS III	Period III										Indo-Greek Period (2nd-1st cent. BC).
	Period II		Period IIA		Period III	Phase 3		Period II	Period III ?	Period III	
	Period I										
BKGCS II								Period IB	Period II	Period II	Period V to VII of the Swat proto-historic sequence.
			Period I BIS		Period II	Phase 2					
					Period I	Phase 1					
BKGCS I			Period I					Period IA	Period I	Period I	Chalcolitic (Period IV of the Swat proto-historic sequence, 1700-1400 BC.)

(L.C.)

- **BKGCS I** (Period I of BKG 3, Period IA of BKG 7, Period I of BKG 8 and the Period I of BKG 9): corresponds to the period IV of the Swat proto-historic sequence (1700-1400 BC) [15].
- **BKGCS II** (Period I bis of BKG 3, the Periods I and II and the Phases 1 and 2 of BKG 4-5, the Period IB of BKG 7, the Period II of BKG 8 and the Period II of BKG 9) seems to corresponds to the periods from the V to the VII of the Swat proto-historic sequence. Unfortunately, the fact that the excavation is so limited at this level and the low number of structures and materials found do not allow a dating or a more precise periodization.
- **BKGCS III**: it includes the phase linked to the building of the defensive structures of the city; this period is dated between the second half of the 2nd century BC and the 1st century BC (Indo-Greek age) (Periods I-III in BKG 1, Period IIA in BKG 3, Period III and Phase 3 in BKG 4-5, Period II in BKG 7, Period III in BKG 8 and Period III in BKG 9).
- **BKGCS IV**: the main event is the reconstruction of some ramparts of the city wall (Period IIB in BKG 3 and Phase 4 in BKG 4-5) which were likely to be damaged by one of the frequent earthquakes typical of this region. On the other hand it is more difficult to associate to this period the episodes pointed out in the other trenches: Period IV in BKG 1; the dating proposed on the basis of the material found is, nevertheless, very next to the one proposed for the reconstruction works: 1st century BC (Śaka period).
- **BKGCS V**: it includes the levels dated between the 1st and the 2nd century AD (Parthian and proto-Kuṣ̄āṇa period) (Periods V and VI in BKG 1, Periods I and II in BKG 2, Period III and Phases 1a and 1b in BKG 3, Periods IV and V and Phase 5 in BKG 4-5). In the layers linked to these structures (trench BKG 3) a fragment of black polished ceramic was found which can be connected to a similar fragment found in the layer of the Period IV in trench BKG 1. This finding seems to demonstrate a substantial continuity between this period (BKGCS V) and the previous one (BKGCS IV). At the moment it is impossible to fix the precise arrival of the Kuṣ̄āṇa: the excavations do not show any clear sign of interruption between this period and the following one.
- **BKGCS VI** (Period VII BKG 1, Period IVA and Phase 2a of BKG 3, Period VI and Phase 6 of BKG 4-5, Period III of BKG 7, Periods IV and V of BKG 9): during this period, entirely dating to the Kuṣ̄āṇa period, 2nd-3rd century AD, the small sacred Buddhist area inside the city walls was built (BKG 4-5). Moreover, in this macro-period we witness the progressive loss of defensive function of the city wall which

tends to become a simple substructure for the inner levels of the city. As a matter of fact, these last levels, as the constant realisation of new structures for the down flow of the waters shows (Period VI and Phase 6 in BKG 4-5), rose very much. It is likely that, as already proposed by OLIVIERI *et al.* [16-17], this phenomenon has to be put into connection with the general demilitarisation of the region following the so called *pax kushanica* [18].

- **BKGCS VII** (Period VIII in BKG 1, Periods IVB and V and Phases 2b and 3 of BKG 3 and Periods VII and VIII and Phases 7 and 8 of BKG 4-5) the process of functional transformation of the perimeter wall is finished and we assist to the building of structures allowing an easier transit to the inner areas (Period V in BKG 3 and Phase 8 in BKG 4-5). The layers belonging to this macro-period date between the 4th and beginning of the 6th century AD.
- **BKGCS VIII**: this macro-period includes the layers referable to the Shahi period (Period IX in BKG 1, Periods IV and V in BKG 2, Periods IA and IB in BKG 6, Periods IV and V in BKG 7, Period IV in BKG 8 and Period VI in BKG 9). During this period the round-towered building was made at the slope of the hill (Period IV in BKG 2); the walls substituting the two terraces overlooking the top of the hill were built (Period IV in BKG 8) as well as the temple overlooking the Eastern terrace (Period IA of BKG 6). The ceramic found in the layers included in this macro-period has two very different horizons; we hope that the research of the ceramic materials which is currently carried out will allow to clearly distinguish these two phases, probably corresponding to the so-called Turkish-Shahi and Hindu-Shahi periods.
- **BKGCS IX**: this macro-period includes all of the layers with a cultural horizon referable to the Ghaznavid conquest and to the first period of the Islamic rule in this region (Period VI and Phase 4 of BKG 3, Periods from II to VI in BKG 6, Periods VI and VII in BKG 7, Periods from the V to the VII in BKG 8, Periods VII and VIII in BKG 9).
- **BKGCS X**: the macro-period includes all of the periods having of traces activity or recent occupation or, at least, after the 15th century AD (Per X in BKG 1, Per VII and Phase 5 in BKG 3).

The excavations of the trenches BKG 1, BKG 2 BKG 3 and BKG 4-5 brought to light 266 objects made of copper alloy; 56 among them, the best preserved, were taken stock of[6].

4. Metallurgical industry indicators

In relation to the specific subject of this article, we have to underline that some of the items brought to light during the excavation can be the proof, for their function or their nature, of the presence of a metallurgical industry in the site.

Slags, prills[7], fragments of melting pots and all the objects which were found folded and ready to be cast and reused are considered as indicators.

The following is a summary table of these objects (table 2).

Table 2. Indicators of metallurgical industry and their distribution in the different macro-periods.

Chronological Sequence	Inv. N. or Field N.	Object	Trench	Locus	S.U.	Period	Phase	Note
BKGCS V	172	Sheet	BKG 4	422	1376	V	IV	2 fragments.
BKGCS V	186	Plaque	BKG 4	449	1408	IV		
BKGCS V	203	Slag	BKG 4	442	1333	V	IV	6 fragments
BKGCS V	99	Crucible	BKG 4	455	1398	V	IV	
BKGCS VI	110	Prill	BKG 4	413	738	VI		
BKGCS VI	121	Sheet	BKG 3	313	206	IVA		10 fragments of very small dimensions
BKGCS VI	75	Sheet	BKG 3	308	260	IV A		
BKGCS VI	160	Crucible	BKG 3	310	179	IVA		Many fragments
BKGCS VI	163	Sheet	BKG 4	428	1253	VI		6 fragments
BKGCS VII	152	Sheet	BKG 5	519	2582	VII		4 fragments
BKGCS VII	162	Slag	BKG 5	504	2602	VII		
BKGCS VII	40	Thread	BKG 4	427	517	VII		
BKGCS VII	52	Prill	BKG 4	422	611	VII	VI	
BKGCS VII	117	Prill ?	BKG 3	305	39		3	
BKGCS VIII	145	Prill ?	BKG 2	218-219	609	IV		
BKGCS VIII	146	Prill	BKG 2	218	558	IV		XRF

(segue)

Table 2 (following). Indicators of metallurgical industry and their distribution in the different macro-periods.

Chronological Sequence	Inv. N. or Field N.	Object	Trench	Locus	S.U.	Period	Phase	Note
BKGCS X	20	Prill	BKG 1	102	60	X	2	
	38	Slag	BKG 4	430	961			
	53	Sheet	BKG 2	Trial NE	Surface			2 fragments; folded and ready to be cast
	58	Tube (bracelet ?)	BKG 4	430	961			Folded and ready to be cast
	71	Casting/Ingot?	BKG 2		339			
	79	Prill	BKG 2		292 ?	VI		
	80	Crucible	BKG 2		292	VI		
	124	Slag	Sporadic					
	127	Crucible	Sporadic					XRF
	128	Slag	Sporadic					XRF
	144	Slag?	BKG 2	218 a	579			
	204	Prill (?)	BKG 2		299			

5. Study hypothesis for the identification of the mining places of the metals found in Barikot

The material evidence brought to light during the excavation of the site, in particular the finding of quite a lot of metal objects ready to be cast and reused (table 2), the discovery of two furnaces for metals (Period VI and Period VII in BKG 4-5), the presence of at least one metal ingot not yet worked (sample n. 71)[8], seem to show that in Barikot there was, at least in some periods, a fairly good metallurgical activity.

Nevertheless, the data found during the excavation are not enough to make wider hypotheses on the dimensions of this activity and on its temporal extension. For this reason, at the end of the excavation campaign of 2000 the MAIP asked to the Department of Archaeology & Museums, Government of Pakistan, to export a few samples to be analysed in Italy. The aim of these analyses is to collect new information on the techniques of metal working, on the used alloys and on the mining places of the minerals.

Six of the samples were brought to Ravenna, where, in co-operation with the Laboratorio Diagnostico del Dipartimento di Storie e Metodi per la Conservazione dei Beni Culturali, Alma Mater Studiorum Università di Bologna, sede di Ravenna, a project for the collection of data useful for the identification of the places of origin of the mineral used in the metallurgical industry was started.

Here as follows there are the cards of the six samples analysed[9].

Field n.:	**127**
Object:	Part of a crucible
Trench:	Sporadic
Locus:	–
SU:	–
Collection Date:	1987
Description:	Part of a crucible with copper traces
Material:	Pottery, copper alloy
Conservation:	Broken; missing parts; oxidation
Dimensions:	Length: 4.7; width: 3.5; thickness: 1.5
Weight (in g):	14.71
Phase:	–
Period:	–
Analysis:	XRF
Comparative evidences:	–

Field n.:	**128**
Object:	Slag
Trench:	Sporadic
Locus:	–
SU:	–
Collection Date:	1987
Description:	Vitrified slag with traces of metal
Material:	Clay, iron, copper
Conservation:	Broken; missing parts
Dimensions:	Length: 5.5; width: 4.9; thickness: 1.6
Weight (in g):	27.74
Phase:	–
Period:	–
Analysis:	XRF
Comparative evidences:	–

Field n.:	**146**
Object:	Prill
Trench:	BKG 2
Locus:	218
SU:	558
Collection Date:	30-10-1990
Description:	Two prills
Material:	Copper alloy
Conservation:	One prill broken; one missing part; encrusted and completely mineralized; crackings; presence of copper corrosion products
Dimensions:	Length: 1.9, 0.9; width: 0.9, 0.9; thickness: 0.5, 0.6
Weight (in g):	2.46 (1.01, 1.45)
Phase:	–
Period:	BKGCS VIII (Period IV)
Analysis:	XRF
Comparative evidences:	–

Field n.:	**211**
Object:	Sheet
Trench:	BKG 4-5
Locus:	4W
SU:	2728
Collection Date:	1990
Description:	Sheet folded and ready to be cast and reused
Material:	Copper alloy
Conservation:	Broken; 5 fragments; missing parts; deformed; presence of copper corrosion products
Dimensions:	Largest fragment: length 2.2; width: 1.2
Weight (in g):	–
Phase:	–
Period:	BKGCS V (Period IV)
Analysis:	XRF
Comparative evidences:	–

Field n.:	**212**
Object:	Sheet
Trench:	BKG 4-5
Locus:	4W
SU:	2734
Collection Date:	1992
Description:	Sheet folded and ready to be cast and reused
Material:	Copper alloy
Conservation:	Broken; 9 fragments; missing parts; almost completely mineralized; presence of copper corrosion products
Dimensions:	Largest fragment: length 3.3; width: 1.2
Weight (in g):	–
Phase:	–
Period:	BKGCS III (Period III)
Analysis:	XRF
Comparative evidences:	–

Field n.:	**213**
Object:	Stud
Trench:	BKG 4-5
Locus:	520
SU:	2747
Collection Date:	1992
Description:	Small metallic stud with traces of incised decoration near the border; two fastening loops on the verso
Material:	Copper alloy
Conservation:	Encrusted; presence of copper corrosion products
Dimensions:	Diameter: 1.2; thickness: 0.8
Weight (in g):	–
Phase:	BKGCS VI (Period VI)
Period:	XRF
Analysis:	–
Comparative evidences:	

At the moment, the data obtained from the excavation witness the presence of a metallurgical activity of an handicraft type, especially as regards the manufacture of copper alloy objects. As already remembered, in the trench BKG 4-5 two rooms (*locus* BKG 512 e BKG 428) which are supposed to be used to work the metals were identified. Their position inside the town, the huge number of metallic objects ready to be cast and reused and the finding of a single non-worked metal ingot[9] seem to prove that in Barikot there only was a secondary metallurgical activity which took care mainly of the reuse of import material. The small extension of the studies, compared to the huge extension of the site (10 ha approx.), make this hypothesis a simple speculation. For these reasons a study project giving data on the origin of the mining resources could be extremely useful.

6. Fluorescence X Spectrometry

The aim of the project here showed is to recognise, through diagnostic-analytical analysis, particular compositional elements useful in order to identify the metals coming from the same mining place. The hope is to identity the number of the mining places and their change as time passed by.

The first of the different phases of this project is a feasibility study on the available samples. To this first step a study of a wider quantity of samples coming from different chronological periods[10] should have followed in case the data collected were considered as interesting enough. It was not excluded, in case the study gave good results, to widen the analyses also to other sites in the region in order to collect useful elements for the reconstruction of the trades linked to the metallurgical industry and to the geographical identification of the supplying mining areas. Unfortunately, despite the fact that the collected data are certainly interesting, the current political situation in Swat brought to the suspension of the excavations and it was not possible to select and import new samples to go on with the analyses. The number of the samples which was possible to analyse is extremely low and the collected data are statistically unusable to formulate concrete hypotheses. Almost all of the objects found during the excavation are made of alloy copper, once the presence of elements which can be specific identified, it will be necessary to find out to which of the metals inside the alloy these elements were linked to originally. This result, which can be obtained with an accurate statistical study, is only achievable thanks to the study of a wide range of samples. Despite this, as we will see later, the results obtained showed at least once interesting working ideas.

The six available samples for the first phase of the project were cleaned with mechanical instruments and a ultrasound bath (Ultrasonic UTA18 by Falc) in order to eliminate the ground residuals still on the samples and in order to eliminate in one portion of each object the more superficial corrosion layers. This last action was made in order to obtain a surface without any external contamination and suitable for the analysis with XRF. After that the objects were weighted (balance model ORMA Model BC), it was taken a picture and a micro-picture of them and finally they were analysed with the fluorescent spectrometry (Spectrometer EIS, 35 keV, 0,5mA e 10 keV, 0.5 mA) both on the surface and, if possible, after cutting them, in their core.

The XRF technique (X-ray fluorescence) allows to obtain the spectrum of the atomically elements characterising the materials analysed. The fluorescent X spectrometer excites the point of the object chosen for the analysis with X radiations (incident or primary rays) of the right wave-length. The consequent resettlement of the electrons of the superior orbits inside the ones remained empty causes the emission of secondary X-rays whose energy is typical of the elements found in the sample irradiated. The fluorescent spectrum has the recording of the secondary X-rays represented by some peaks. the analysis is limited to the elements between the atomic numbers 11 e 92 [19].

The analyses of this study are made with a portable fluorescent spectrometer EIS.

Two of the six analysed samples (n. 127 and n. 128) are not made of alloy metallic, but they are a fragment of a melting pot and of a vitreous slag with some traces of metal. Even if they are not optimum for this study, we decided to analyse them anyway. The analysis of these two samples is here as follows and the spectrum of fluorescent X-ray obtained are commented together.

The sample n. 127 is likely to be a fragment of melting pot with some traces of cop-

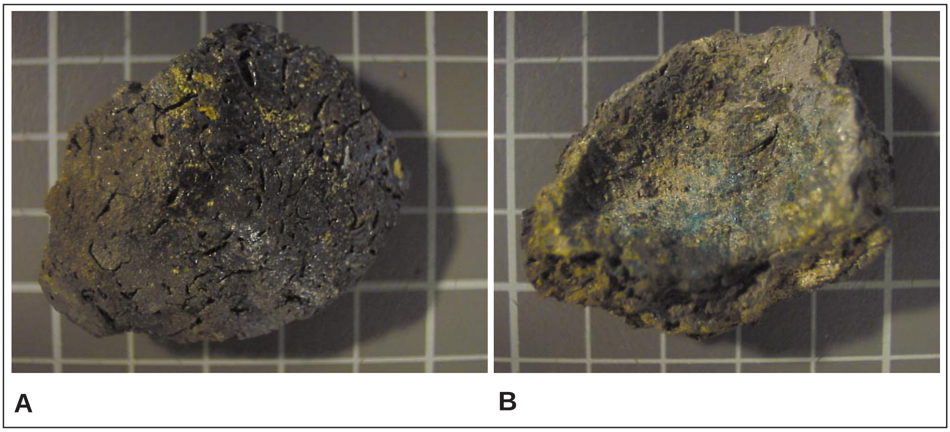

Figure 8. Photograph of sample n. 127: A) recto; B) verso.

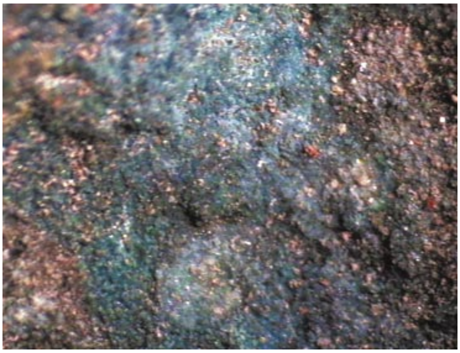

Figure 9. Microphotograph (12x) of sample n. 127, verso.

per (or alloy copper) fund during the excavation campaign of 1987 (fig. 8-9). The sample was found outside the excavation contest and therefore the object has no stratigraphic period.

The sample **n. 128** is a working slag made of clay partially vitrified, with traces of metal (fig. 10-11). As the previous one, also this sample, when was found was outside a precise archaelogical context.

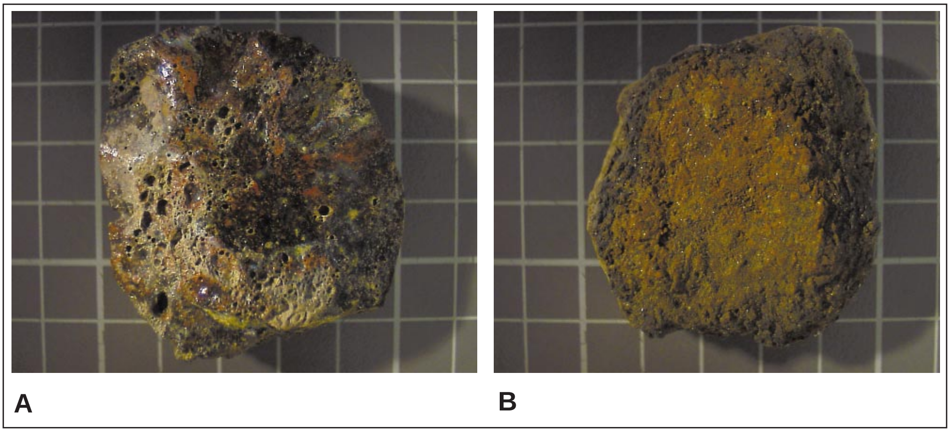

Figure 10. Photograph of sample n. 128: A) recto; B) verso.

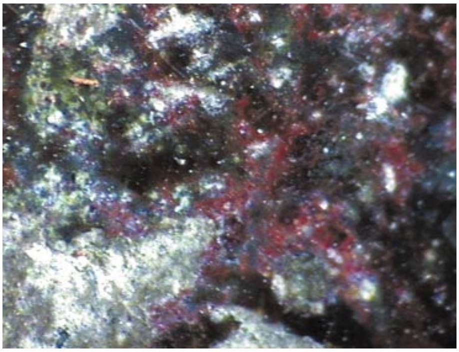

Figure 11. Microphotograph (20x) of sample n. 128, recto.

Surely the nature of these two samples is not ideal for this kind of study: the danger that the traces of metal inside them are contaminated by the other materials is too high and it is impossible to prove if the presence of a particular composition origins from the alloy metallic or if it is present inside the clay to which the metals are linked. Despite that we decided to analyse also these samples with the XRF.

Both the surfaces of the samples were analysed (fig. 12-13 and 15-16) and after a mechanical cutting also their nucleus was analysed. As regards the inside nucleus of n. 128 we analysed both the clay and the vitreous sections (fig. 14 and 17-18).

As it was possible to foreseen, the analyses showed the presence of many elements and there are also many variations of compositions found in the different points analysed.

In both the samples a high concentration of iron (Fe) was found (figures from 12 to 18) and it is in all of the analyses made. Also the calcium (Ca) is in both the samples (fig.

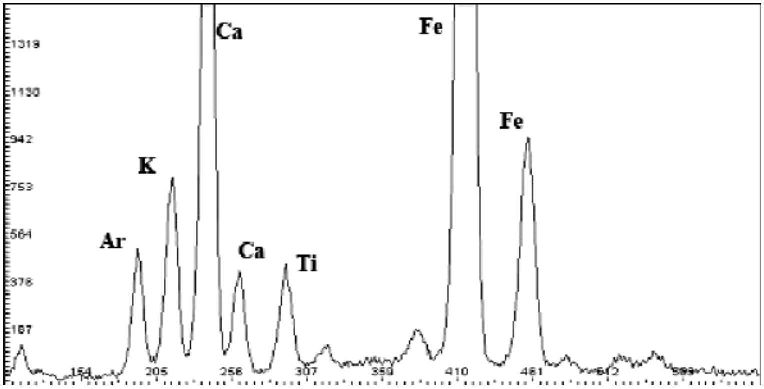

Figure 12. X-rays fluorescence spectrum of sample n. 127, recto (10 keV, 0.5 mA).

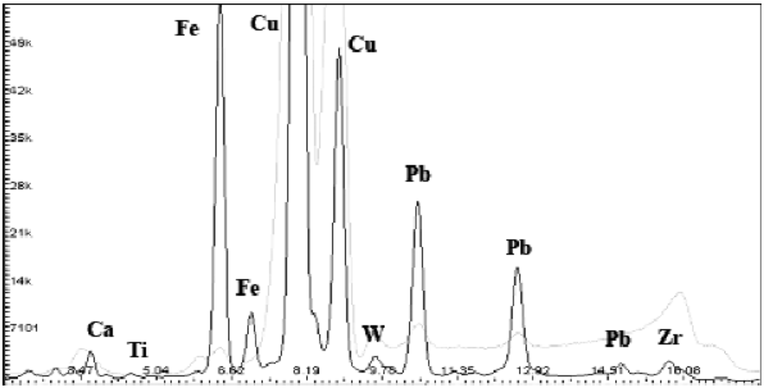

Figure 13. X-rays fluorescence spectrum of sample n. 127, verso (35 keV, 0.5 mA).

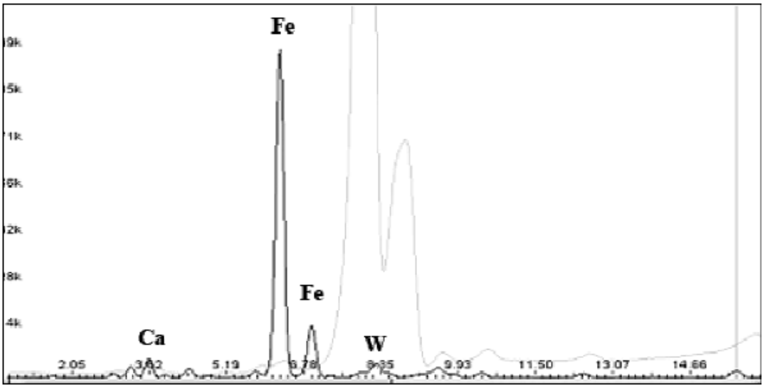

Figure 14. X-rays fluorescence spectrum of sample n. 127, core (35 keV, 0.5 mA).

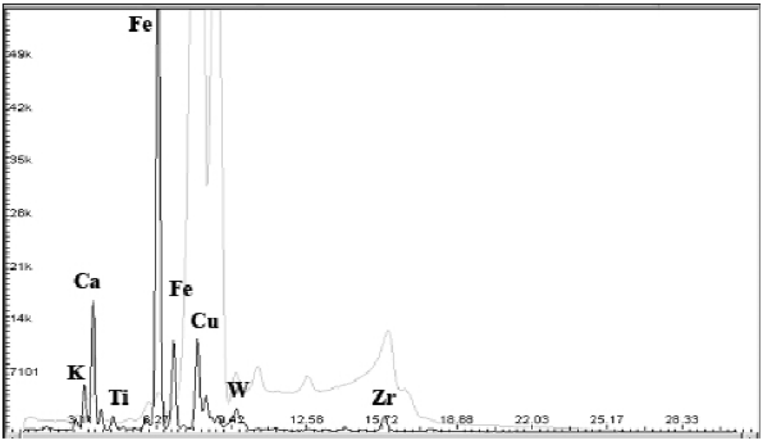

Figure 15. X-rays fluorescence spectrum of sample n. 128, recto (35 keV, 0.5 mA).

12 and 15) even if in the sample n. 127, in its nucleus (fig. 13-14) and in the vitreous part of the nucleus of the sample n. 128 (fig. 17), there are only traces of it. On the other hand, the copper (Cu), which has a high concentration only in the rear part of the sample n. 127 (fig. 13), as predictable by the green colour of the corrosion products, has only some traces in the other parts of this sample and in the sample n. 128 (fig. 15-18). In the sam-

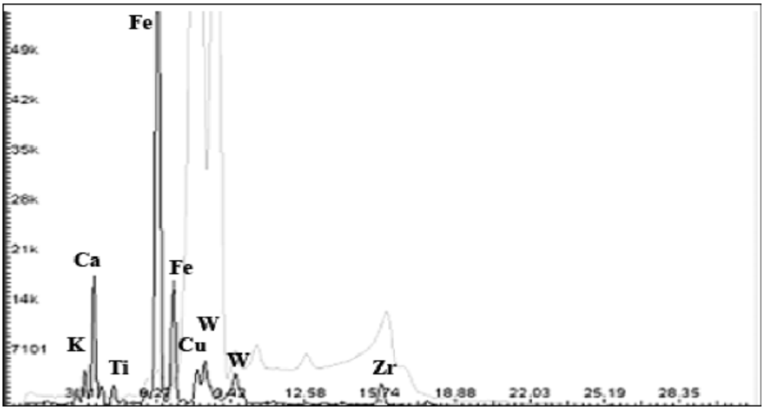

Figure 16. X-rays fluorescence spectrum of sample n. 128, verso (35 keV, 0.5 mA).

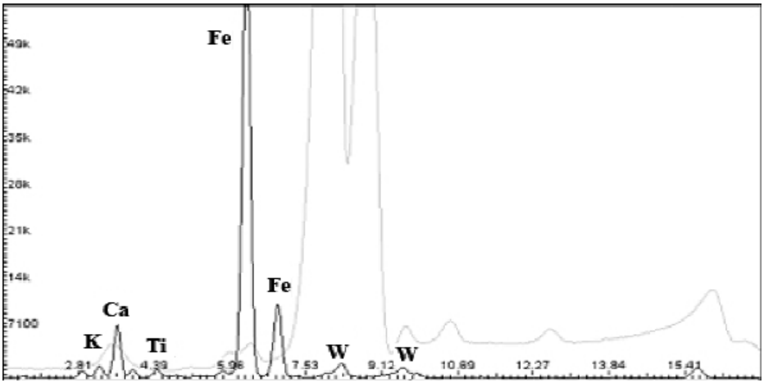

Figure 17. X-rays fluorescence spectrum of sample n. 128, core (35 keV, 0.5 mA).

ple n. 127 there are traces of silver (Ar), potassium (K), titanium (Ti), zirconium (Zr) and lead (Pb) (fig. 6 and 12-14). In the sample n. 128 there are traces of potassium, (K), titanium (Ti), zirconium (Zr) (fig. 15-18).

The presence of tungsten (W) is due to the instruments used for the analyses.

Sample n. 146 consists of two prills in copper alloy found in the layers of the BKGCS VIII macro-period (fig. 19-20).

Both the fragments have been photographed and analysed although, even in this

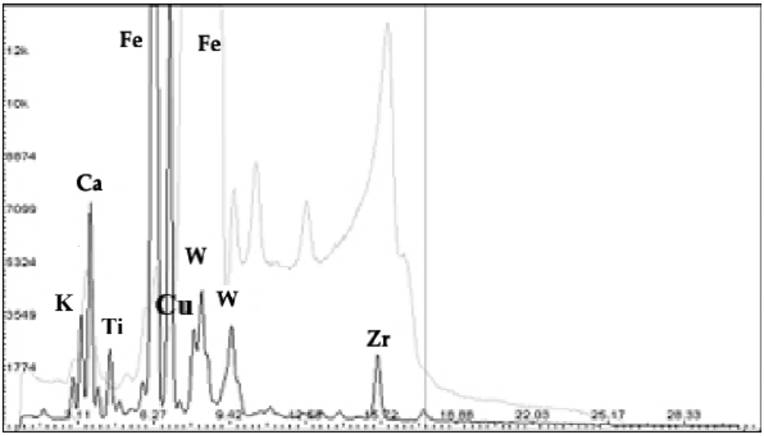

Figure 18. X-rays fluorescence spectrum of sample n. 128, verso (35 keV, 0.5 mA).

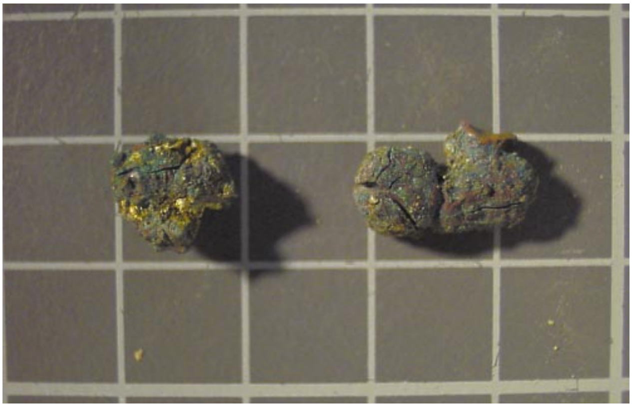

Figure 19. Photograph of sample n. 146, from right to left, fragments A e B.

Figure 20. Microphotograph (15x) of sample n. 146 A.

case, being just working waste, they were not suitable for this study. Despite this introductive remarks, very interesting results have been brought to light through the analyses of these samples.

The analysis of the samples shows, as it was expected, a very high percentage of copper (Cu) (fig. 21-24); iron (Fe) is present as well, at least on the surface, with high concentration (fig. 21 and 23). Sample n. 146B presents also an important quantity of calci-

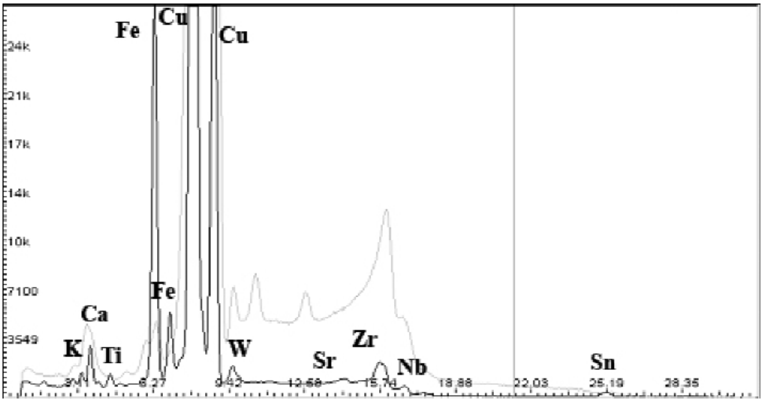

Figure 21. X-rays fluorescence spectrum of sample n.146 A (35 keV, 0.5 mA).

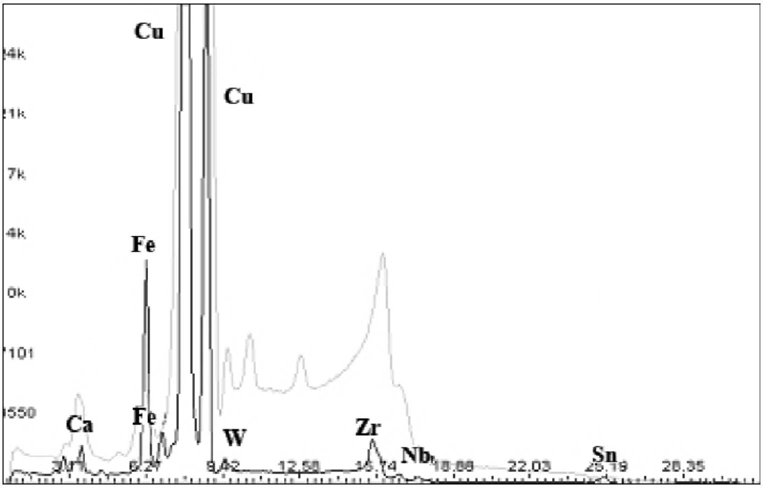

Figure 22. X-rays fluorescence spectrum of sample n.146 A (35 keV, 0.5 mA), core.

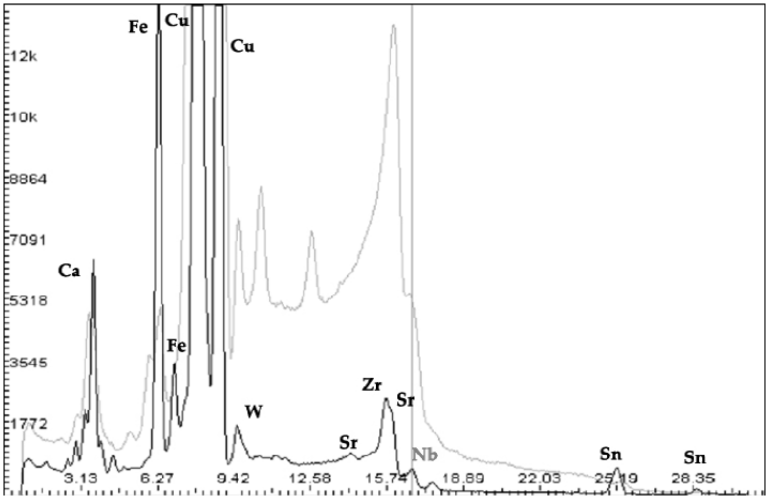

Figure 23. X-rays florescence spectrum of sample n.146 A (35 keV, 0.5 mA).

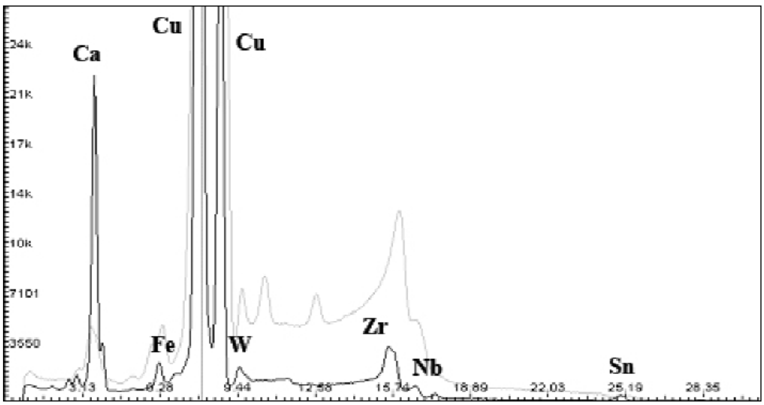

Figure 24. X-rays fluorescence spectrum of sample n.146 B (35 keV, 0.5 mA), core.

um (Ca) (fig. 23) which, on the contrary, is barely present in sample n. 146 (fig. 21). On the surface of the two samples there are also traces of titanium (Ti), strontium (Sr) and zirconium (Zr) (figs. 21 and 23), probably coming from the soil and indeed less clear in the analyses of nuclei (fig. 22 and 24). On the other hand, it is very interesting to notice the presence of tin (Sn) and niobium (Nb), both on the surface and within the nuclei (fig. 21-24).

Sample n. 211, composed of 5 copper alloy sheet fragments, has been found in the layers belonging to the BKGCS V macro-period (1st-2nd century AD) of trench BKG 4-5 (fig. 25-26). Due to the unique nature of the sample, the XRF analysis has been carried out only on the biggest fragment and, because of the reduced thickness, only on the uncoated surface.

The analyses brought to light a very high percentage of copper (Cu), a moderate presence of iron (Fe) and nickel (Ni) and also some traces of calcium (Ca) and zirconium (Zr) (fig. 27), even in this case probably linked to the soil where they were found.

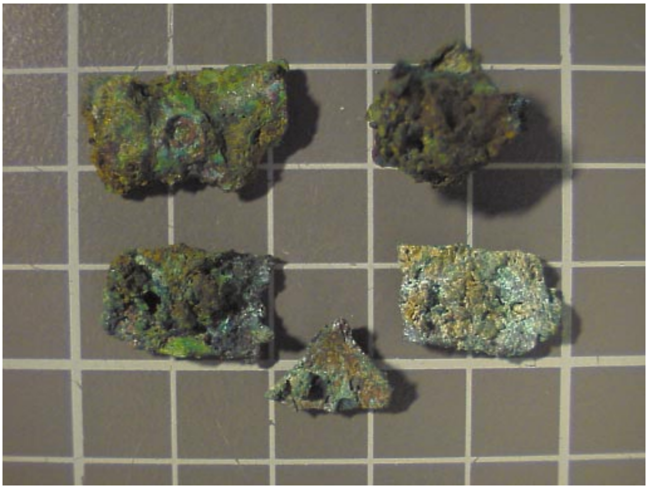

Figure 25. Photograph of sample n. 211.

Figure 26. Microphotograph (15x) of sample n. 211.

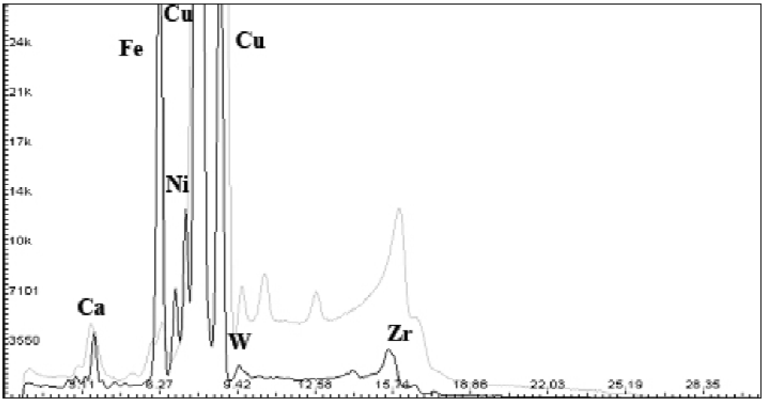

Figure 27. X-rays fluorescence spectrum of sample n. 211, (35 keV, 0.5 mA).

Sample n. 212 is composed of 9 sheet fragments (3 of them very little) found in the layers belonging to the BKGCS III macro-period of trench BKG 4-5 (figs. 28-29). As for this sample, the same considerations made for n. 177 are valid: the analysis was carried out only for the biggest fragment and, because of the poor thickness, no cut was done and only the uncoated portion was analysed.

The analyses confirmed the high presence of copper (Cu) already expected after the observation of the corrosion coat; moderate percentages of calcium (Ca), iron (Fe) and zirconium were found (Zr). Even in this case the presence of tin (Sn) and niobium (Nb)

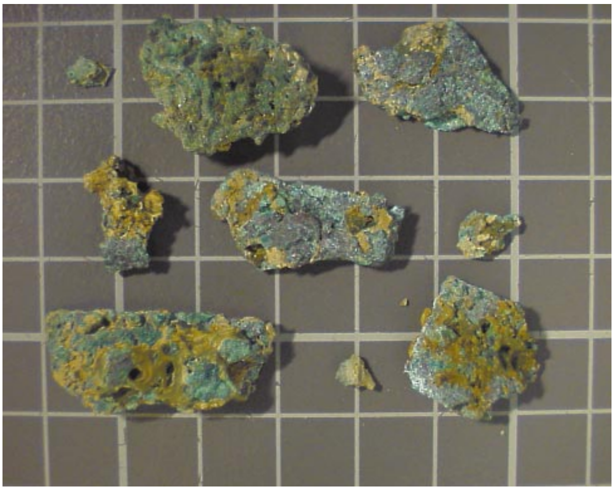

Figure 28. Photograph of sample n. 212.

Figure 29. Microphotograph (20x) of sample n. 212.

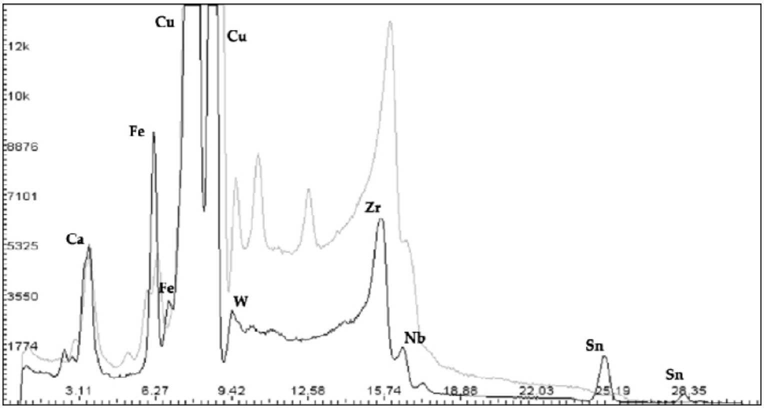

Figure 30. X-rays fluorescence spectrum of sample n. 212 (35 keV, 0.5 mA).

results to be particularly interesting (fig. 30). As in the previous spectrum, the presence of tungsten (W) is due to the instrumentation it was used.

Sample n. 213 consists of a little copper alloy stud found out in trench BKG 4-5 and dated back to the BKGCS VI macro-period (2nd-3rd century AD) (fig. 31-32).

This sample has been examined, through XRF both on its external and internal surfaces, but it has not been cut.

The analyses show that the sample presents a high concentration of copper (Cu) and important quantities of calcium (Ca) and iron (Fe); in this case as well there are relevant traces of zirconium (Zr). The sample presents, moreover, traces of tin (Sn), niobium (Nb) and titanium (Ti).

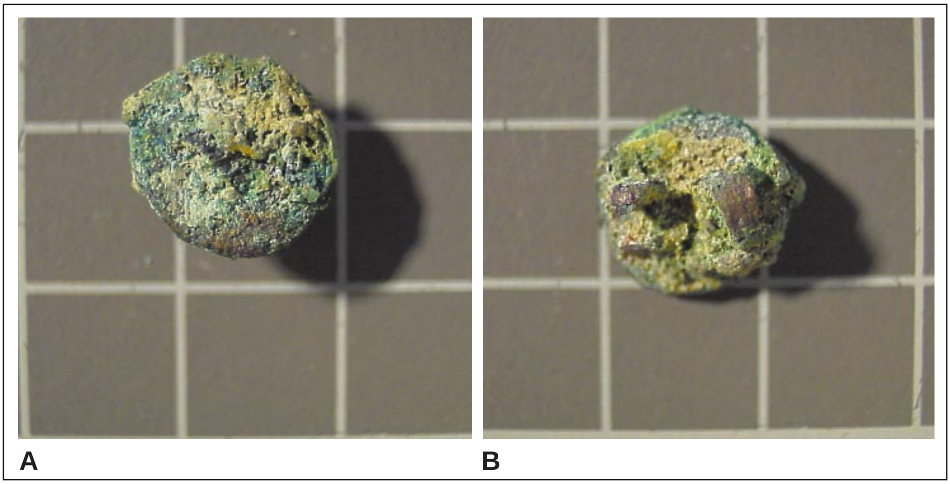

Figure 31. Photograph of sample n.213, recto and verso.

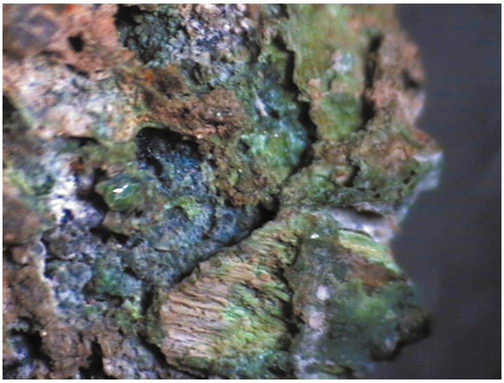

Figure 32. Microphotograph (15x) of sample n. 212, recto.

As we have pointed out since the beginning, the analyses carried out on the few samples available, can be considered only as a proof of feasibility for a future project. The number of samples, the sporadic origin of some of these and the typology of the first three samples examined, definitely unsuitable for this kind of analysis, do not allow the formulation of concrete hypotheses regarding the supplying sources of the metals found in Barikot. Unfortunately, when the samples have been imported, this project was not conceived yet and, since its creation, the Swat politic situation has prevented a new mission and therefore a new selection of samples.

Nevertheless, the few data collected showed at least two points of particular interest:

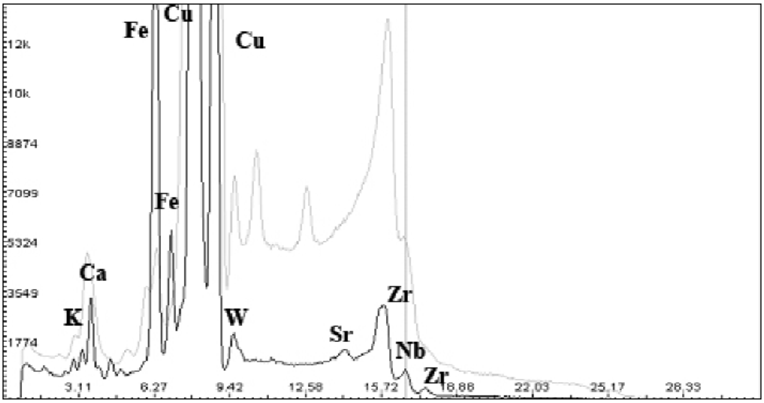

Figure 33. X-rays fluorescence spectrum of sample n. 213, recto (35 keV, 0.5 mA).

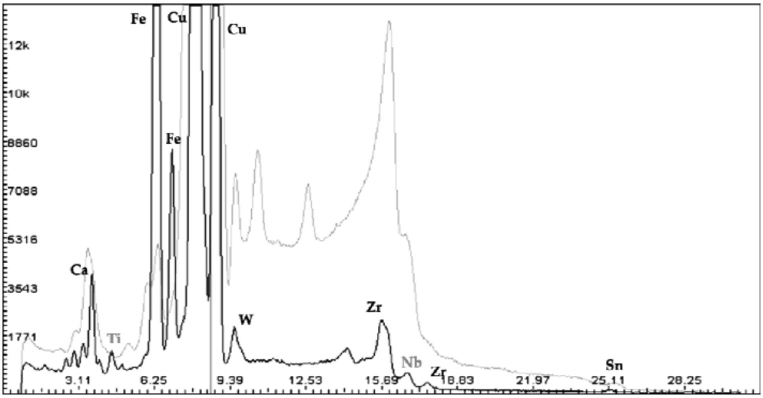

Figure 34. X-rays fluorescence spectrum of sample n. 213, verso (35 keV, 0.5 mA).

1) Four of the analysed samples – n. 127, n. 128, n. 146 and n. 213 – showed traces of titanium presence. Even though this presence was relevant to the authors, it results to be particularly evident only in the fragment of melting pot (n. 127), in the waste (n. 128) (fig. 12-17) and on the surface of the other samples (fig. 21, 23, 33 and 34) but not within their internal nucleus (fig. 22 and 24); it is not possible, therefore, to exclude it could be the result of an external contamination rather than an original element of the metallic alloy.
2) In three of the analysed samples, n. 146, n. 212 and n. 213, presence of niobium (Nb) was found (fig. 23-26, 30, 33 and 34). This last element is relatively rare and it is not

present in nature at a native state, but, in some cases, traces of it can be found in the crystal web of cassiterite (SnO_2) and, in particular, in cassiterite coming from some south-east Asian mines[11].

In the samples we have analysed, niobium is present both on the surface and within the core of samples; moreover, traces of niobium always coincides with the presence of tin in the alloy.

All we have said until now remains, for the already mentioned reasons, a mere speculation; nevertheless, if these data will be confirmed, it will be possible to think that the tin minerals used in Barikot come from mines or collecting zones characterised by the presence of niobium within the mineral.

7. Some conclusive considerations

As for the metallurgic production in the Barikot site, we have to confirm what we have previously pointed out: the data we have collected are still not enough to formulate reconstructive hypotheses regarding the development and the extension of this activity .

The concentration of those which have been recognised as indicators of the presence of a metallurgic activity, mainly during the BKGCS V, BKGCS VI and BKGCS VII macro-periods (see tab. 2), seems to indicate that this activity saw a development only since 1st-2nd century AD The extension of the site and the presence of wide areas which have not been studied yet make this data extremely partial.

The technical-diagnostic analyses carried out by the Laboratorio Diagnostico del Dipartimento di Storie e Metodi per la Conservazione dei Beni Culturali, Alma Mater Studiorum Università di Bologna, sede di Ravenna, showed that a variety of metallic alloys is present in the metallic objects discovered in Barikot; this variety goes further the too simplistic division copper/bronze.

This fact confirms the importance of diagnostic analyses and invites to be cautious when describing the discovered objects. The collected data and the several experiences demonstrate how the attempts to recognise materials on a superficial observation of the object could be misleading [20].

The study of spectres obtained from XFR analyses, realised within the Laboratorio di Ravenna, opened the way to a new project of studies which could give precious information about the metals' place of mining and, despite the narrow quantity of analysed samples, already supplied important data underlining the presence of niobium in the copper-tin alloy samples and giving, therefore, a possible indicator for the identification of tin supplying sites to which this presence seems to be linked.

We have to point out again that the objects which could be analysed with technical-diagnostic methodologies are too few in comparison with spatial extension and temporal development of the site. All the hypotheses we have illustrated will have to be compared with the data obtained from the studies which are still being carried on.

The importance of the Barikot site is always increasing with regards to the comprehension of the historical processes of this region, in particular the studies on the urban settlements in the pre-Kuṣ̌āṇa period [10] and on the Buddhism development in the region [21-22]. This, together with the relevance of data which, despite the difficulties, it was possible to obtain, invites to continue with even greater care the studies on this site.

Note

[1] For a more detailed description of trenches see the preliminary reports constantly published by MAIP:

- for trench **BKG 1**: CALLIERI P., FACCENNA D., FILIGENZI A. 1984, *Pakistan 1. Excavations and Researches in the Swat valley – Bīr-kot-ghwaṇḍai*, East and West, 15/1-2, 7-23.
- for **BKG 2**: CALLIERI P., FILIGENZI A., STACUL G. 1990, *Excavation at Bīr-kot-ghwaṇḍai, Swat: 1987*, Pakistan Archaeology 25, 163-192. CALLIERI P., BROCATO P., FILIGENZI A., OLIVIERI L.M., NASCARI M. 1992, *Bīr-kot-ghwaṇḍai 1990-1992. A Preliminary Report on the Excavations of the Italian Archaeological Mission*, *IsMEO.* Napoli, AION, 52, 4. Suppl. 73.
- for **BKG 3**: CALLIERI P., FILIGENZI A., STACUL G. 1990, *Excavation at Bīr-kot-ghwaṇḍai, Swat: 1987.* Pakistan Archaeology 25, 163-192.
- for **BKG 4-5**: CALLIERI P., BROCATO P., FILIGENZI A., OLIVIERI L.M., NASCARI M. 1992, *Bīr-kot-ghwaṇḍai 1990-1992. A Preliminary Report on the Excavations of the Italian Archaeological Mission, IsMEO.* Napoli, AION, 52, 4. Suppl. 73.
- for **BKG 6**: CALLIERI P., COLLIVA L., MICHELI R., NASIR ABDUL, OLIVIERI L.M. 2000, *Bīr-kot-ghwaṇḍai*, *Swat, Pakistan. 1998-1999 Excavation Report.* East and West, 50/1-4, 191-226, 204-225. CALLIERI P., COLLIVA L., NASIR ABDUL 2000-2001, *Bīr-kot-ghwaṇḍai*, *Swat, Pakistan. Preliminary Report on the Autumn 2000 Campaign of IsIAO Archaeological Italina Mission in Pakistan.* Annali, Napoli, Istituto Universitario Orientale, 60-61, 215-232. CALLIERI P. 2005, *Excavations of the IsIAO Italian Archaeological Mission in Pakistan at Bīr-kot-ghwaṇḍai, Swat: the Sacred Building on the Citaled*, in C. JARRIGE & V. LEFÈVRE (eds.), Paris, South Asian Archaeology 2001, II, 417-425.
- for **BKG 7**: OLIVIERI & MICHELI in CALLIERI P., COLLIVA L., MICHELI R., NASIR ABDUL & OLIVIERI L.M. 2000, *Bīr-kot-ghwaṇḍai*, *Swat, Pakistan. 1998-1999 Excavation Report.* East and West, 50/1-4, 191-226.

- for **BKG 8**: OLIVIERI & MICHELI in CALLIERI P., COLLIVA L., MICHELI R., NASIR ABDUL & OLIVIERI L.M. 2000, *Bīr-kot-ghwaṇḍai, Swat, Pakistan. 1998-1999 Excavation Report.* East and West, 50/1-4, 191-226.
- for **BKG 9**: OLIVIERI in CALLIERI P., COLLIVA L., MICHELI R., NASIR ABDUL, OLIVIERI L.M. 2000, *Bīr-kot-ghwaṇḍai*, *Swat, Pakistan. 1998-1999 Excavation Report.* East and West, 50/1-4, 191-226.

The excavation report regarding BKG 10 is being prepared.

2 In the chronological sequence hereby proposed, differently from what Olivieri prevously did (OLIVIERI 2003, 25-27), the abandon phase have not been indicated. In order to be more complete, we can say that, from the absolute chronology point of view, Phase 2 proposed by Olivieri can be put between BKGCS I and BKGCS II; Phase 4 is inserted between BKGCS II and BKGCS III; Phase 7 is included between BKGCS VII and BKGCS VIII whereas Phase 10 is between BKGCS IX and BKGCS X.

We are still not sure about some periods or phases which, failing sure data, we preferred to treat separately. Period III in BKG 2, yet uncertain, should come before Shahi period and could therefore be part of BKGCS VI or BKGCS VII macro-period.

Period VI of BKG 2 could be linked to BKGCS IX macro-period, and, maybe, the earthquake thought to be responsible for the falling down of the precedent structure could be the same which caused relevant damages to the monumental temple in the eastern terrace of the hill (Period III in BKG 6).

As for Period IX and X of BKG 4-5, the collected data are so narrow, even because of the limited structure extension, that their introduction in a macro-period would result totally arbitrary.

3 The inventoried objects have been handed over to the Department of Archaeology & Museums, Government of Pakistan, and are now kept in Saidu Sharif Swat Museum; the objects which have not been inventoried are kept, for study reasons, in the Saidu Sharif MAIP office.

4 City walls internal area.

5 City walls internal area.

6 The prills are drops of melted metal which fall to the soil during the working process.

7 Doubts remain regarding the function of object n. 162 and it is not possible to exclude it was used as ingot.

8 In the Barikot excavations, due to the wide extension of many trenches, the system of *loci* was used instead of squares. At the item “locus” we indicate the origin environment of the object; the first number of the *locus* indicates its trench.

The linear measures, if not differently indicated, are in centimetres; the weight in grams.

In the field “Period”, when possible, we indicate the macro-period of the chronological sequence previously proposed (preceeded by the abbreviation BKGCS); in these cases the periods of the sequence of the origin trench are indicated between round brackets.

9 See note VII.

10 The samples imported in 2000 were not chosen following their period, but because their were almost useless as for the typological studies.

11 See the Trento university website: (http://www.ing.unitn.it/~colombo/Niobio/html/niobio.htm) and the articles by C.K GUPTA: *Extractive metallurgy of niobium, tantalum, and vanadium International Metals Reviews*, vol. 29, n. 9 and G. KORINEK: *The tantalum and niobium industry: an overview,* TIC Bulletin, n. 80.

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Summary

The authors introduce new studies on the metallurgic activity carried out in the archaeological site of Barikot (Swat, Pakistan).

The collaboration between the IsIAO Italian Archaeological Mission in Pakistan and the Diagnostic Laboratory of the Department of Storie e Metodi per la Conservazione dei Beni Culturali of the Alma Mater Studiorum University of Bologna allowed the achievement of new useful data that are quite interesting even if the research is still at the beginning and needs further checks.

In particular some samples show traces of niobium. This element is fairly rare but, in some cases, is present into the crystal net of cassiterite. In the samples, the traces of niobium are always correlated with the presence of tin in the alloy. If these data will be confirmed, it's going to be possible to hypothesise that tin minerals used for the alloy of the object found at Barikot may come from mining sites characterized by the presence of niobium.

Riassunto

Gli autori presentano nuovi studi riguardanti l'attività metallurgica sviluppatasi nel sito archeologico di Barikot (Swat, Pakistan).

La collaborazione tra la Missione Archeologica Italiana dell'IsIAO in Pakistan e il Laboratorio Diagnostico del Dipartimento di Storie e Metodi per la Conservazione dei Beni Culturali, Alma Mater Studiorum Università di Bologna ha permesso la raccolta di nuovi dati che si sono dimostrati, anche se la ricerca è ancora in corso e necessita di ulteriori conferme, estremamente interessanti.

In particolare alcuni dei campioni presentano niobio in tracce. Questo elemento è estremamente raro, ma, in alcuni casi, è presente nella rete cristallina della cassiterite. Nei campioni, il niobio è sempre correlato alla presenza di stagno nella lega. Se questi dati verranno confermati, sarà possibile ipotizzare che i minerali di stagno, usati per le leghe degli oggetti rinvenuti a Barikot, provengano da siti estrattivi caratterizzati dalla presenza di niobio.

Résumé

Les auteurs présentent des nouvelles études concernant l'activité métallurgique qui s'est développée dans le site archéologique de Barikot (Swat, Pakistan).
La collaboration entre la Mission Archéologique Italienne de l'IsIAO au Pakistan et le Laboratoire Diagnostique du Département d'Histoires et Méthodes pour la Conservation des Biens Culturels, Alma Mater Étudesrum Université de Bologne a permis la récolte de nouvelles données qui se sont démontrées, même si la recherche est encore en cours et a besoin d'ultérieures confirmations, extrêmement intéressantes.
En particulier, certains des échantillons présentent niobium en traces. Cet élément est extrêmement rare, mais, dans certains cas, il est présent dans le réseau cristallin de la cassitérite. Dans les échantillons, le niobium est toujours corrélé à la présence d'étain dans l'alliage. Si ces données étaient confirmées, il sera possible de supposer que les minéraux d'étain, employés pour les alliages des objets retrouvés à Barikot, proviennent de sites d'extraction caractérisés par la présence de niobium.

Zusammenfassung

Die Autoren stellen die neuen Studien über die metallurgische Aktivität vor, die sich in der Ausgrabungsstätte von Barikot (Swat, Pakistan) entwickelt hat.
Die Kooperation zwischen der Italienischen Archäologischen Mission von IsIAO in Pakistan und dem Diagnostischen Labor vom Fachbereich Geschichten und Methoden für die Erhaltung von Kulturgütern, Alma Mater Studiorum, Universität von Bologna ermöglichte es, neue Daten zu sammeln, die sich extrem interessant erwiesen, obwohl die Forschung noch im Gang ist und noch bestätigt werden muss.
Insbesondere tragen einige der Muster Spuren von Niob, dieses Element ist sehr selten aber ist manchmal im Kristallgitter des Kassiterits. In den Mustern ist Niob immer zu finden, wenn es Zinn in der Legierung gibt. Wenn diese Daten bestätigt werden, kann man vermuten, dass die Mineralien aus Zinn, die für die Legierungen der in Barikot aufgefundenen Gegenstände verwendet wurden, aus Ausgrabungsstätten mit Niob stammen.

Resumen

Los autores presentan nuevos estudios en relación con la actividad metalúrgica desarrollada en el enclave arqueológico de Barikot (Swat, Pakistán).
La colaboración entre la Misión Arqueológica Italiana del IsIAO en Pakistán y el Laboratorio Diagnóstico del Departamento de Historias y Métodos para la Conservación de los Bienes Culturales, Alma Mater Studiorum Universidad de Bolonia ha permitido la recogida de nuevos datos que han resultado extremadamente interesantes, si bien la investigación todavía está en curso.
En particular, algunas de las muestras presentan trazas de niobio. Este elemento es extremadamente raro, pero en algunos casos está presente en la red cristalina de la casiterita. En las muestras, el niobio siempre se presenta en correlación con la presencia de estaño en la aleación. Si estos datos se confirmasen, se podrá teorizar que los minerales de estaño, usados para las aleaciones de los objetos hallados en Barikot, proceden de los enclaves de extracción caracterizados por la presencia de niobio.

Резюме

Авторы представляют новые исследования, касающиеся металлургического производства в области археологических раскопок в Барикоте (Swat, Pakistan). Сотрудничество в Пакистане между «Итальянской археологической экспедицией институтута ИзИАО» и диагностической лабораторией при кафедре истории и методов сохранения памятников (Болонского Университета), позволило собрать новые данные, представляющие собой чрезвычайный интерес (хотя исследование еще не закончено и нужны подтверждения верности некоторых данных).

В частности, некоторые образцы содержат следы ниобия. Этот элемент очень редок, но в некоторых случаях он присутствует в кристаллической сети касситерита. В образцах ниобий всегда связан с присутствием в сплаве олова. Если эти данные будут подтверждены, станет возможным предположить, что минералы олова, использованные в сплавах при производстве изделий, найденных в Барикоте, происходят из других зон, содержащих ниобий.