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## **Typo-technological, elemental and lead isotopic characterization and interpretation of Đông Sơn miniature drums**

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1 Title:

2 Typo-technological, elemental and lead isotopic characterization and interpretation of Đông  
3 Sơn miniature drums

4

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17

18 **Abstract:** Copper-base drums are among the most iconic artefacts of mid-late 1<sup>st</sup>  
19 millennium BC Southeast Asia and southern China, and more specifically of the Vietnamese  
20 Đông Sơn culture and the Yunnanese Dian culture. The wide distribution of these drums, in  
21 public museums and private collections, renders their technical and stylistic study difficult,  
22 and their comparison complex. In this paper, we focus on a copper-base miniature drum  
23 assemblage, discovered in a tightly delimited area of northern Vietnam, associated to the  
24 Đông Sơn culture. This multi-disciplinary study incorporates morphological, stylistic,  
25 technological, elemental and lead isotopic analysis of a large proportion of a regional drum  
26 assemblage for the first time. With this combined approach was intended to improve our  
27 knowledge of the people who produced and consumed miniature drums; a class which, until  
28 now, has not aroused much interest. The present paper details the archaeometric results of  
29 this original analysis, based on 25 samples from the National Museum of History (Hanoi). The  
30 results indicate a wide variety of alloy types was used, alongside a range of raw material  
31 sources, both with weak correspondence to morpho-stylistic classification. We propose  
32 these data evidence Đông Sơn drum miniature production was practiced in a decentralised  
33 manner, using materials at hand, but questions concerning their emergence and their link to  
34 burial practices seen in contemporary southern China remains unsolved from an  
35 archaeometallurgical point of view but will be the subject of another paper (Le Meur *et al.*  
36 (forthcoming)).

37 **Keywords:** Vietnam; Đông Sơn culture; Protohistoric/Iron Age Southeast Asia;  
38 Copper-base metal; Microstructure; Elemental composition; Lead isotopes

39

## 40 **1. Introduction**

### 41 1.1 Đông Sơn culture and Iron Age Mainland Southeast Asia

42 As per many regions of the world, the Iron Age of Mainland Southeast Asia ('MSEA'),  
43 beginning during the 5<sup>th</sup>/4<sup>th</sup>. c. BC, was a period of immense cultural, economic and political  
44 change, with generally sharp increases in the social complexity of regional social groups (e.g.  
45 Higham, 1989, 2014). In addition to regional population growth, partly fuelled by innovations  
46 in intensive wet-rice agriculture stimulated by an increasingly dry climate (e.g. Castillo et al.,  
47 2018; Wohlfarth et al., 2016), the beginnings of monumental combined hydraulic/defensive  
48 earthworks and evidence for rising conflict in the run up to the emergence of proto-states  
49 (e.g. Bellina, 2017; Boyd et al., 1999; Kim, 2013; O'Reilly and Scott, 2015), the second half of  
50 the 1<sup>st</sup> millennium BC saw the intensification of pre-existing long-range social interaction  
51 networks, linking MSEA with South Asia, East Asia and Island Southeast Asia ('ISEA') (e.g.  
52 Bellina, 2007; Bellwood, 2007; Hung, 2017). Given MSEA's massive ecological and cultural  
53 diversity, the presence and intensity of these Iron Age changes varied considerably, between  
54 populations occupying mountains and plains, inland and coastal zones, but the most  
55 extreme differences were, as might be expected, to be found on the extremities of the MSEA  
56 Peninsula.

57

58 *Figure 1: Map of Vietnam (red outline) in geographical relation to Mainland Southeast Asia and East Asia (top), and the Red*  
59 *River delta and the principal site's location (bottom).*

60 Located the closest to South India, widely thought to be the proximal source of MSEA iron  
61 technologies (e.g. Bellwood, 2007; Higham, 2014; Pryce et al., 2017), Myanmar has provided  
62 amongst the earliest regional Iron Age dates, namely from Kan Gyi Gon in Magway Region  
63 (Pryce et al., 2013), but even these are not significantly earlier than reliably dated sites in  
64 central and northeast Thailand (Higham et al., 2015, 2020). What is now very clear, some  
65 forty years after the initial signs were spotted at Ban Don Tha Phet in west-central Thailand  
66 (e.g. Bellina and Glover, 2004; Glover, 1990), is that the earliest intense and sustained  
67 contacts, including limited migration, between South Asia and MSEA took place on the  
68 Myanma-Thai-Malay Peninsula, as evidenced by two decades of intensive archaeological  
69 investigation by the Franco-Thai and Franco-Myanma team in Thailand's Chumphon Province  
70 (Bellina, 2017) and Myanmar's Tanintharyi Region (e.g. Bellina et al., 2018).

71

72 Concomitantly, after millennia of sustained interactions with populations of the present-day  
73 southern Chinese provinces of Guangxi and Yunnan, which led to the MSEA Neolithic  
74 (Higham et al., 2011) and Bronze Age (Higham et al., 2019, 2020; Pryce et al., 2018; Yao et  
75 al., 2020) transitions, the mid-late 1<sup>st</sup> millennium BC saw ever-heightening confluence and  
76 indeed conflict between Warring States, Qin and Han China and northern Vietnam.

77 Ultimately this trend culminated with the annexing of Nam Việt by Emperor Wu's armies in  
78 111 BC, marking the beginning of the Bắc thuộc ('Northern Domination') period that was to  
79 last, with some unsuccessful disruptions, until AD 938. However, who were the Lạc Việt  
80 peoples conquered in Nam Việt, and what was the nature of their societies, before and after  
81 the imposition of direct Han control via the Han Governance of Jiaozhi ('Giao Chỉ Bộ') (Papin,  
82 2000). There is little doubt that some northern Vietnamese gradually adopted some Han  
83 practices in the first centuries of the Christian era, but to what extent, with what degree of  
84 fidelity, and hybridisation?

85

86 The late prehistoric chronological sequence leading to the Han Commandery in northern  
87 Vietnam is not yet precisely known. The Bronze Age, rather than Neolithic/Bronze Age status  
88 of the early-mid 2<sup>nd</sup> millennium BC Phùng Nguyên culture remains somewhat disputed (e.g.  
89 Kim, 2015) but the proceeding late 2<sup>nd</sup> millennium BC Đông Đậu period is widely agreed to  
90 be Bronze Age. The following period, at the outset of the 1<sup>st</sup> millennium BC, was known as  
91 Gò Mun, which between the 8<sup>th</sup>-6<sup>th</sup> c. BC gave way to that of the Đông Sơn. This latter,  
92 persisted at least until the beginning of the Eastern Han period (AD 25). The eponymous site  
93 of this period, which also gave its name to the iconic copper-base drums of various sizes that  
94 continue to serve as the image of late prehistoric Vietnam, provides the bulk of the study  
95 assemblage for this paper. The 'Đông Sơn drum' artefact class, whose ultimate origin and  
96 social meaning has been hotly debated for over a century, is claimed to have been found  
97 across southwestern China, MSEA and much of ISEA (e.g. Bernet Kempers, 1988; Calò, 2014;  
98 Heger, 1902; Jusoh et al., 2014; Oliveira et al., 2019; Pirazzoli-t'Serstevens, 1979; Sinh, 1989).  
99 Regional copper-base drums were initially classified by F. Heger (1902) into various types, I –  
100 IV, with Is being the oldest and later types continuing to be used for rituals in many ethnic  
101 minority populations, often in upland and remote regions (e.g. Andaya, 2016; Izikowitz,  
102 2001). Closer reading soon reveals the ancient, Heger I, drums are typically referred to as  
103 either 'Đông Sơn' or 'Dian' (Yunnan) bronzes (typically but not exclusively leaded bronze  
104 alloys), as there are clear stylistic differences between the two, but discussion continues on  
105 which was the earliest type (Han, 2004) and on the production technique (e.g. Bennett,  
106 2008; Chiou-Peng, 2008). The dating is difficult to resolve satisfactorily as whilst the Yunnan  
107 Metal Age is increasingly well-dated (Yao et al., 2020), Metal Age Vietnam continues to  
108 suffer from a lack of reliable radiometric dating (Kim, 2015), with some notable exceptions  
109 like Động Xá (Bellwood et al., 2007). Indeed, Động Xá is a Red River Delta site that produced  
110 a drum of Dian rather than Đông Sơn style and of an atypical elemental and lead isotopic  
111 composition, so the devil is clearly in the detail (Pryce et al., 2014). This period also  
112 corresponds to the Hallstatt Plateau (e.g. Jacobsson et al., 2018), so without targeted  
113 chronological campaigns, preferably combining radiocarbon with dendrochronology and  
114 Bayesian stratigraphical statistical analysis, we are unlikely to see an entirely satisfactory  
115 resolution to the question of which drum tradition came first.

116

117 For the question of technology, opinion splits between piece-mould casting (Meyers, 2011;  
118 Nguyễn, 2017), long known in the Bronze Age Central Plain of China, or lost wax casting,  
119 whose origin is less clear but potentially Southeast Asian (e.g. Barnard, 1996; Bennett, 2008;  
120 White, 1988; Notis and Wang, 2017) or Chinese (Peng, 2020). Here is not the place to go into  
121 the details of these two broad techniques, for which a large literature exists. Needless to say,  
122 no single scholar has made an exhaustive technological, let alone archaeometric, study of  
123 the hundreds of known large drums, such is their wide geographical distribution, across  
124 Southeast Asia and Western museums, and the inaccessibility of examples in private  
125 collections. As such, the important potential for variation in production technique, or  
126 combinations of decorative style, techniques and materials, remains unexplored. This lacuna  
127 could well obscure multiple production centres, and/or core-periphery interactions as  
128 expressed via imitations or re-interpretations of imported material culture. Of the limited  
129 archaeometric studies available (e.g. Pryce et al., 2014), those from peninsular Thailand  
130 (Pryce and Bellina, 2018) and Bali (Pryce et al., 2018) bear out these possibilities, as do  
131 findings of drums moulds from the Non Nong Ho site in northeastern Thailand (Baoneod,  
132 2010; Lertlum, 2011).

133  
134 This paper takes a different direction to preceding efforts, in that the entire sub-class of  
135 miniature drums constitutes the study assemblage. Ninety percent of all known miniature  
136 drums have been directly studied by the authors, and nearly 20% of the total has been  
137 subjected to stylistic, technological, elemental and lead isotope analyses at a much higher  
138 level of representativity. Such a focus, on artefacts that are only found in cemeteries in a  
139 restricted area of the Red River Delta, as opposed to the large drums' regional distribution,  
140 may be able to shine light, not only on the possibility of production variation in large drums,  
141 but also on the nature of the Han occupation of northern Vietnam, as funerary miniatures  
142 are a well-known Han trait (e.g. Selbitschka, 2015).

## 143 144 **1.2 Đông Sơn site**

145 The cemetery at Đông Sơn village (105.78295° E, 19.84934° N) in Thanh Hóa province  
146 (Figures 1 & 2) was first investigated by Louis Pajot, a French colonial officer assigned by the  
147 Ecole Française d'Extrême-Orient (EFEO) to supervise the discovery of archaeological  
148 remains in this province between 1924 and 1928. Following criticism over a lack of  
149 professionalism, the EFEO engaged the Swedish archaeologist Olov Janse to succeed Pajot in  
150 1935. Two burials and 16 funeral deposits were identified and associated to the Đông Sơn  
151 occupation period.

152  
153 Subsequent Đông Sơn excavations in 1959, 1961-1962, 1969-70 and 1976 by the Institute of  
154 Archaeology of Hanoi, expanded the known extent and understanding of the site. A total of  
155 129 tombs were recorded over an area of 2033 m<sup>2</sup>. Unfortunately, very few human bones  
156 were preserved, making it impossible for a solid study of age and sex profiles to be  
157 conducted. The cemetery presented three strata with superposed and intercutting burials

158 suggesting a phase of use ranging from a period qualified as 'pre-Đông Sơn' to the Han  
159 occupation period. Regrettably there are no available radiocarbon dates for the site. The  
160 miniature drums, for those we have excavation records, were found in indigenous tombs  
161 and were clearly intended as burial offerings.

162

### 163 **1.3 Thiệu Dương and Lăng Ngâm sites**

164 Thiệu Dương is a cemetery site in the hamlet of Dương Xá (19.859722°N, 105.760556° E),  
165 Thiệu Dương village, Thanh Hoá province, located a few kilometres away from the Đông Sơn  
166 site. It was discovered during the French colonial period and excavated three times by a  
167 team lead by the Vietnamese Institute of Archaeology, between 1960 and 1965. A total of  
168 123 burials from the late Đông Sơn period were discovered in an area covering more than  
169 3000 m<sup>2</sup> (Reinecke, 2016; Tỳ et al., 1968). Among 444 copper-base artefacts, one miniature  
170 drum was found in an adult grave. Notably this grave also contained the largest number of  
171 metal artefacts within the site. One other miniature was found in 1925 during Pajot's  
172 excavations but its location is unknown. Another chance find is known of but is not  
173 documented.

174

175 Lăng Ngâm is a cemetery site in Núi Thiên Thai hamlet (106.168753° E, 21.074227°N), Lăng  
176 Ngâm village, Bắc Ninh, province. It was excavated in 1972 by the National History Museum  
177 in Hanoi (*Bảo tàng Lịch sử Quốc gia*), after the reporting of a chance find. In the limited area  
178 excavated, four burials were recorded, one of which contained a miniature drum (Huyền,  
179 1996).

180

### 181 **2. Assemblage**

182 There is no formal definition regarding the dimensions of miniature drums, though Phạm  
183 Minh Huyền et al. (1987: 120-122) and Bernet Kempers (1988: 45) suggest a maximum  
184 height of 150 mm or a tympanum diameter of 200 mm, respectively. In this study we  
185 propose that miniature drums are those less than 200 mm in height, which gives a clear  
186 differentiation from their larger counterparts whose height is considerably more and can  
187 even exceed 600 mm. As per the large drums, the miniature are hollow, though in a few  
188 cases baked clay probably corresponding to the casting core remains. The miniature drum  
189 assemblage, their contextual information and method of typological classification, in  
190 particular their casting technique, will be dealt with at length in Le Meur et al. (forthcoming),  
191 so we will limit ourselves here to the details necessary to cross-reference the archaeometric  
192 approach that is the focus of this paper. A total of 131 drum miniatures are known, of which  
193 118 were personally examined by the lead author. The remaining 13 are known either from  
194 bibliographic sources, or through correspondence with museum curators. 53 of the 131  
195 examples come from archaeological excavations, with the remainder being the result of  
196 chance finds, donations, private collections and police seizures of looted material. The major  
197 repositories for the drum miniatures are the National History Museum, the Thanh Hóa  
198 provincial museum, and the Cernuschi Museum in Paris, whose combined collections

199 constitute 78% of the total. All of the 25 samples whose analyses are presented here come  
200 from the National History Museum and were legally sampled and exported to France in  
201 November 2018. This gives an archaeometric study ratio of ca. 19%, which is high compared  
202 to most regional assemblages and offers an rare level of representativity (e.g. Pryce et al.,  
203 2014).

204

205 The five miniature drum types, plus exceptional and non-classifiable examples are shown in  
206 Figure 2. They may be defined thus: Type 1 drums have a ring on the tympanum, no seams, a  
207 flat tympanum, a rounded profile upper mantle, a truncated cone shape lower mantle and a  
208 wide foot. Hollow designs cover the tympanum and, most of the time, the mantle. The  
209 quantity and appearance of handles are varied, with no pattern identified. Sub-types have  
210 been created considering the presence of frog figurines on the tympanum (Type B) or the  
211 significant height of the upper mantle (Type C). Type D gathers incomplete drums associated  
212 to Type 1 due to the presence of a ring or their morphological characteristics.

213 Type 2 drums have neither seams nor decoration, a very flat and large tympanum and two  
214 symmetric handles. Considering the shapes, two sub-types have been identified. Sub-type A  
215 includes drums with a sharp oblique upper mantle. As the shape of the lower mantle differs  
216 between cylindrical and truncated cones, associated with a wide foot differentiated by an  
217 inflection from the lower mantle or included in the lower mantle base, two groups have  
218 been created. Sub-type B consists of drums with oblique rounded upper mantle, truncated  
219 cone-shaped lower mantle from which foot is not stressed.

220 Type 3 drums bear a single seam bisecting the drums vertically, were undecorated and have  
221 a slightly convex tympanum associated with an oblique rounded upper mantle. As the  
222 number of handles and the shape of the lower mantle differs, four sub-types have been  
223 created (Figure 3). The first one includes drums with two handles between the seam, with a  
224 cylindrical lower mantle and a wide foot or with a truncated cone-shaped lower mantle with  
225 no foot emphasised by an inflexion. Sub-type Bs have only one handle disposed between the  
226 seam, and two shape have been identified as in sub-type A. Drums gathered in sub-type C  
227 have two handles on the seam, a cylindrical lower mantle and a wide foot emphasised by an  
228 inflexion. Sub-type D drums are similar to sub-type A1 drums in shape, but are bigger and  
229 does not have handles attached to the upper mantle and the lower mantle but only on the  
230 lower mantle.

231 Type 4 drums have three seams, no decoration, a tympanum slightly heightened and a  
232 rounded upper mantle. Two sub-types have been created considering the different shapes of  
233 the lower mantle and the foot (Figure 4).

234 Type 5 drums have three seams and designs in relief are always present on the tympanum,  
235 and frequently on the mantle. The large and various shapes of the upper mantle, lower  
236 mantle and foot, lead us to identify four sub-types. Sub-type A have raised tympana,  
237 rounded upper mantles, cylindrical lower mantles and wide feet so as a star at the centre of  
238 the tympanum and two handles disposed between the seams, contrary to sub-type B with  
239 two handles on the seams, a flat tympanum, an oblique rounded upper mantle, a truncated

240 cone shape lower mantle and designs both on the tympanum and the lower mantle. Sub-  
241 type C drums carried a shape similar to sub-type A but are bigger, and the tympanum  
242 surface is decorated with a star and other geometric designs. Sub-type D consists of drums  
243 with heightened tympanums, four handles, decorated on the tympanum and the mantle.  
244 Those are the only examples to have four flying bird designs on the tympanum. Body shapes  
245 differed so we have divided this sub-type in three sub-groups. The first one of small drums,  
246 with oblique rounded upper mantles associated with wide lower mantles. Drums belonging  
247 to the second group are the largest our assemblage, with rounded upper mantles, a  
248 truncated cone shape lower mantle with a wide foot highlighted by an inflexion. The last  
249 Type 5 D group include drum similar to Type 5 B with a significant addition, four frog  
250 figurines on the tympanum.

251 Two more categories have been added for drums not associated to one of the five types  
252 (Incategorizable) and for drums which stand out (Exceptional).

253

254 *Figure 2: Analysed miniature drums typology (from Le Meur's forthcoming doctoral thesis).*

255 *Figure 3: Miniature drum typological classification schematic (from Le Meur's forthcoming doctoral thesis).*

256 As can be seen in Figure 4 (left), Type 1 drums are the predominant type, followed by Type  
257 5s, 3s and 2s tied, and Type 4s the least common. Details of the analysed samples can be  
258 found in Table 1, and it can be seen (Figure 4, right) that our sampling strategy at the  
259 National History Museum followed the overall type distribution closely, with the exception  
260 of Type 2s being under-represented and Type 3s over-represented, which was simply due to  
261 the unavoidable sub-sampling issue of being granted permission to cut only in Hanoi. We can  
262 notice the particular shape and aspect of one of the two Remarquable drums sampled  
263 (Figure 4) compared to the ones associated to the five types.

264

265 *Figure 4: Proportion of whole (left) and archaeometrically-studied (right) assemblages by typological classification.*

266 *Table 1: Nomenclature, context and metric data for the archaeometrically studied assemblages from Đông Sơn, Lãng Ngâm*  
267 *and Thiệu Dương.*

268

### 269 **3. Methodology**

270 The studied artefacts were all cut on site in the National History Museum, Hanoi, using an  
271 ultra-fine jeweller's saw, taking into account areas of existing damage (preferred) and  
272 corrosion (avoided). As such it was not possible to cut the artefacts across macroscopically-  
273 visible seams and/or decoration so as to get microscopic proof of production technique. The  
274 artefacts were immediately restored with copper oxide dust-impregnated dental wax. The  
275 cut samples were 2-4 mm<sup>3</sup>, cut from exterior surfaces and may not be representative of  
276 object heterogeneity due to poor alloy mixing, segregation during solidification, or any  
277 unidentified joints or welds. The cut samples were then halved, for  
278 elemental/microstructural and isotopic analyses, respectively.

279



### 280 3.1 Optical Microscopy (OM)

281 Cut samples were epoxy resin-mounted and ground using silicon carbide wet-dry paper (80-  
282 4000 grit), prior to polishing with diamond pastes (3, 1 and 0.25  $\mu\text{m}$ ). The microstructure  
283 was studied by OM before (for corroded samples) and after ferric chloride etching to reveal  
284 crystalline structures.

285

### 286 3.2 X-ray fluorescence (XRF)

287 XRF was used for the OM samples' bulk elemental composition of major, minor and (some)  
288 trace elements, conducted at the *Laboratoire Archéomatériaux et Préviation de l'Altération*  
289 (LAPA-IRAMAT/CEA) in Saclay, France. XRF data were acquired using a NITON XL 3t GOLDD+  
290 portable XRF analyser in 'laboratory mode' (fixed stand), with a max 40 kV accelerating  
291 voltage in the 'alloys' mode. Accuracy and precision were assessed with eleven Certified  
292 Reference Materials (CRMs): B10, B12, B31, UZ 52-3, B21 and L 20-1 from the *Centre de*  
293 *Development des Industries de Mise en Forme des Matériaux*, France, 71.32-4 and 51.13-4  
294 from the Bureau of Analyzed Samples Ltd., England and 500, C1123 and 1275 from the  
295 National Institute for Standards and Technology (NIST, Table 2). Good results for majors and  
296 minor components were confirmed but note that light elements at low concentrations like  
297 phosphorous, silicon, aluminium, magnesium and also sulphur were not reliably detected  
298 due to non-vacuum conditions. The analyses were performed on the OM mounted and  
299 polished sections using a 3 mm beam diameter, which allowed for reliable results as long as  
300 the sample was larger than this. Three such spot analyses were made for each sample to  
301 account for corrosion and inclusions.

302

### 303 3.3 Scanning Electron Microscopy with Energy Dispersive Spectrometry (SEM-EDS)

304 The OM/XRF samples were carbon coated for analysis in a JEOL 7001F instrument, in order  
305 to establish the bulk composition of samples less 3 mm in diameter, those with intergranular  
306 corrosion, and to study any inclusions. Both secondary electron (SE) and backscattered  
307 electron (BSE) modes were used, using a 20 kV accelerating voltage, a 10 mm working  
308 distance with an Oxford Silicon Drift Detector, and processed using Oxford Instruments Aztec  
309 software. The detection limit was fixed at 0.5 wt.% with a count rate of 4000/s (detection  
310 time of 40 s), which gave good spectral resolution with respect to background noise. We  
311 consider the relative quantification error ( $2\sigma$ ) is circa 10% of the measured value. SEM-EDS  
312 accuracy was evaluated using the same CRMs as used for the pXRF analysis, and we obtained  
313 good results for the major elements (Table 2). Bulk compositions for each sample were  
314 obtained by a mean of 3-4 areas scan ( $0.4\text{ mm}^2$ ) per sample. The analyses were performed in  
315 areas without corrosion products, when it was possible, as it can have an effect on the SEM  
316 results, especially on the major components.

317

318 *Table 2: CRM results. The table presents raw data from XRF and SEM-EDS analyses.*

319

### 320 3.4 Multi Collector – Inductively Coupled Plasma – Mass Spectrometer (MC-ICP-MS)

321 Lead isotope analysis (LIA) was performed at the *Service d'Analyse des Roches et des*  
322 *Minéraux* of the Centre for Petrographic and Geochemical Research (SARM-CRPG) in Nancy,  
323 France, using MC-ICP-MS after lead extraction (Manhes et al., 1980). Thallium NIST SRM 997  
324 was used to correct for instrumental mass bias and all parameters were adjusted to obtain  
325 the closest values relative to NIST SRM 981, as determined by DSTIMS (Thirlwall, 2002).  
326 More details about SARM-CRPG lead isotope analysis are available in (Cloquet et al., 2006;  
327 Pienitz et al., 2015).

328

329 As one case study within the SEALIP/BROGLASEA programme, LIA was used to look for  
330 'consistency' with known and characterised production systems, in recognition that there  
331 could be other, as yet uncharacterised, primary and/or secondary production systems, as  
332 well as recycling impacting interpretation (e.g. Budd et al., 1993; Pryce et al., 2014, 2011b;  
333 Wilson and Pollard, 2001).

334

## 335 **4. Results**

### 336 4.1 Optical Microscopy

337 As was expected given the typology and decoration of the miniature drums, all presented as-  
338 cast microstructures with no evidence for post-casting treatment (Figure 5). Some variation  
339 is visible in the speed of cooling, with dendrites indicating extended cooling, preheated  
340 moulds and/or lack of quenching/immediate breaking of the moulds. At higher  
341 magnifications, elemental segregation is visible, as would be expected with longer cooling  
342 times. Inter-granular corrosion is frequent and some samples are almost exclusively  
343 composed of corrosion products (DS/9, THD/2, DS/8 and DS/19), potentially impacting the  
344 XRF elemental analyses (see below), as would the relatively common fully-segregated lead  
345 prills, formed due to Cu-Pb solid-state immiscibility. The dimension of lead nodules is  
346 variable and dependent on the cooling rate, the slower the cooling rate is the larger are the  
347 lead nodules (Mille, 2017: 383). Some samples have a two-phases microstructure, namely  
348 the  $\alpha+\delta$  eutectoid, with a brittle and hard high-tin  $\delta$  phase and a rich-copper  $\alpha$  phase. The  
349 quantity/area of these second phase in some samples is also indicative of fast cooling rates.  
350 For every sample (except those composed exclusively of corrosion products), copper  
351 sulphide inclusions are observed with rounded and polylobed form

352

353 *Figure 5: (top row, left to right), DS11 x 10 ppl showing intergranular corrosion and faster-cooled as-cast structure, DS14 x*  
354 *10 ppl showing elemental segregation, lead inclusions (black areas) and an  $\delta$  tin-rich phase (light blue) DS20 x 10 ppl*  
355 *showing intergranular corrosion and slower-cooled dendritic as-cast structure, (bottom row, left to right), DS2 x 20 ppl after*  
356 *etching, showing porosity, intergranular corrosion, elemental segregation and lead[ ?] inclusions, DS10 x 50 ppl showing*  
357 *copper sulphide inclusions (grey), an  $\delta$  tin-rich phase (light blue) and faster-cooled structure, DS7 x 400 SEM BSE showing*  
358 *intergranular corrosion, elemental segregation, an  $\alpha+\delta$  eutectoid (light grey) and lead inclusions (white).*

359

### 360 4.3 Elemental analyses – XRF + SEM-EDS

361 *Table 3: Elemental compositional data for Đông Sơn, Lãng Ngâm and Thiệu Dương samples. Major alloying components (Sn,*  
362 *Pb, Cu) are highlighted, as are those indicative of corrosion and thus interpretative caution. O percentage, not measured by*  
363 *stoichiometry, are also an indicator of corrosion degree. Detection limit is 0.5 wt. % for SEM-EDS and 700 ppm for XRF*  
364 *(varying in function of the element, note that light elements detection is not accurate with XRF).*

365

366 The studied assemblage contains four classes of copper-base alloy using the standard 1 wt%  
367 as the cut-off for alloying components: 1. Effectively pure copper, 2. Bronze, 3. Leaded  
368 copper and 4. Leaded bronze. Table 1 shows both bulk (XRF) and phase (SEM-EDS) elemental  
369 results, which sometimes differ considerably, which highlights the level of corrosion.  
370 However, only in two cases, DS/12 and DS/19, does this potentially change the alloy  
371 identification, and in realistic 'borderline' terms, it can be considered not to. Overall, there is  
372 a clear trend towards leaded alloys, at 81% of the assemblage (Figure 6). In provenance  
373 terms, this means that our LIA data must be discussed largely with respect to lead exchange  
374 systems, though no prehistoric lead production systems have yet been studied (Pryce, 2014,  
375 2012) as well as those for copper/bronze.

376

377 *Figure 6: Major alloy classes for studied samples across all sites.*

378 In terms of standardisation, there is near continuous variation in tin content from below  
379 detection limit (bdl. XRF/SEM-EDS) to 21 wt.% (Figure 7). The samples with the higher tin  
380 concentrations are not true 'high-tin bronzes' in the sense of the hot-worked and quenched  
381 beta alloys often associated with the Indian subcontinent (Murillo-Barroso et al., 2010; Pryce  
382 and Bellina, 2018; Srinivasan and Glover, 1995): the high Sn values are simply due to copper  
383 depletion and apparent enrichment of residual tin oxide in the burial environment. Tin  
384 values measured by SEM-EDS in less corroded metal do not exceed 15 wt%. Similar but not  
385 quite identical results can be seen for lead content, from bdl. to 18 wt.%, perhaps some  
386 modalism at ca. 1-2, 6-8 and 10-12 wt. % lead compositions (Figure 8), though corrosion  
387 depletion of copper remains the most likely reason, as seen in the optical microscopy.

388 *Figure 7: Variation of tin content in wt. %.*

389 *Figure 8: Variation of lead content in wt. %.*

390 In Table 1 we include a column for 'Alloy-Type', that is cross-referencing the typological  
391 classification and the alloy, to see if there were preferred 'recipes' for certain shapes. This  
392 could potentially identify control of alloying to achieve more complex shapes, and/or the  
393 practices of individual workshops. Although there is a predominance (31%) of leaded bronze  
394 Type LB1 miniature drums this is most likely a simple function of Type 1 being the prevalent  
395 artefact class and leaded bronze being a very common Iron Age MSEA alloy (Pryce, 2014;  
396 Pryce et al., 2014). As such, with these data we see no correspondence between style and  
397 alloy (Figure 9).

398 *Figure 9: Proportion of 'Alloy-Types' for the miniature drums.*

#### 399 4.4 Lead isotopes

400 Complete raw lead isotope ratio data may be consulted in Table 3, alongside the 'Alloy-Type'  
401 column seen in Table 2. Being a four-fifths leaded assemblage, we are clearly limited but not  
402 mute, in what we can say about the sources of the primary alloy component, copper, whose  
403 own trace lead isotope signature will be totally overwhelmed by that of the added lead  
404 metal. Let us begin then by assessing the general clustering of the study assemblage, as  
405 labelled for leaded and unleaded artefacts (Figure 10). Without reference to a regional  
406 database, not a great deal could be said other than that the sources of copper for DS/13,  
407 THD2 and DS20, itself perhaps with THD/1, are probably different. Likewise, we can see two  
408 main lead clusters to the left and centre of the figure, with possible outliers in DS/2 and  
409 DS/6. These *a priori* potential consistencies show no correspondence with the attributed  
410 typological classification.

411  
412 *Table 4: Raw lead isotope ratios for the studied artefacts.*

413 *Figure 10: LI ratios seen for the study assemblage alone, labelled by Alloy-Type.*

414 Considering the unleaded examples, of which there are only five, we can at least assess  
415 consistency with the Southeast Asian copper production LI database (Figure 11, see Cadet et  
416 al., 2019; Pryce et al., 2014, 2011b, 2011a; Zou et al., 2019). Here we see that DS/13 appears  
417 to lie within the LI signature as well-defined for the Vilabouly Complex in central Laos (Cadet  
418 et al., 2019; Pryce et al., 2011a) but the correspondence is actually with artefacts that are  
419 considered exotics at that site, probably imports, and thus we have a comparison for  
420 consumption but not production (provenance). Likewise, for DS/10 and THD/2, which plot  
421 close to the Vilabouly Complex signature, but not close enough as to be considered  
422 consistent with it, especially as this area of the plot is very highly populated when taking the  
423 whole regional database into account. Phu Lon, in northeastern Thailand, has always had a  
424 poorly defined LI field due to a reliance on excavated mineral samples of uncertain human  
425 use as opposed to slag samples (Pigott and Weisgerber, 1998; Pryce et al., 2011a), as well as  
426 multiple hydrothermal depositional episodes in geological time giving a dispersed and  
427 radiogenically-trending plot (Kamvong and Zaw, 2009). Nevertheless, THD/1 is relatively  
428 consistent, as much as individual samples can be, with TH/PL/11, which was one of the rare  
429 slag samples, and as such an indication of the anthropogenic Phu Lon copper signature  
430 (Pryce et al., 2011a). Likewise, both THD/1 and DS/20 are not unreasonable candidates for  
431 the recently published Guangfentou copper production signature, from south of Kunming in  
432 Yunnan Province, PRC (Zou et al., 2019). The Guangfentou slag samples exhibit high variation  
433 LI ratios, which, as the authors acknowledge, is indicative of variable ore feedstock.  
434 However, given known close associations between north Vietnamese Đông Sơn and  
435 Kunming-centred Dian culture (e.g. Calò, 2014; Chiou-Peng, 2008; Yao, 2016) it is perfectly  
436 reasonable to expect some movement of metals, either raw or processed, over the 500-600  
437 kilometres separating the two areas, especially as most can be accomplished afloat on the

438 Red River. Nevertheless, none of the present study's copper-base samples can be considered  
439 to be reliably provenanced.

440

441 *Figure 11: Lead isotope ratios for the copper-base study samples and known regional primary copper production centres :*  
442 *the Khao Wong Prachan Valley in central Thailand (NKH and NPW), Phu Lon in northeastern Thailand (PL), the Vilabouly*  
443 *Complex in central Laos (PBL and TNN) and Guangfentou in central Yunnan (GFT)(data from Cadet et al., 2019; Pryce et al.,*  
444 *2014; Zou et al., 2019).*

445 In terms of lead production centres, as previously stated, none have yet been studied in  
446 Southeast Asia (Pryce, 2014, 2012). Some unpublished LI data for lead minerals (galena) by  
447 Dr Tom Chase under the aegis of the Thailand Archaeometallurgy Project during the mid-  
448 1980s (courtesy of Prof. Vincent C. Pigott) offer no consistency with our study samples but  
449 these are not proven anthropogenic lead signatures and this whole field remains massively  
450 understudied at a regional scale – i.e. there are known and/or suspected pre-modern lead  
451 production sites but none have been investigated yet (Figure 12).

452

453 *Figure 12: Present study LI data and available LI data for Thai lead minerals (TLM, courtesy V.C. Pigott).*

454 Of course, a considerable proportion of the complete recent SEALIP/BROGLASEA database  
455 consists of leaded alloys (e.g. Cadet et al., 2019; Pryce et al., 2018; Pryce and Bellina, 2018),  
456 and these offer some potentially useful insights (Figure 13). There is substantial variability,  
457 overlap and outliers but the Đông Sơn and Thiệu Dương samples have a distinct tendency to  
458 form an 'upper' (higher  $^{207}\text{Pb}/^{204}\text{Pb}$ ) cluster and are consistent with a number of continental  
459 and littoral Thai and one Cambodian site, whereas as the bulk of the previously studied  
460 Vietnamese leaded copper-base alloys fall in a 'lower' cluster. It should be noted that the  
461 Pacung site is on Bali, and thus at quite some distance (ca. 3400 km geodesic) from the Red  
462 River delta but such maritime links have been previously proposed (Calò, 2014) and  
463 potentially detected (Pryce et al., 2018).

464

465 *Figure 13: LI ratios for leaded (>1 wt.%) copper-base and lead artefacts in the published SEALIP/BROGLASEA database.*

466 Finally, we can drill down into these, predominantly leaded data, to compare the Đông Sơn  
467 drum miniatures to the, albeit limited, medium and large-sized drum population of the  
468 SEALIP/BROGLASEA database for which elemental and lead isotope datasets exist (Figure 14,  
469 N=12 out of hundreds of stylistically reported examples e.g. Calò, 2014). Again, these larger  
470 drums have a range of alloy types: copper, leaded copper and leaded bronze, thus  
471 representing Cu and Pb exchange systems, and three (VN/DX/10, ID/ML/4 & ID/ML/5) are  
472 not considered to be of the Đông Sơn style (Pryce et al., 2014; Pryce et al., 2018). Firstly, we  
473 note a cluster of four Đông Sơn leaded miniatures (DS/5, 7, 14 & 17) in apparent  
474 compatibility with a single drum, LA/VC/13, from the central Lao Vilabouly Complex (Cadet  
475 et al., 2019). Secondly, we observe that the bulk of the Đông Sơn leaded miniature  
476 assemblage plots near to TH/KS/2. This is a false match as this peninsular Thai drum was  
477 made from near pure copper, itself consistent with the Vilabouly Complex signature, and  
478 may have been a poorly-executed ancient imitation (Pryce and Bellina, 2018). Generally,

479 there is some lead isotope consistency between the miniature and large drums but far more  
480 large drum data are needed. Of note, however, is the complete incompatibility of VN/DX/10,  
481 a large unleaded bronze drum found in northern Vietnam but with Dian-style decoration  
482 (Pryce et al., 2014). DX/10 does plot broadly within the newly characterised Yunnanese  
483 Guangfentou copper production signature (Figure 11), though many more such analyses are  
484 needed to reinforce this, admittedly enticing, association.

485

486 *Figure 14: LI ratios of medium/large vs miniature leaded and unleaded drums (data from Pryce et al., 2014; T. O. Pryce et al.,*  
487 *2018; Pryce and Bellina, 2018).*

## 488 5-Discussion

489

### 490 5.1- Đông Sơn miniature drum production: regular workshops or random funereal alloying 491 practices?

492 In 2014, the excavation at Luy Lâu (or Liên Lâu) Citadel in Bắc Ninh Province, led by the  
493 National Museum of History and the Japanese University of East Asia, uncovered the  
494 remains of a drum foundry, the first of its kind (Reinecke, 2016: 457-458). Previously, only  
495 two fragments of an investment clay drum mould had been recovered from the same site,  
496 only 30 meters away (Masanari, 1998 ; 2011: 164-167). These recent discoveries tend to  
497 confirm that some of the big-sized Đông Sơn bronze drums were cast by piece moulds.

498 Due to the significant difference in scale, it is evident miniature drums do not imply the  
499 same type or mastery of technical skills as large drum production. For the latter, whatever  
500 the casting method used, merely the melting and pouring of dozens of kilograms of metal,  
501 synchronised to avoid cold-shuts in the fine-walled finished product, implies significant  
502 technical skill and organisation of production. For the miniatures, the lack of 'alloy-type'  
503 correspondence suggests the metal used in their manufacture was probably recycled. The  
504 risks involved in these much smaller castings were far lower, not requiring particular alloys  
505 to have a reasonable chance of success, and thus we can imagine these artisans using  
506 whatever copper-base scrap was available to them.

507 Should we, therefore, consider miniature drums as technically uninteresting and socially  
508 irrelevant, as opposed to the prestige so often associated to large drums? We think this  
509 would be an error, for a number of reasons. Firstly, there is the admittedly subjective  
510 element of production quality. In particular, the typological study highlighted two types  
511 within the corpus, 1A & 5D, whose decoration and lack of any casting failures suggest they  
512 were made by a reasonably competent artisan. Secondly, the central ring on the tympanum  
513 of the type 1 miniatures may indicate a real difference in their use, possibly as suspended  
514 bells with the general appearance of a miniature drum. This could indicate an evolution of  
515 traditional use and external influences in musical instruments during a period of deep  
516 cultural change (i.e. the Han occupation of northern Vietnam). Thirdly, the apparently poor  
517 technical execution of the other miniature drum types does not necessarily imply low social  
518 value. As noted, the Thiệu Dương example was found in the richest burial of 123 excavated.  
519 Miniature drums have rarely been discovered in the same burials as their large counterparts,

520 for which they presumably stood in as models but nevertheless attest to the importance of  
521 drums for the Lạc Việt people.

522  
523 The range of miniature drum production indicates that Lạc Việt craftspersons used multiple  
524 methods to produce material culture that would normally be categorised as a single, simple  
525 type (Le Meur et al, forthcoming). These variations of style, technology, alloy type and raw  
526 material sourcing are important, and rarely considered by archaeologists, as they suggest  
527 multiple and overlapping communities of practice. Lạc Việt people maintained contact with  
528 other 'drum cultures', as the miniature drum classified as 'Exceptional' was probably made  
529 in Yunnan or inspired by Yunnan examples.

530  
531 By a reimagining of the size and the use of drums, and their lack of morphological and  
532 technical standardisation, the north Vietnamese phenomenon of drum miniaturization  
533 seems to be slightly but importantly different from Han funerary customs. The question of  
534 the miniature drums' function remains, as does their importance within the broader 'drum  
535 cultures' of northern Vietnam and southern China. These leads will require a much larger  
536 study of well-contextualised north Vietnamese mid-late 1<sup>st</sup> millennium BC burial  
537 assemblages containing drums, for comparison with southern Chinese funeral practices.

538

## 539 **5.2 Relation to wider Southeast Asian metal exchange networks**

540 At this point in the SEALIP/BROGLASEA programme, there is little detailed geochemical  
541 interpretation that can be given of the miniature drums at a regional level. The present  
542 assemblage is majority leaded copper alloy and we lack primary production signatures for  
543 lead. Nevertheless, those leaded, and unleaded, consumption signatures fall into the very  
544 dense cloud of data that makes up the bulk of the Southeast Asian non-ferrous/non-precious  
545 metals dataset – the miniatures drums are coherent with their regional context. The  
546 imminent, at the time of writing, receipt of Yunnan artefact analyses will greatly aid our  
547 ability to resolve chemical clustering issues, and forthcoming multifactorial network analysis  
548 (Radivojević and Grujić, 2018) will enable typological, chronological and geographical aspects  
549 to be taken into account.

550

## 551 **6. Conclusion**

552 The present study represents the first comprehensive multi-method study of a discrete Đông  
553 Sơn culture metal assemblage. Our study of all 131 known examples of miniature drums  
554 identified five main morpho-stylistic groups, encompassing three broad technological  
555 traditions: lost wax, bivalve and multiple piece moulding. Four alloy classes were identified  
556 in samples of varying corrosion: copper, bronze, leaded copper and leaded bronze; the latter  
557 predominating in an ca. 80% leaded alloy assemblage. Twelve 'alloy-types' were identified,  
558 with LB1 (leaded bronze Type 1) drums being the most common. Lead isotope analyses  
559 identified two main leaded alloy groups, and two unleaded groups, the latter of which may  
560 offer some consistency with Yunnan copper production. In summary, the miniature drums

561 show high variation in form, decoration, production methods and materials that suggest an  
562 intriguing intersection in indigenous and exotic artisanal and burial practices at a critical  
563 juncture in Vietnamese history.

564

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574

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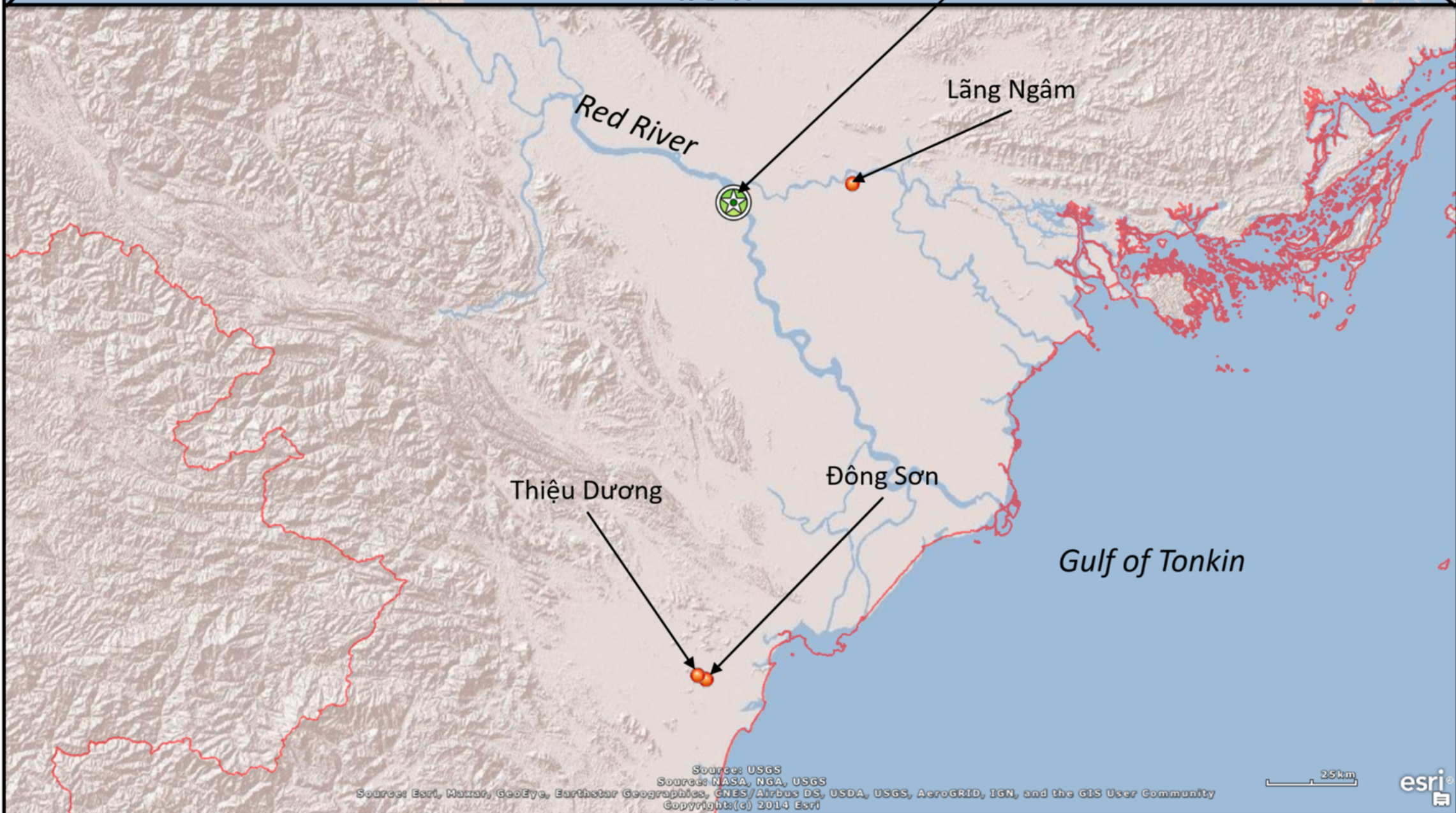
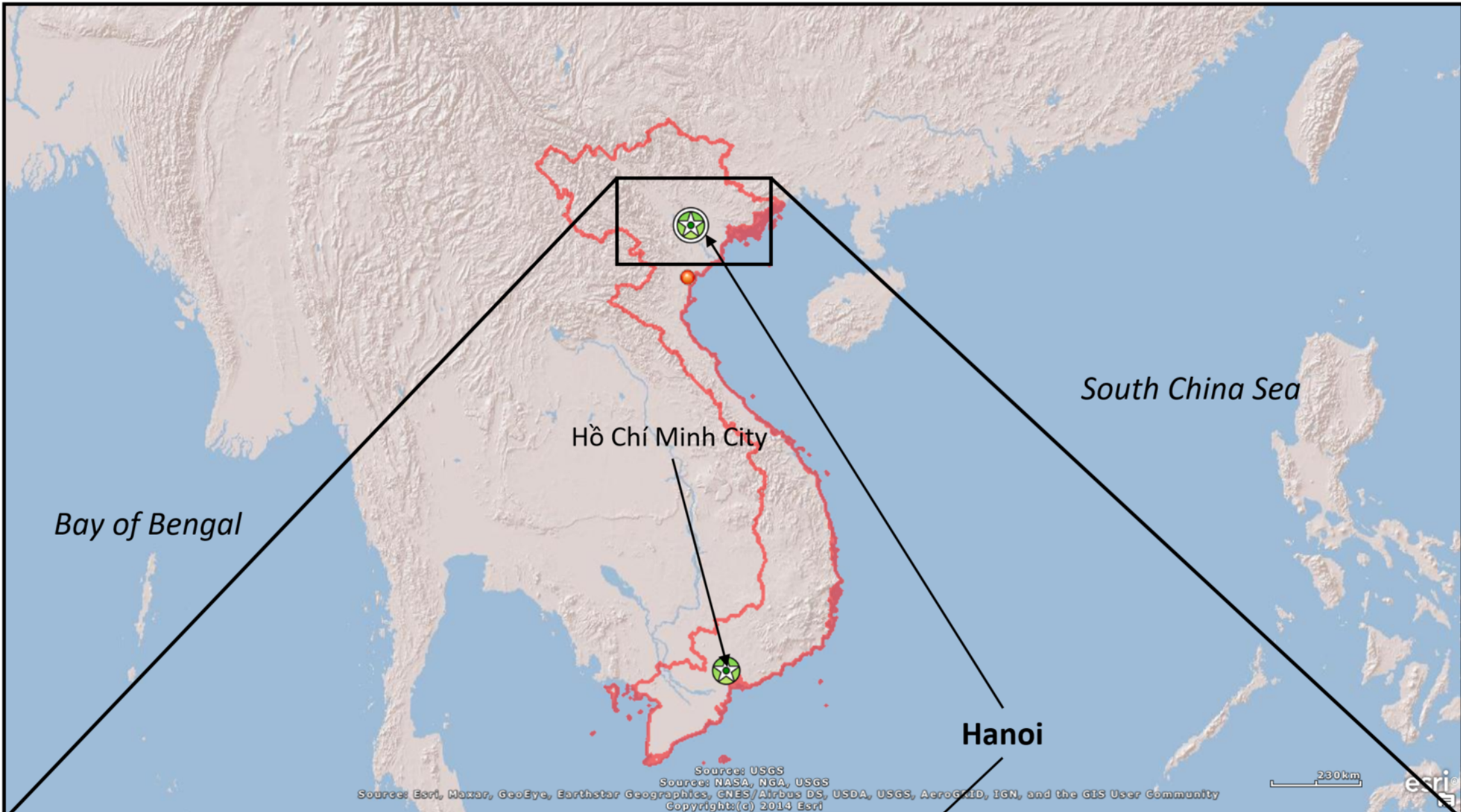
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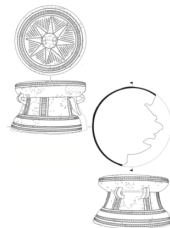
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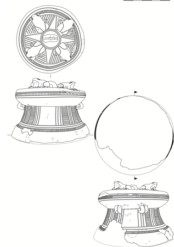
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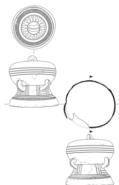
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**TYPE 1 B**

LSb-21123

**TYPE 1 C**

LSb-1160/16

**TYPE 1 D**

LSb-529/6



LSb-1666



LSb-1667/11

**TYPE 2 A**

LSb-3618/141

**TYPE 3 A**

LSb-1792/29

**TYPE 3 B**

LSb-583/11



LSb-1769/19

**TYPE 3 D**

LSb-519/13



LSb-520/14



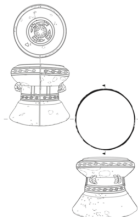
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**TYPE 4 B**

LSb-3617/140

**TYPE 5 D(2)**

LSb-2752

**TYPE 5 D(3)**

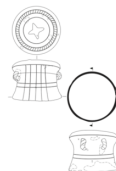
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**UNCATEGORIZABLE**

LSb-1013



LSb-3435/682



LSb-4975/35



LSb-1228/36

**EXCEPTIONAL**

LSb-1257



# THE 5 TYPES (108)

central ring on the tympanum  
(48)

∅ central ring on the tympanum  
(60)

∅ seams

∅ seams (9)

1 seams (21)

3 seams (30)

decoration

∅ decoration

∅ decoration

∅ decoration (7)

decoration (23)

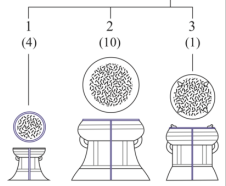
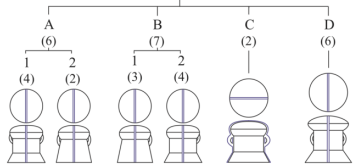
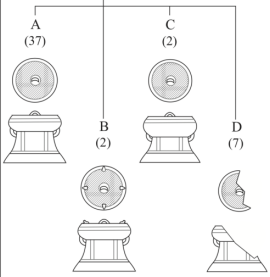
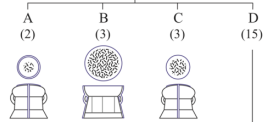
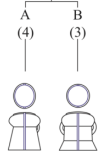
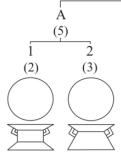
**TYPE 1**

**TYPE 2**

**TYPE 3**

**TYPE 4**

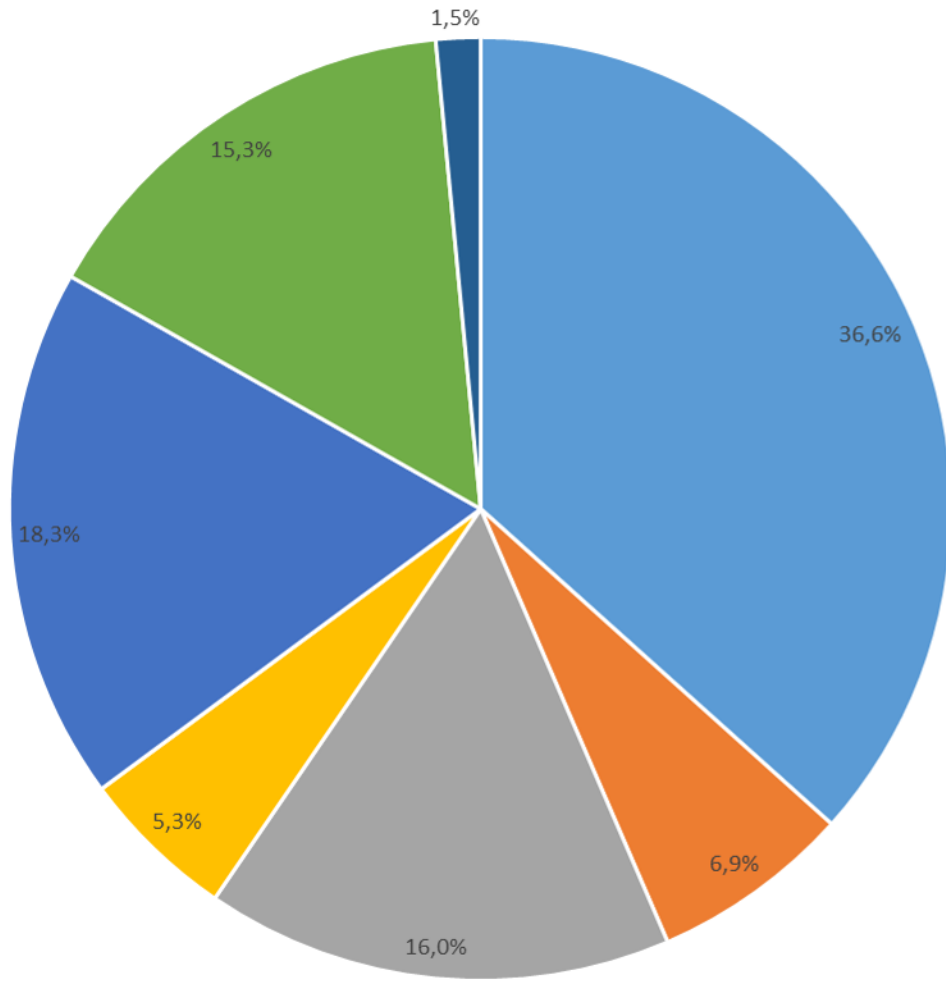
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(21)

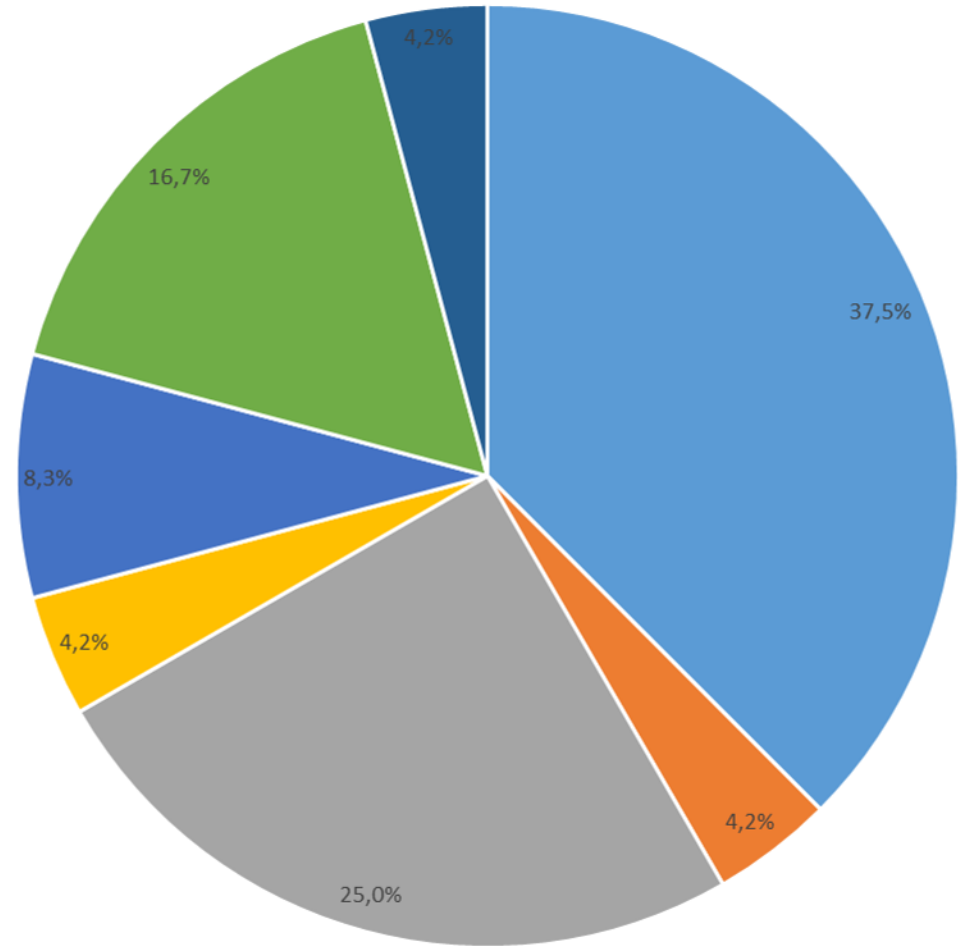
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(2)

Whole assemblage



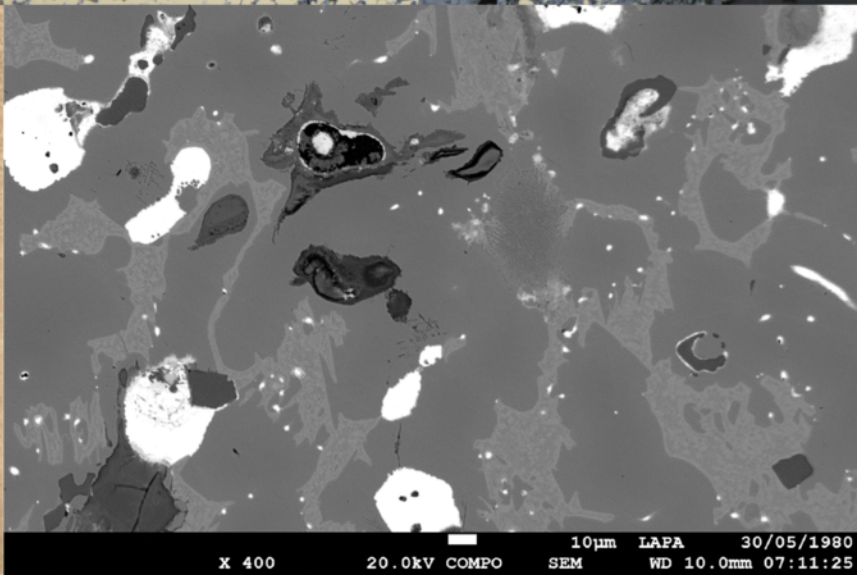
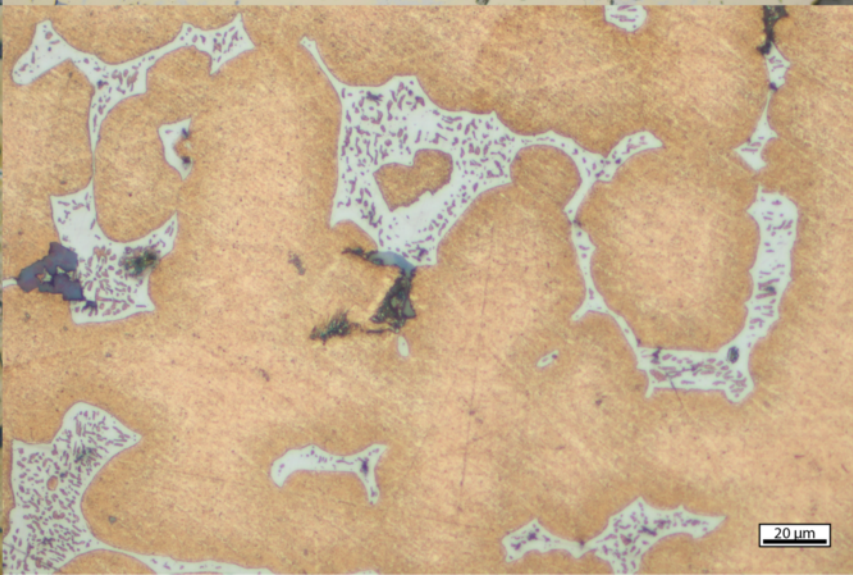
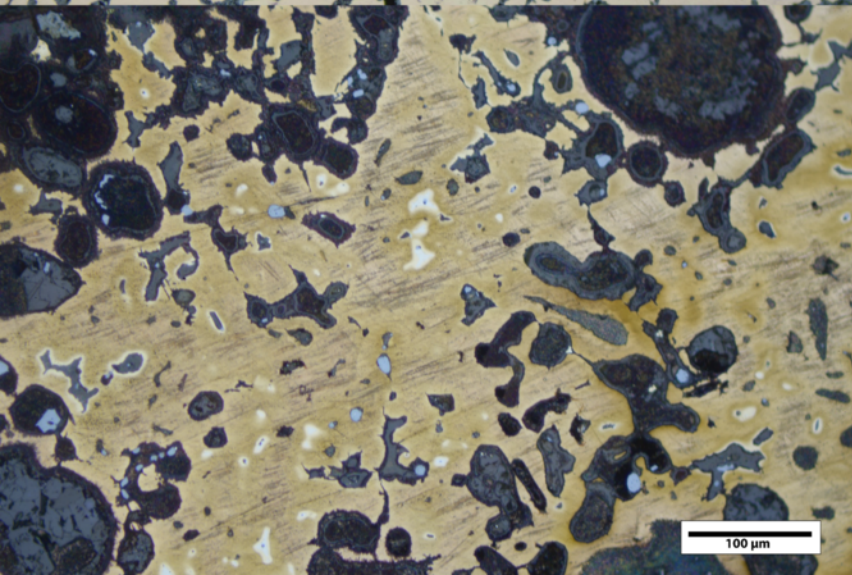
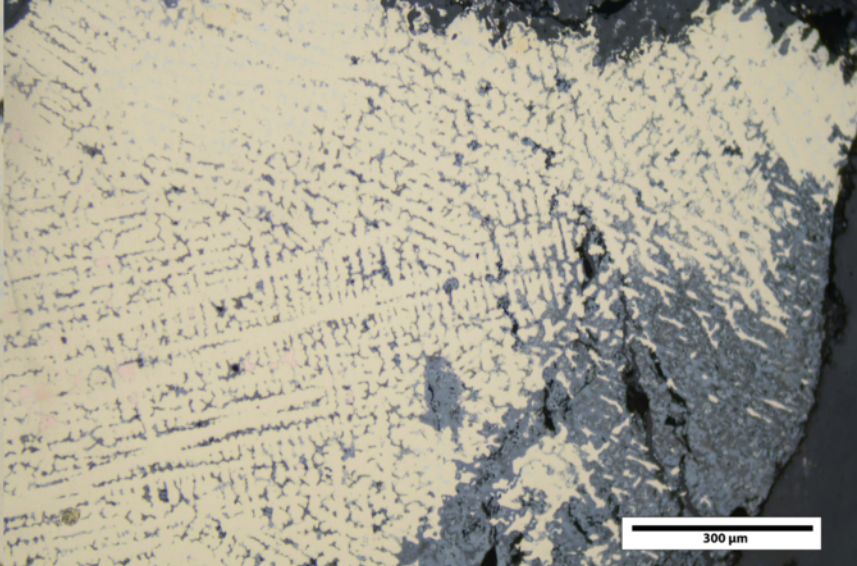
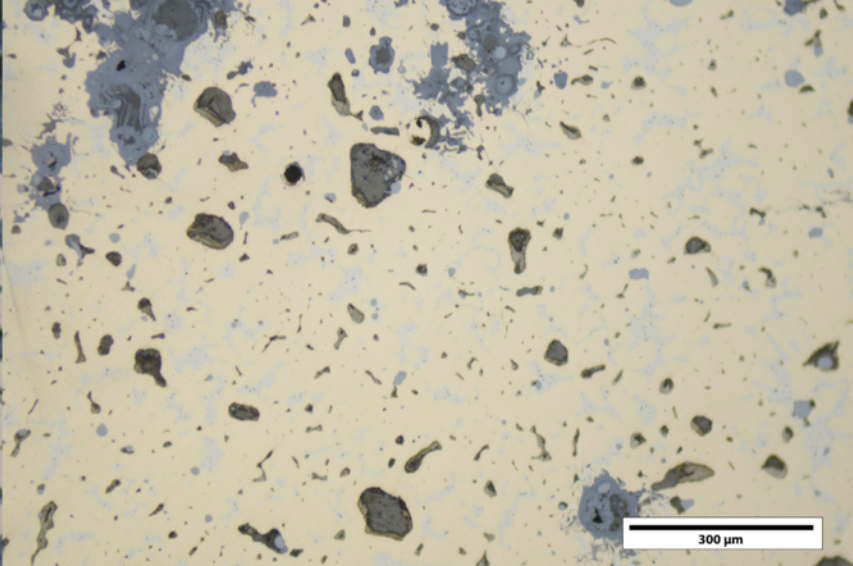
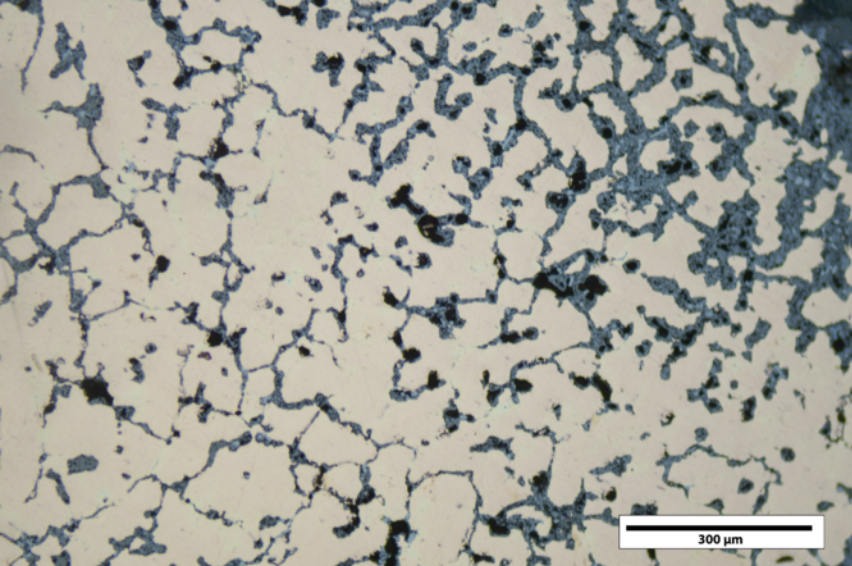
■ 1 ■ 2 ■ 3 ■ 4 ■ 5 ■ NC ■ RM

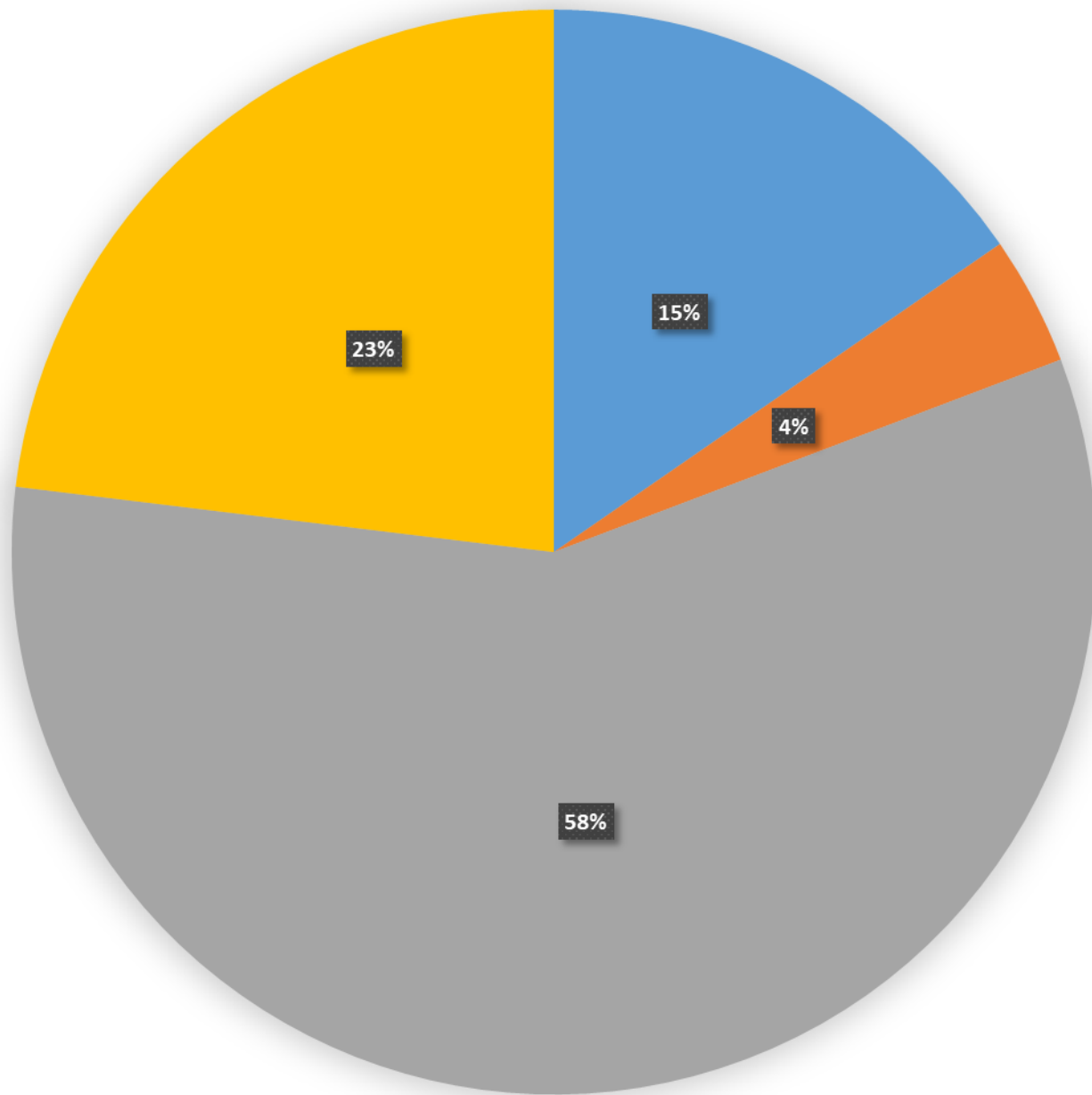
Studied assemblage

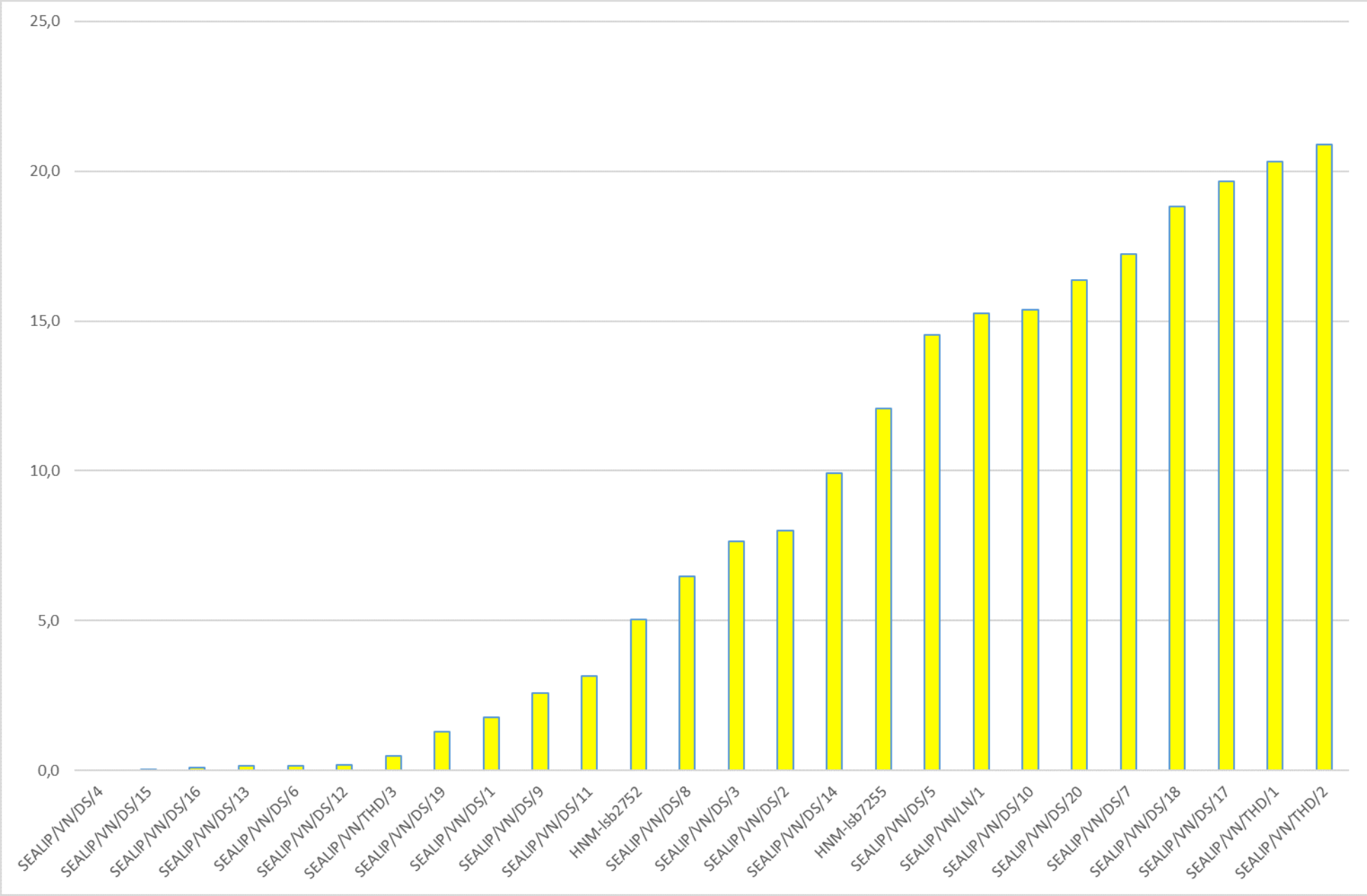


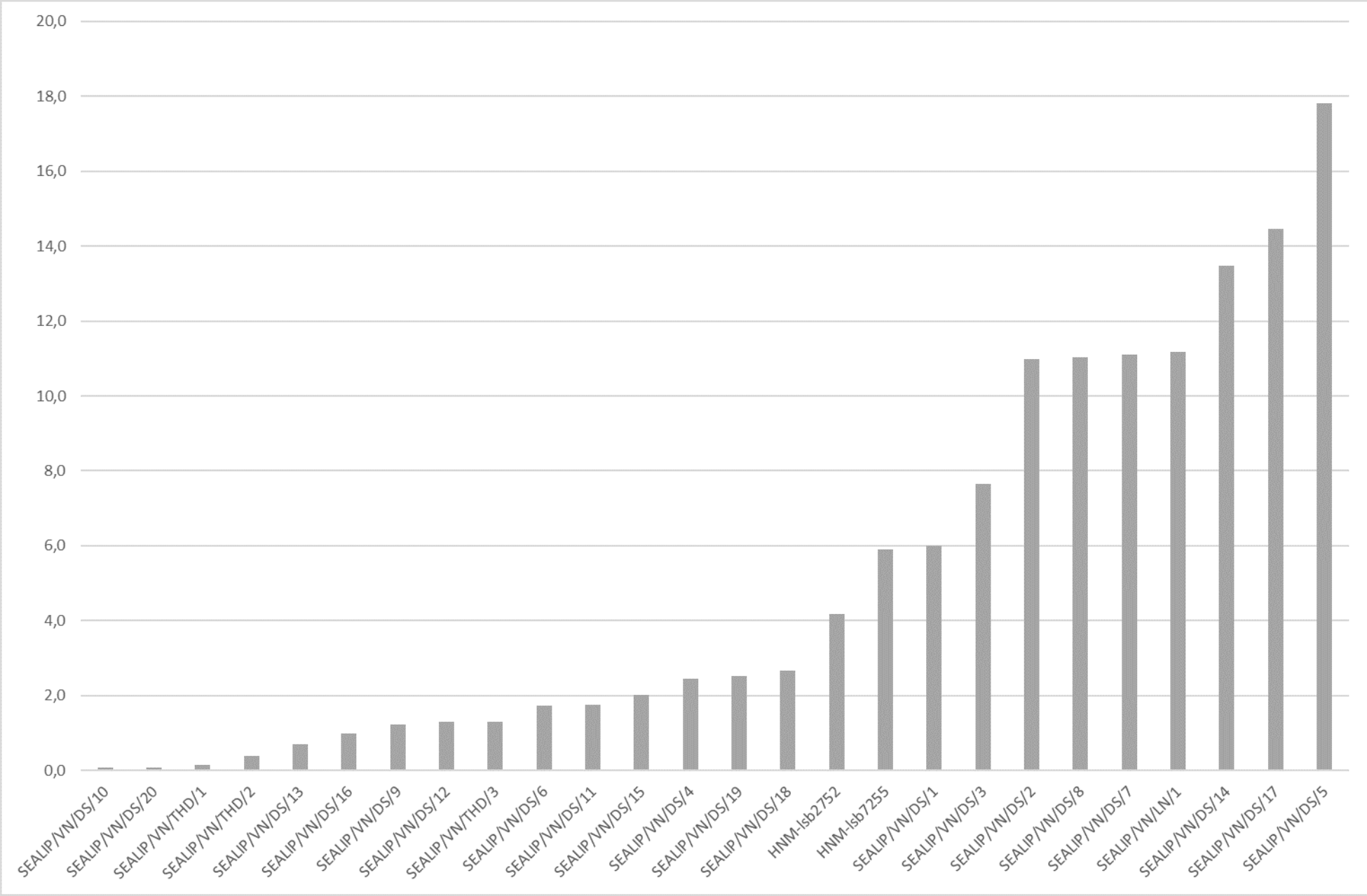
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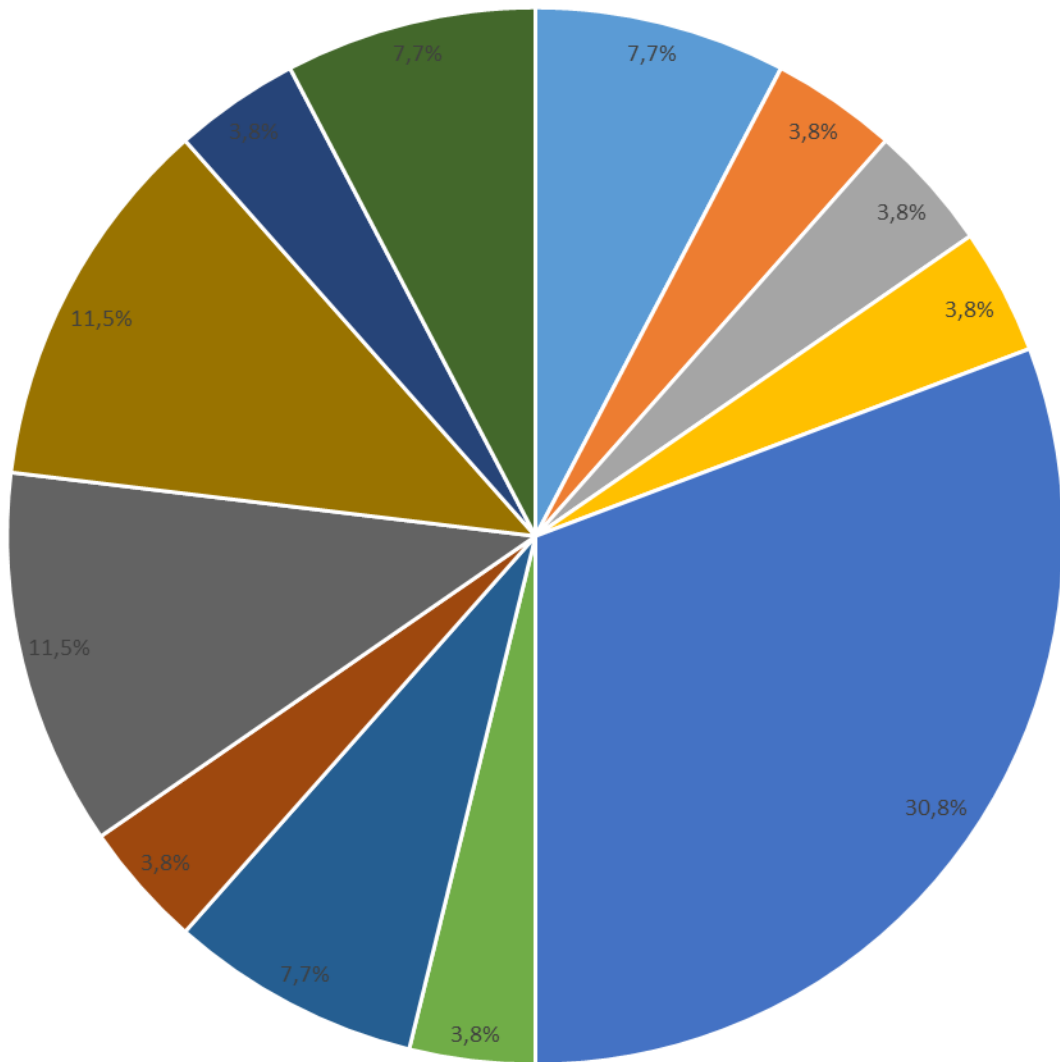




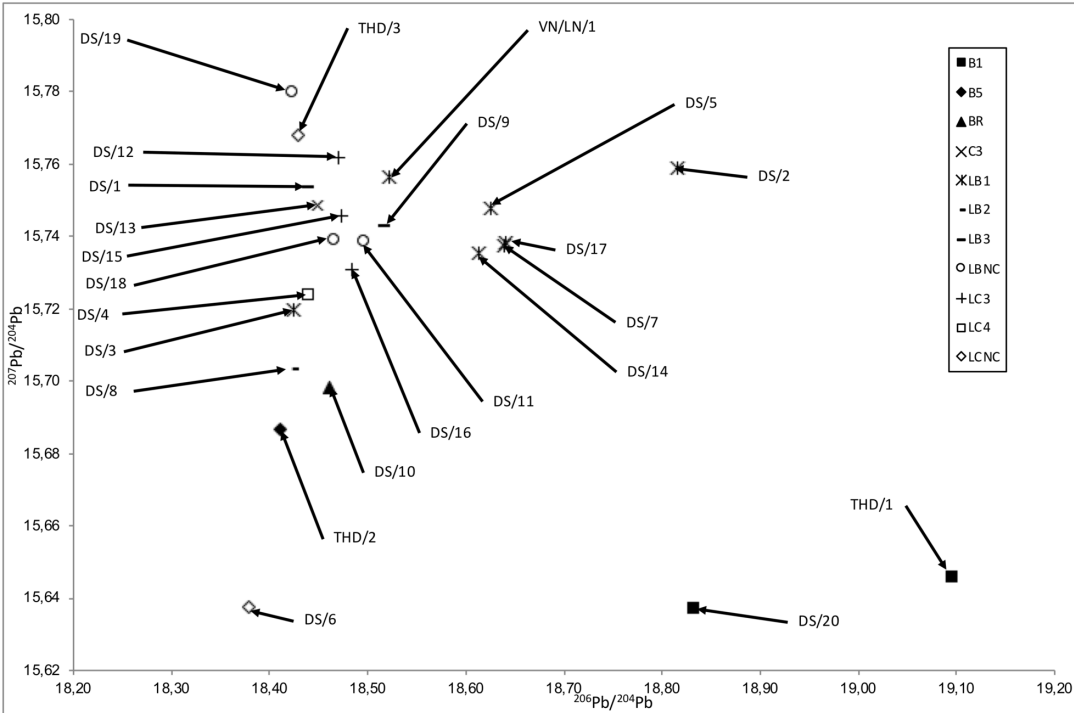


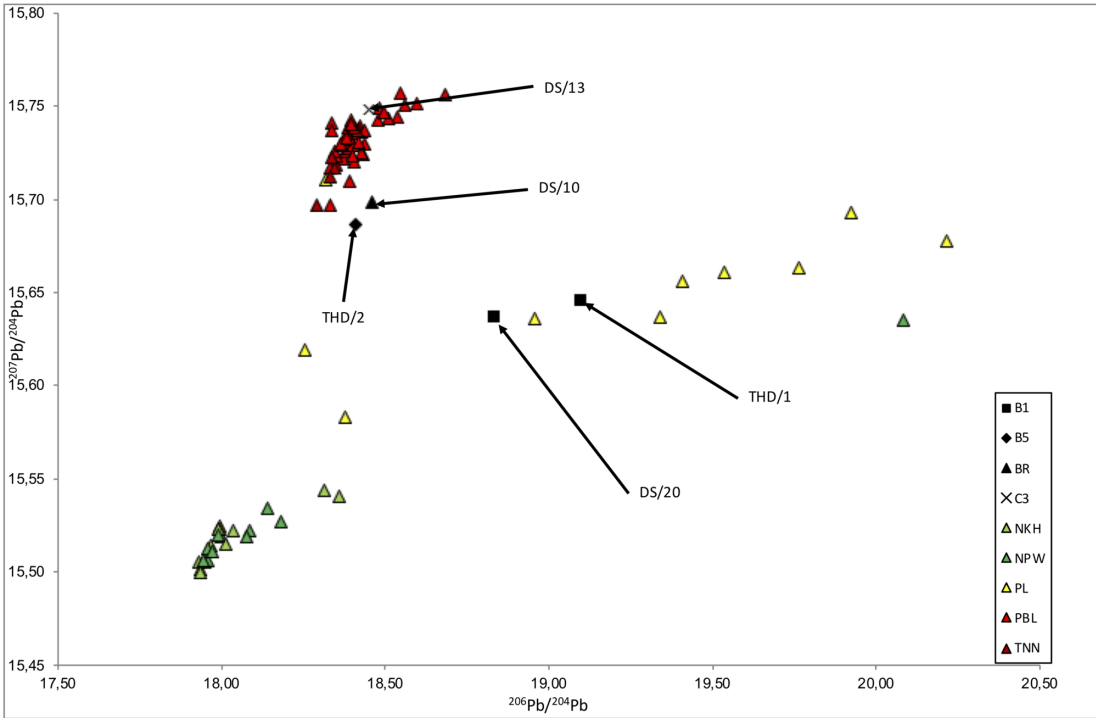


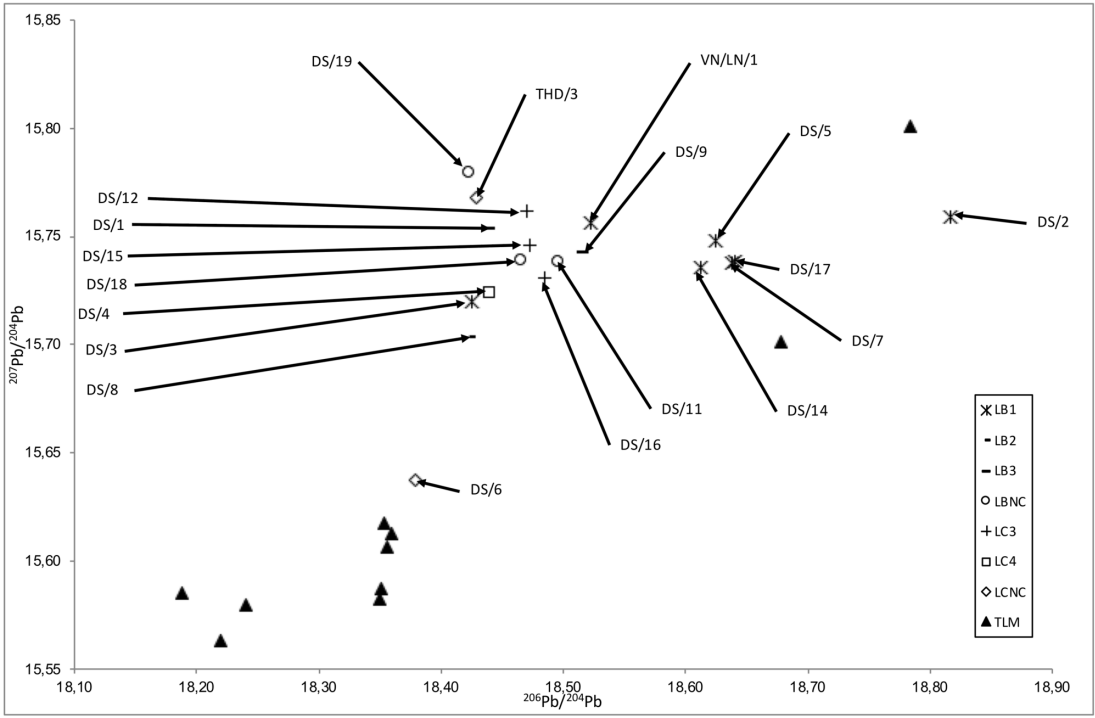




- B1
- B5
- BR
- C3
- LB1
- LB2
- LB3
- LB5
- LBNC
- LC3
- LC4
- LCNC













SEALIP ID	HNM ID	Site	Artefact	Mass (g)	Typological classification
SEALIP/VN/DS/1	LSB 520/14	Đông Sơn	miniature drum	83	Type 3
SEALIP/VN/DS/2	LSB 21122-9	Đông Sơn	miniature drum	141	Type 1
SEALIP/VN/DS/3	LSB 3616/139	Đông Sơn	miniature drum	58	Type 1
SEALIP/VN/DS/4	LSB 3617/140	Đông Sơn	miniature drum	33	Type 4
SEALIP/VN/DS/5	LSB 1160/16	Đông Sơn	miniature drum	123	Type 1
SEALIP/VN/DS/6	LSB 1228/36	Đông Sơn	miniature drum	?	not classified
SEALIP/VN/DS/7	LSB 1667/11	Đông Sơn	miniature tympanum	26	Type 1
SEALIP/VN/DS/8	LSB 3618/141	Đông Sơn	miniature drum	38	Type 2
SEALIP/VN/DS/9	LSB 519/13	Đông Sơn	miniature drum	84	Type 3
SEALIP/VN/DS/10	LSB 1257	Đông Sơn	miniature drum	125	exceptional
SEALIP/VN/DS/11	LSB 4975/35	Đông Sơn	miniature drum	191	not classified
SEALIP/VN/DS/12	LSB 521/15	Đông Sơn	miniature drum	52	Type 3
SEALIP/VN/DS/13	LSB 1769/19	Đông Sơn	miniature drum	15	Type 3
SEALIP/VN/DS/14	LSB 529/6	Đông Sơn	miniature drum	64	Type 1
SEALIP/VN/DS/15	LSB 583/11	Đông Sơn	miniature drum	21	Type 3
SEALIP/VN/DS/16	LSB 1792/29	Đông Sơn	miniature drum	37	Type 3
SEALIP/VN/DS/17	LSB 1666	Đông Sơn	miniature drum	47	Type 1
SEALIP/VN/DS/18	LSB 1013	Đông Sơn	miniature drum	?	not classified
SEALIP/VN/DS/19	LSB 1013	Đông Sơn	situla	?	not classified
SEALIP/VN/DS/20	LSB 7250	Đông Sơn	medium drum	6000	not classified (Heger 1 big drum)
SEALIP/VN/LN/1	LSB 21124	Lãng Ngâm	miniature drum	164	Type 1
SEALIP/VN/THD/1	LSB 21123	Thiệu Dương	miniature drum	185	Type 1
SEALIP/VN/THD/2	LSB 21121	Thiệu Dương	miniature drum	480	Type 5
SEALIP/VN/THD/3	LSB 3435/682	Thiệu Dương	miniature drum	154	not classified
*	LSB 2752	?	miniature drum	1132	Type 5
*	LSB 7255	?	miniature drum	227	Type 1

\*Not analysed for LIA due to lack of context

SAMPLE	Sb	Sn	Bi	Pb	Zn	Cu	Ni	Co	Fe	Mn	Al	S
B12 pXRF	0.12	10.00	nd	0.20	0.66	85.20	2.79	nd	0.17	0.24	nd	nd
B12 SEM-EDS	nd	9.5	nd	nd	0.9	85.0	3.0	nd	nd	nd	nd	nd
B12 CRMs value	0.12	9.57	0.00	0.20	0.61	85.65	2.63	0.00	0.16	0.24	0.13	0.00
51.13-4 pXRF	nd	0.30	nd	0.11	0.4	91.00	nd	nd	1.95	0.90	4.95	nd
51.13-4 SEM-EDS	nd	nd	nd	nd	0.7	87.7	nd	nd	2.0	1.0	8.0	nd
51.13-4 CRMs value	0.00	0.27	0.00	0.00	0.34	88.79	0.06	0.00	1.81	0.90	7.30	0.00
71.32-4 pXRF	0.25	6.40	nd	4.30	7.00	80.50	0.78	nd	0.40	nd	nd	nd
71.32-4 SEM-EDS	nd	6.5	nd	3.0	7.0	82.0	0.8	nd	0.4	nd	nd	nd
71.32-4 CRMs value	0.26	6.46	0.05	4.43	6.52	80.48	0.70	0.00	0.35	0.05	0.12	0.00
C1123 pXRF	nd	nd	nd	nd	nd	97.40	nd	2.49	nd	nd	nd	nd
C1123 SEM-EDS	nd	nd	nd	nd	nd	96.5	nd	3.5	nd	nd	nd	nd
C1123 CRMs value	0.00	0.01	0.00	0.00	0.01	97.40	0.01	2.30	0.00	0.00	0.02	0.00
L-20-1 pXRF	nd	0.54	nd	0.30	14.35	84.15	0.25	nd	nd	0.15	nd	nd
L-20-1 SEM-EDS	nd	0.5	nd	nd	14.5	84.0	nd	nd	nd	nd	nd	nd
L-20-1 CRMs value	0.00	0.49	0.00	0.27	13.33	85.20	0.22	0.00	0.04	0.13	0.07	0.00
B31 pXRF	0.50	7.95	nd	10.60	0.84	79.40	0.55	nd	nd	nd	nd	nd
B31 SEM-EDS	1.8	8.0	nd	9.9	1.1	78.6	0.5	nd	nd	nd	nd	nd
B31 CRMs value	0.48	7.70	0.00	11.79	0.82	78.55	0.49	0.00	0.02	0.00	0.04	0.03
UZ-52-3 pXRF	0.08	0.99	nd	0.10	18.00	80.30	0.10	nd	0.34	nd	nd	nd
UZ-52-3 SEM-EDS	nd	1.0	nd	nd	18.5	80.5	nd	nd	nd	nd	nd	nd
UZ-52-3 CRMs value	0.08	1.06	0.00	0.11	17.00	81.08	0.08	0.00	0.31	0.00	0.00	0.00
B21 pXRF	0.19	5.35	nd	3.75	6.53	82.20	1.35	nd	0.30	nd	nd	nd
B21 SEM-EDS	nd	5.0	nd	4.0	7.0	82.0	1.0	nd	nd	nd	nd	nd
B21 CRMs value	0.18	5.13	0.00	3.79	6.22	83.00	1.21	0.00	0.29	0.00	0.14	0.05
SRM1275 pXRF	nd	nd	nd	nd	nd	86.90	10.70	nd	1.63	0.39	nd	nd
SRM1275 SEM-EDS	nd	nd	nd	nd	nd	87.9	10.1	nd	1.5	0.5	nd	nd
SRM1275 CRMs value	0.00	0.01	0.00	0.01	0.09	88.20	9.76	0.02	1.46	0.42	0.00	0.00
SRM-500 pXRF	nd	nd	nd	nd	0.10	99.70	0.08	nd	nd	nd	nd	nd
SRM-500 SEM-EDS	nd	nd	nd	nd	0.5	99.5	nd	nd	nd	nd	nd	nd
SRM-500 CRMs value	0.01	0.00	0.00	0.01	0.01	99.70	0.06	0.00	0.00	0.00	0.00	0.00
B10 pXRF	1.15	7.20	nd	4.14	2.95	83.20	1.10	nd	0.18	nd	nd	nd
B10 SEM-EDS	2.0	6.5	nd	3.5	3.0	83.0	1.0	nd	nd	nd	nd	nd
B10 CRMs value	1.14	6.95	0.00	4.07	2.75	83.65	1.01	0.00	0.17	0.00	0.21	0.00

SAMPLE	O	Sb	Sn	Ag	Bi	Pb	As	Cu	Ni	Fe	Cr	V	Ti	Al	S	P	Si	Analysis	Alloy (1 wt.% threshold)	Corrosion	Type	Alloy-Type	Artefact
	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %						
Đồng Sơn																							
SEALIP/VN/DS/1		0.06	2.00	0.00	0.00	6.00	0.00	89.50	0.02	0.06	0.00	0.00	0.00	1.00	0.00	0.00	1.00	XRF	lead bronze	Medium	Type 3	LB3	miniature drum
	6.5		1.5			3.0		89.0										SEM-EDS					
SEALIP/VN/DS/2		1.00	8.00	0.24	0.00	11.00	0.00	77.00	0.00	0.10	0.00	0.00	0.00	1.50	0.00	0.00	0.40	XRF	lead bronze	Medium	Type 1	LB1	miniature drum
	6.4	2.5	7.0			16.0		68.0										SEM-EDS					
SEALIP/VN/DS/3		0.00	8.00	0.00	0.00	7.50	0.00	77.50	0.00	0.33	0.00	0.04	0.00	3.45	0.00	0.50	2.00	XRF	lead bronze	Low	Type 1	LB1	miniature drum
	5.5		8.0			2.0		84.5										SEM-EDS					
SEALIP/VN/DS/4		0.00	0.00	0.00	0.00	2.46	0.00	88.00	0.00	0.50	0.00	0.00	0.00	2.54	0.00	2.00	4.00	XRF	lead copper	High	Type 4	LC4	miniature drum
	7.0		0.0			1.4		91.5										SEM-EDS					
SEALIP/VN/DS/5		0.28	14.50	0.00	0.00	18.00	0.00	63.00	0.00	0.12	0.00	0.00	0.00	2.00	0.00	0.41	1.00	XRF	lead bronze	High	Type 1	LB1	miniature drum
	8.0		7.0			39.9		45.0										SEM-EDS					
SEALIP/VN/DS/6		0.00	0.16	0.00	0.02	2.00	0.27	91.50	0.01	0.13	0.00	0.00	0.00	2.50	0.00	0.32	3.02	XRF	lead copper	Low	not classified	LCNC	miniature drum
	2.0		0.0			1.0		97.0										SEM-EDS					
SEALIP/VN/DS/7		0.11	17.00	0.00	0.14	11.00	0.00	67.00	0.05	0.34	0.00	0.00	0.00	2.70	0.00	0.00	1.00	XRF	lead bronze	Medium	Type 1	LB1	miniature tympanum
	7.0		16.0			15.0		62.0										SEM-EDS					
SEALIP/VN/DS/8		0.09	6.45	0.00	0.10	11.00	0.58	75.50	0.01	0.20	0.00	0.00	0.00	1.50	0.00	0.82	3.60	XRF	lead bronze	High	Type 2	LB2	miniature drum
	10.0		3.5			7.0		78.5										SEM-EDS					
SEALIP/VN/DS/9		0.92	2.60	1.84	1.18	1.24	1.23	86.14	0.00	0.10	0.35	0.60	1.58	0.00	0.19	0.95		XRF	lead bronze	High	Type 3	LB3	miniature drum
	45.0		1.0			2.0	0.4	25.5							4.0	8.0		SEM-EDS					
SEALIP/VN/DS/10		0.02	15.40	0.00	0.00	0.08	0.04	83.50	0.00	0.50	0.00	0.00	0.18	0.00	0.06	0.02	0.24	XRF	bronze	Low	remarkable	BR	miniature drum
	4.0		14.0			0.0		82.0										SEM-EDS					
SEALIP/VN/DS/11		0.07	3.00	0.00	0.00	1.70	0.18	94.50	0.03	0.07	0.00	0.00	0.00	0.00	0.00	0.30		XRF	lead bronze	Medium	not classified	LBNC	miniature drum
	6.0		3.0			1.0		90.0										SEM-EDS					
SEALIP/VN/DS/12		0.05	0.20	0.00	0.01	1.00	0.23	97.59	0.04	0.00	0.00	0.00	0.00	0.00	0.10	0.40		XRF	lead copper	Low	Type 3	LC3	miniature drum
	4.00		0.0			1.0		95.0										SEM-EDS					
SEALIP/VN/DS/13		0.13	0.15	0.00	0.02	0.60	0.63	97.00	0.07	0.06	0.01	0.06	0.06	0.00	0.00	0.03	0.66	XRF	copper	Low	Type 3	C3	miniature drum
	4.5		0.2			0.3		95.0										SEM-EDS					
SEALIP/VN/DS/14		0.07	10.00	0.00	0.02	13.45	0.00	76.00	0.01	0.00	0.00	0.10	0.00	0.00	0.00	0.00		XRF	lead bronze	Medium	Type 1	LB1	miniature drum
	13.0		14.5			13.5		58.5										SEM-EDS					
SEALIP/VN/DS/15		0.00	0.02	0.00	0.01	2.00	0.13	97.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62		XRF	lead copper	Low	Type 3	LC3	miniature drum
	4.0		0.0			1.0		95.0										SEM-EDS					
SEALIP/VN/DS/16		0.17	0.10	0.00	0.00	1.00	0.02	93.48	0.00	0.01	0.00	0.00	0.03	1.75	0.00	0.12	1.73	XRF	lead copper	Low	Type 3	LC3	miniature drum
	2.0		0.2			1.0		96.0										SEM-EDS					
SEALIP/VN/DS/17		0.16	19.66	0.00	0.16	14.45	0.00	65.00	0.04	0.18	0.00	0.00	0.20	0.00	0.00	0.00		XRF	lead bronze	Low	Type 1	LB1	miniature drum
	3.5		14.0			11.0	0.5	71.0										SEM-EDS					
SEALIP/VN/DS/18		0.02	19.00	0.00	0.01	2.66	0.00	73.95	0.00	0.64	0.00	0.00	0.00	0.66	0.00	0.19	2.50	XRF	lead bronze	Medium	not classified	LBNC	miniature drum
	5.5		14.5			3.0		75.0						0.5		1.0		SEM-EDS					
SEALIP/VN/DS/19		0.11	1.50	0.00	0.00	2.50	0.11	91.00	0.00	0.01	0.01	0.02	0.04	0.00	0.13	4.57		XRF	lead bronze	High	not classified	LBNC	situla
	16.0		1.0			1.0		82.0							0.5			SEM-EDS					
SEALIP/VN/DS/20		0.05	16.50	0.00	0.00	0.08	0.08	82.00	0.03	0.21	0.00	0.00	0.09	0.00	0.24	0.16	0.34	XRF	bronze	Medium	Type 1	B1	medium drum
	3.5		12.5			0.0		83.5							0.5			SEM-EDS					
Lãng Ngâm																							
SEALIP/VN/LN/1		0.14	15.00	0.00	0.00	11.00	0.00	72.20	0.00	0.60	0.02	0.08	0.27	0.00	0.00	0.00	0.00	XRF	lead bronze		Type 1	LB1	miniature drum
	2.0		13.0			13.5		71.0		0.5								SEM-EDS					
Thiệu Dương																							
SEALIP/VN/THD/1		0.00	20.40		0.00	0.15	0.07	73.50	0.05	3.00	0.00	0.00	0.00	0.00	0.35	1.00	1.16	XRF	bronze	Medium	Type 1	B1	miniature drum
	4.0		13.5			0.0		80.0		1.0				0.5				SEM-EDS					
SEALIP/VN/THD/2		0.00	21.00	0.00	0.00	0.38	0.02	74.50	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.36	2.00	XRF	bronze	High	Type 5	B5	miniature drum
	19.0		18.0			0.0		61.5						1.0		0.5		SEM-EDS					
SEALIP/VN/THD/3		0.60	0.49	0.00	0.00	1.30	0.00	95.50	0.00	0.01	0.10	0.25	0.65	0.00	0.00	0.00		XRF	lead copper	Medium	not classified	LCNC	miniature drum
	2.5		0.0			1.5		96.0										SEM-EDS					
No context																							
HNM-lsb2752		0.10	5.05	0.16	0.00	4.10	0.16	89.50	0.04	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	XRF	lead bronze	Medium	Type 5	LB5	miniature drum
	5.5		4.0			5.0	0.4	84.0		1.0								SEM-EDS					
HNM-lsb7255		0.12	12.00	0.00	0.06	6.00	0.27	80.45	0.01	0.30	0.03	0.00	0.13	0.00	0.00	0.00		XRF	lead bronze	Medium	Type 1	LB1	miniature drum
	5.5		11.0			9.5	1.0	73.0										SEM-EDS					

Sample	Site	<sup>208</sup> Pb/ <sup>206</sup> Pb			<sup>207</sup> Pb/ <sup>206</sup> Pb			<sup>208</sup> Pb/ <sup>204</sup> Pb			<sup>207</sup> Pb/ <sup>204</sup> Pb			<sup>206</sup> Pb/ <sup>204</sup> Pb			Alloy-Type
			±			±			±			±		±			
SEALIP/VN/DS/1	Đông Sơn	2.109	±	0.00007	0.854	±	0.00002	38.899	±	0.0076	15.754	±	0.0030	18.440	±	0.0033	LB3
SEALIP/VN/DS/2	Đông Sơn	2.087	±	0.00009	0.837	±	0.00001	39.267	±	0.0032	15.759	±	0.0010	18.816	±	0.0010	LB1
SEALIP/VN/DS/3	Đông Sơn	2.108	±	0.00020	0.853	±	0.00003	38.832	±	0.0084	15.720	±	0.0035	18.425	±	0.0039	LB1
SEALIP/VN/DS/4	Đông Sơn	2.112	±	0.00018	0.852	±	0.00004	38.941	±	0.0126	15.724	±	0.0048	18.440	±	0.0050	LC4
SEALIP/VN/DS/5	Đông Sơn	2.095	±	0.00016	0.845	±	0.00002	39.016	±	0.0064	15.748	±	0.0020	18.625	±	0.0018	LB1
SEALIP/VN/DS/6	Đông Sơn	2.107	±	0.00011	0.851	±	0.00001	38.721	±	0.0042	15.637	±	0.0014	18.378	±	0.0015	LCNC
SEALIP/VN/DS/7	Đông Sơn	2.094	±	0.00010	0.844	±	0.00002	39.038	±	0.0042	15.737	±	0.0014	18.638	±	0.0016	LB1
SEALIP/VN/DS/8	Đông Sơn	2.115	±	0.00012	0.852	±	0.00002	38.976	±	0.0041	15.703	±	0.0013	18.424	±	0.0013	LB2
SEALIP/VN/DS/9	Đông Sơn	2.104	±	0.00023	0.850	±	0.00002	38.958	±	0.0094	15.743	±	0.0031	18.517	±	0.0029	LB3
SEALIP/VN/DS/10	Đông Sơn	2.110	±	0.00027	0.850	±	0.00002	38.955	±	0.0108	15.698	±	0.0034	18.461	±	0.0030	BR
SEALIP/VN/DS/11	Đông Sơn	2.105	±	0.00013	0.851	±	0.00004	38.938	±	0.0095	15.739	±	0.0036	18.496	±	0.0042	LBNC
SEALIP/VN/DS/12	Đông Sơn	2.107	±	0.00025	0.853	±	0.00004	38.922	±	0.0135	15.762	±	0.0048	18.470	±	0.0042	LC3
SEALIP/VN/DS/13	Đông Sơn	2.108	±	0.00019	0.854	±	0.00006	38.888	±	0.0168	15.748	±	0.0067	18.449	±	0.0077	C3
SEALIP/VN/DS/14	Đông Sơn	2.096	±	0.00015	0.845	±	0.00001	39.014	±	0.0055	15.735	±	0.0017	18.613	±	0.0015	LB1
SEALIP/VN/DS/15	Đông Sơn	2.105	±	0.00022	0.852	±	0.00004	38.878	±	0.0143	15.746	±	0.0053	18.473	±	0.0058	LC3
SEALIP/VN/DS/16	Đông Sơn	2.103	±	0.00020	0.851	±	0.00008	38.875	±	0.0248	15.731	±	0.0099	18.484	±	0.0116	LC3
SEALIP/VN/DS/17	Đông Sơn	2.094	±	0.00016	0.844	±	0.00002	39.042	±	0.0054	15.738	±	0.0018	18.641	±	0.0018	LB1
SEALIP/VN/DS/18	Đông Sơn	2.105	±	0.00015	0.852	±	0.00003	38.876	±	0.0062	15.739	±	0.0023	18.465	±	0.0028	LBNC
SEALIP/VN/DS/19	Đông Sơn	2.111	±	0.00013	0.857	±	0.00002	38.892	±	0.0055	15.780	±	0.0020	18.423	±	0.0022	LBNC
SEALIP/VN/DS/20	Đông Sơn	2.081	±	0.00022	0.831	±	0.00011	39.180	±	0.0307	15.637	±	0.0125	18.833	±	0.0173	B1
SEALIP/VN/LN/1	Lãng Ngâm	2.109	±	0.00012	0.851	±	0.00002	39.058	±	0.0050	15.756	±	0.0016	18.522	±	0.0019	LB1
SEALIP/VN/THD/1	Thịệu Dương	2.067	±	0.00017	0.819	±	0.00009	39.466	±	0.0399	15.646	±	0.0162	19.096	±	0.0189	B1
SEALIP/VN/THD/2	Thịệu Dương	2.110	±	0.00025	0.852	±	0.00007	38.847	±	0.0253	15.687	±	0.0105	18.411	±	0.0125	B5
SEALIP/VN/THD/3	Thịệu Dương	2.110	±	0.00013	0.856	±	0.00005	38.891	±	0.0107	15.768	±	0.0038	18.428	±	0.0046	LCNC