Copper-base Metallurgy in Metal Age Bali: Evidence from Gilimanuk, Manikliyu, Pacung, Pangkung Paruk and Sembiran

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Abstract:	The Indonesian Archipelago extends over 5000 km and hosts some of the world's largest active metal mines but virtually nothing is known of the country's prehistoric metallurgical traditions. With this paper we seek to elucidate some metal production and consumption behaviours on Bali. The studied early Metal Age assemblage of 27 artefacts from the sites of Pacung, Sembiran, Bangkah, Pangkung Paruk, Gilimanuk and Manikliyu includes bangle, bowl, drum, hook, mirror and ornamental typologies. There is a strong tendency towards leaded copper alloys, with some bronzes, a high-tin bronze, and a leaded high-tin bronze. There is good consistency with Mainland Southeast Asian Iron Age leaded alloy signatures for the bulk of the assemblage, possibly indicating the existence of long-range (c. 2-3000 km one way) exchange systems at the outset of the Island Southeast Asian Metal Age, and perhaps as far as China and India. Of particular note, the Manikliyu 'Pejeng' drum, a stylistically idiosyncratic type, transpired to be consistent in terms of elemental composition and lead signature with Mainland 'Dong Son' drums. This could suggest that Pejeng drums were produced not just from metal imported from the Mainland but with melted down Mainland drums; an intriguing case of local reinterpretation of foreign elite material culture and iconography.

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Abstract

The Indonesian Archipelago extends over 5000 km of latitude, from 95° to 141° E, and hosts some of the world's largest active metal mines. Whilst some fascinating ethnographic and historic sources exist, virtually nothing is known of the country's prehistoric metallurgical traditions. Given Indonesia's scale this situation cannot be remedied in short order but with this paper we seek to elucidate some metal production and consumption behaviours on Bali, located around 115° E, during the last centuries of the first millennium BC and the early-mid first millennium AD. The studied early Metal Age assemblage of 27 copper-base artefacts from the sites of Pacung, Sembiran, Bangkah, Pangkung Paruk, Gilimanuk and Manikliyu includes bangle, bowl, drum, hook, mirror and ornamental typologies, and fragments thereof. Fourteen of the 27 samples were suffering from corrosion but a strong tendency towards leaded copper alloys (21 of 27) can be distinguished, with some bronzes, a high-tin bronze, and a leaded high-tin bronze. The high proportion of leaded artefacts mean lead isotope data cannot be used to identify possible sources of copper but there is good consistency with Mainland Southeast Asian Iron Age leaded alloy signatures for the bulk of the assemblage, possibly indicating the existence of long-range (c. 2-3000 km one way) exchange systems at the outset of the Island Southeast Asian Metal Age, and perhaps as far as China and India in the case of the mirror and bowl, respectively. Of particular note, the Manikliyu 'Pejeng' drum, a stylistically idiosyncratic type known from Bali and Java and for which there is local production evidence, transpired to be consistent in terms of elemental composition and lead signature with Mainland 'Dong Son' drums. This could suggest that Pejeng drums were produced not just from metal imported from the Mainland but with melted down Mainland drums; an intriguing case of local reinterpretation of foreign elite material culture and iconography.

Keywords:

Southeast Asia; Indonesia; Bali; Archaeometallurgy; Lead Isotope

1. Introduction

At approximately 115 degrees of longitude east, Bali lies at the centre of an Indonesian archipelago that stretches over 5000 km from the Banda Aceh Peninsula of Sumatra to the border with Papua New Guinea and the rest of Melanesia (Figure 1). Despite its remoteness from the Eurasian landmass, the investigation of the Metal Age (c. 200 BC to c. 500 AD) coastal sites of Sembiran, Pacung, Julah and Bangkah in northern Bali from the late 1980s (Ardika 1987) has revealed the island's participation in exchange networks stretching far beyond Insular and even Mainland Southeast Asia, reaching as far west as the Roman world via the Indian subcontinent (Ardika, 1991;

Ardika & Bellwood, 1991, Ardika et al., 1997; Calo et al., 2015). Concurrently, evidence for South Asian contact, including pottery, semi-precious stone and glass ornaments and high-tin bronze vessels, was building in littoral Mainland Southeast Asia, particularly on the Thai-Malay Peninsula (Srisuchat, 1993), west-central Thailand (Glover, 1996, You-Di, 1978) and in central Vietnam (Yamagata & Glover, 1994). Indeed, the presence of some coins and cameos, typically at sites dating to the early centuries AD, suggest exchange, almost certainly indirectly via India, with the Mediterranean sphere of Imperial Rome (Bellina, 1998, Bellina & Glover, 2004, Malleret, 1960).

These glimpses of a vast ancient exchange network, though certainly revelatory, revealed little of the underlying interaction mechanisms responsible for the distribution of ‘exotic’ material culture. This situation improved significantly during the mid-late 2000s with the excavations of the Franco-Thai Archaeological Mission at Khao Sam Kaeo, a c. 50 hectare settlement and industrial centre dated to 4th-2nd c. BC, located on the banks of the Tha Thapao river on the upper Thai-Malay Peninsula (Figure 1). The site was selected for investigation due to the identification of semi-precious stone bead production debris bearing traits of highly skilled South Asian knapping techniques (Bellina, 2001, Bellina, 2017). As anthropological studies indicate that mastering complex psycho-motor skills takes about a decade (e.g. Roux et al., 1995), it was proposed that South Asian artisans may have been physically present at Khao Sam Kaeo, probably at the behest of local emergent elites rather than as part of any larger general migration (Bellina, 2003, Bellina, 2007). Subsequent studies of the site’s physical structure and material culture (glass, metals, pottery) indicated that Khao Sam Kaeo was internally divided according to the ethnicity and occupation of its population, and externally protected with ramparts (Bellina, 2014, Bellina et al., 2014, Bouvet, 2008, Dussubieux & Gratuze, 2010, Murillo-Barroso et al., 2010, Pryce & Bellina in press, Pryce et al. 2017). The Franco-Thai project’s fuller picture of early trans-Asiatic maritime interaction systems is constantly being added to by research in Thailand, Cambodia and Vietnam (e.g. Dussubieux et al., 2012, Reinecke et al., 2009, Yamagata, 2007).

Conversely, Island Southeast Asia’s role in these exchanges has been, until recently, far less well understood, in particular that of the region’s largest and most populous country, Indonesia. By returning between 2012 and 2015 to the promising area of Pacung and Sembiran identified in 1987, and of Pangkung Paruk, identified in 2009 (Gede 2009), the “Archaeology of the North Coast of Bali: a Strategic Crossroads in Early Trans-Asiatic Exchange” (or ‘ANCB’) project aimed to bring the full panoply of archaeological and archaeometric techniques to bear in elucidating the connectedness and socio-economic participation of the central part of the Indonesian archipelago. In particular, substantial quantities of Indian ‘Rouletted Ware’, a fine black pottery, found at the sites of Pacung and Sembiran, together with recent compositional data from glass and semi-precious stone beads, archaeobotanical and zooarchaeological evidence, strongly indicated continuous intensive contacts with the Indian subcontinent from the second century BC to the second century AD (Ardika et al., 1993; Calo et al., 2015; Fenner et al 2017). Rouletted Ware in second-first century BC contexts in Indonesia is also known from the site of Batujaya in northwest Java (Manguin and Indradjaya 2011). The ANCB project also produced new compositional evidence for Indian glass in first century BC contexts at the burial complex of Gilimanuk in northwest Bali (Figure 2), while Sembiran and the second-third century AD stone sarcophagus burial site of Pangkung Paruk, the project’s other main site in north central Bali, also gave evidence of Roman soda-natron glass (Calo et al., 2015). This paper concerns the analysis of the copper-base artefact assemblage from that and previous scholars’ campaigns.

2. Archaeology

Sembiran and Pacung are located c. 700 m apart, west to east; on the coastal plain, c. 20 km northwest of the Mount Batur crater (Figure 2). The sites lie c. 250 m inland but two millennia of alluvial sedimentation has aggraded the shoreline by 50-70 m, and buried the prehistoric layers 2.7 – 3.2 m below the present day land surface (Calo et al., 2015: 380-381). Figure 3 shows the location of the numerous excavations over the years, to which the 2012 season added a 4 x 4 m trench (SBN XIX) at Sembiran and a 5 x 6 m trench (PCN IX) at Pacung. The 2012 Sembiran trench constituted a dense occupation deposit up to four metres deep, whereas the Pacung trench revealed seven burials at up to five metres depth. The sites' stratigraphies are linked by a lens of c. 10% volcanic ash at 2-2.1 m depth. A single 14C date on charcoal from Indian ceramic-bearing layer 8 (2.9-3 m depth) at SBN XIX gave a result of 142 cal BC–AD 25 (S-ANU 37107) and one charcoal and seven bone 14C determinations from PCN IX give a tight range from 163 cal BC - AD 13 to 51 cal BC - AD 137 (Calo et al., 2015: 381, Figure 4). Copper-base metal samples were recovered from both these and previous excavations, of which ten Pacung and four Sembiran artefacts were incorporated in the present study (Table 1, Figure 5). Sembiran also has evidence of casting activities in the form of stone moulds for copper alloy axes (Calo et al., 2015: 390-391).

Excavations in 1997 by Bali Institute of Archaeology (BALAR) at Manikliyu, on the western slope of the Batur volcano in north-central Bali (Figure 2, Gede 1997-1998), unearthed a large bronze drum used as a primary burial container next to a stone sarcophagus burial (Figure 4). The drum is stylistically unique to Bali and Java, from where a total of 21 examples of the 'Pejeng-type' are known (Calo 2014: 127-129). Four large stone casting mould fragments for this type of drum at Manuaba in central Bali (Bernet Kempers 1988: 21, 409), and of a smaller stone mould fragment excavated in first century AD context at Sembiran, near the previous chance find in 1978 of a large drum of this type at adjacent Pacung (Ardika and Bellwood 1991; McConnell and Glover 1990; Widia 1981), indicated the presence of a Balinese bronze casting tradition, perhaps inspired by Mainland imports of 'Dong Son-type' drums. The drum plus three other Manikliyu artefacts were incorporated in the present study (Figure 5, Table 1).

Following the discovery by the landowner of two stone sarcophagi with rich local and imported burial goods at Pangkung Paruk (Figure 2), BALAR conducted further investigations in 2009 (Gede 2009). A total of four sarcophagus burials were formally excavated, containing dozens of gold, glass, carnelian, copper-base, and shell beads and ornaments. Charcoal dates from the 2013 ANCB excavations at Pangkung Paruk, from the depth of the sarcophagi, indicated a second-third century AD date for the site (S-ANU 3711: cal AD 122-cal AD 240; S-ANU 37112: cal AD 128-cal AD 331), and the analysis of previously excavated glass beads gave evidence of Roman natron-soda glass white beads covered with gold dust, typical of the western Indian Ocean (Calo et al. 2015). A copper-base mirror, bowl and wire coil from the landowner discovery were included in the present study.

The burial complex of Gilimanuk on the north-western coastal tip of Bali was first excavated in 1961 by Soejono of the National Institute of Archaeology (Soejono 1977), up to the most recent 2013 campaign by BALAR. It has yielded over 150 burials including stone sarcophagi, jar, and open burials and is dated from the first century BC to the mid first millennium AD (Anggreani 1999: 23-25; Bronson and Glover 1984; Soejono 1977: 280-81). A new Gilimanuk AMS date on human bone at 1.7m depth by the ANCB project (S-ANU 38219: 52 cal BC – cal AD 135) confirmed the previous earliest first century BC dating of the site. A copper-base rod, large swallow-tailed socketed point, a platy and an unidentifiable fragment were incorporated in the present study.

The coastal site of Bangkah is located ca. 6 Km to the west of Sembiran and was excavated by Ardika in 1987-1988 (Ardika 1991:17-26). Although no dates are available for the site, based on the excavated local pottery and two stone structures revealed by the sea post-excavation, the site was thought to be later than the Metal Age. A copper-base hook was included in the present study.

3. Methodology

Our funding allowed for the analysis of twenty-seven copper alloy samples, which, for a relatively localised site cluster, compares favourably with many of the assemblages studied by the Southeast Asian Lead Isotope Project ('SEALIP' Pryce et al., 2014). A selection was made on the basis of representing the different burials and morphologies, as well as expected corrosion levels, which unfortunately affected 14 samples and rendered two (SEALIP/ID/GLM/1 and SEALIP/ID/PCN/6) not worth analysing (Figure 3). The artefacts were cut in Bali using a 0.2 mm jeweller's saw blade after photographic recording. The cut samples were sent to the Curt-Engelhorn Centre for Archaeometry (CEZA) in Mannheim (Germany) for elemental analysis using energy-dispersive X-ray Fluorescence Spectrometry (XRF) and lead isotope ratios with Multi-Collector Inductively-Coupled Plasma Mass Spectrometry (MC-ICP-MS) using the established instruments and protocols of the CEZA laboratories (Lutz & Pernicka, 1996, Niederschlag et al., 2003).

SEALIP was engaged with the firm understanding that firstly, as an additive technology, geochemical patterning in metal artefacts can be very heavily influenced by mixing (multiple sources of the same metal, e.g. copper plus copper), alloying (multiple sources of different metals, e.g. copper plus lead), and recycling (repeated cycles of mixing and alloying); and secondly, that an artefact can never truly be 'provenanced' and that a more neutral interpretation of an artefact's lead isotope signature would be whether it was 'consistent' or not with any of the known sources; implying that other matches are in theory possible (Bray & Pollard, 2012, Bray et al. 2015; Gale, 2001, Pollard, 2009, Pryce et al., 2011).

4. Results

4.1 Elemental data

21 of the 25 analysed samples are, by the conventional measure of containing ≥ 1 wt. % Pb, leaded copper alloys (Table 1). There is substantial variation in the proportion of lead in those artefacts with remnant metal (1.0 – 10.7 wt. % Pb); the higher readings of corroded artefacts probably caused by the depletion of copper from the matrix. There does not seem to be a correlation between lead content and artefact type, except in the case of SEALIP/ID/PKP/2, a typologically Han high-tin leaded bronze mirror, which is a known alloy class distinct to these artefacts (Figure 5, Mabuchi et al., 1985, Pryce et al., 2014: 290-291).

Of the four non-leaded copper alloys, two (SEALIP/ID/ML/3 and SEALIP/ID/SBN/3) are uncorroded bronze rings, though the Manikliyu example does have 0.6 wt. % Pb as opposed to the below-detection-limit result for the Sembiran ring. The third bronze artefact, a hollow point from Sembiran (SEALIP/ID/SBN/1) has what appears to be a high-tin bronze composition (21.2 wt. % Sn) but this must be discounted due to the corrosion, which is corroborated by the 1.4 wt. % Fe measured, and thus a lower tin:copper ratio probably existed in the original artefact. The final non-leaded artefact, SEALIP/ID/PKP/3, represents a likely exotic category, that of an 'Indian' high-tin bronze bowl. High-tin bronzes, which contain 22-24 wt. % Sn, have, when new, a golden appearance and require particular high-temperature working techniques due to the brittleness of the alloy (Murillo-Barroso et al., 2010, Scott, 1991).

4.2 Isotopic data

As 21 of the 25 samples are leaded bronzes, it follows that their lead isotope signatures cannot be linked to their original copper production systems, which are identified through the trace lead content of the copper ore (Pernicka, 2014, Pollard, 2009). Leaded bronzes' lead isotope signatures can however be compared to each other, and could potentially reveal the original lead production systems, were such sites to be identified within Southeast Asia (Hirao & Ro, 2013, Pryce, 2012, Pryce, 2014). The lead isotope data indicate that most of the leaded copper alloy artefacts share a similar signature, with three plotting slightly down the same axis, and one (SEALIP/ID/PKP/2, the leaded high-tin bronze mirror) plotting as a highly radiogenic sample (Figure 6). Three of the four non-leaded artefacts plot distinctly, and individually, from the main leaded cluster. One 'unleaded' bronze ring, SEALIP/ID/ML/3, does plot in the main leaded cluster, which is significant as it suggests that its 0.6 wt.% Pb content shares the same lead source as the others, and therefore our labelling it 'unleaded' does not represent any historical distinction in this instance. Likewise, although SEALIP/ID/PKP/3 and SEALIP/ID/SBN/3 appear to plot in the northern Thai copper production signature (Figure 5) we consider this highly unlikely to be a real association. The Phu Lon production site, though contemporary with the Bali sites, lies on multiple copper mineralisations (Kamvong & Zaw, 2009) and as such the production signature, largely defined by mineral rather than more reliable slag samples, is highly diffuse and generally unsuited to precise provenance attributions (Pryce et al., 2011).

5. Discussion

The prevalence of leaded bronzes in the assemblage, and the absence of investigated prehistoric lead production centres in Mainland and Island Southeast Asia limits the attribution of confident provenance for the artefacts in the present study. Nevertheless, as most of the leaded bronzes plot into a tight cluster it is possible they contain lead from the same primary source, the same geological region, or from the same secondary source (or recycling pool). Approximately half of SEALIP's samples, which are predominantly from mainland sites, are leaded alloys (Pryce et al 2014: 282) and the Bali examples presented here have similar a similar range of lead isotope ratios. As stated in our methodology, it is always possible to have duplicate isotopic signatures, nevertheless we are inclined to see the consistency of the Bali and Mainland lead signatures as perhaps representing an exchange system between these two areas. This could potentially be further refined to the Annam Cordillera, which runs along the Lao/Vietnamese border, given the similar signatures for Mainland leaded artefacts and central Lao copper production at Sepon (Figure 6), with potentially some compatibility with the Mainland "Region N" lead signature identified by Hirao & Ro (2013: 301). We must not, however, overlook the potential for Island Southeast Asian primary metal production (Pryce et al., 2014: 289): put simply, Indonesia and the Philippines host some of the world's largest non-ferrous base metal deposits and mines and it is difficult to imagine that they, or their surficial outcroppings, were never exploited in antiquity. This remains difficult to assess at present due to the low density of archaeological exploration over a vast territory, nor comparative isotopic data for those mineral deposits. By rights, the Indo-Malaysian archipelago should be one of the richest areas for archaeometallurgical prospection in the world, as also suggested by regular finds of prehistoric secondary production evidence like moulds. In the meantime, we are able to compare selected, typologically or chemically distinctive, artefacts to the Mainland Southeast Asian database.

5.1 'Indian' high-tin bronze bowls

The high-tin bronze bowl from Pangkung Paruk presents an interesting example. It was reported in 2009 to have been found, together with two Chinese bronze mirrors (see below), in a stone sarcophagus burial by the land owner of the site, which was later excavated by the Bali Institute of Arkaeologi (Gede 2009). The bowl's elemental composition and decoration are both consistent with it being identified as an 'Indian' import but its lead isotope ratios are at variance with most of the SEALIP high-tin bronze database (Figure 7, Pryce & Bellina in press). Most of the high-tin bronze bowls currently known were found in Southeast Asia but production is claimed in India from the 8th c. BC (Srinivasan, 2010). However, the potential Indian copper (and tin) sources and the necessary highly specialised workshops from c. 2000 years ago are currently unknown. The high-tin bronze lead isotope patterning is also quite strange and, at present, unexplained, in that most samples fall on an axis that extends to some highly radiogenic examples (Figure 7). Pryce et al (2014: 291) have suggested that such a data distribution might come about if two copper sources were mixed, with one of them being in association with a uranium deposit; suggesting the Singhbhum range of Jharkhand state as a possibility. High-tin bowls plotting on this axis were found in peninsular and western Thailand and West Bengal but critically the Thai peninsular sites also present evidence for high-tin bronze production: crucible-based cassiterite cementation at Khao Sam Kaeo (Murillo-Barroso et al., 2010) and casting at nearby Khao Sek (Pryce & Bellina, in press). Peninsular Thailand, like neighbouring peninsular Myanmar and Malaysia, host some of the richest tin deposits in the Old World, which may or may not be a coincidence. The SEALIP high-tin database also suggests a second axis / third source area with a cluster of samples that includes the Pangkung Paruk bowl. The samples do not plot very close together but include bowls from northern Vietnam, peninsular Thailand, Sri Lanka and West Bengal (Figure 7). Therefore, whilst we cannot yet offer an origin for SEALIP/ID/PKP/3 it is consistent with a high-tin bronze database that highlights a long-distance network linking littoral South and Southeast Asia.

5.2 Han mirror

Next we will consider SEALIP/ID/PKP/2, the leaded high-tin bronze mirror, also from Pangkung Paruk. This mirror, which can be stylistically identified as Han Dynasty Chinese (Figure 5), is certainly consistent from the point of view of its elemental composition (Table 1) but the lead isotope signature is more complicated. Fascinatingly, it was appreciated in the 1980s that the isotope ratios of Han Dynasty Chinese mirrors found in contemporary Yayoi period Japanese tombs varied in accordance with their date attribution (Mabuchi et al., 1985). Mirrors that were stylistically attributed to, in chronological order, the Western Han (206 BC to 9 AD), Transitional Period (9 to 24 AD) and Eastern Han (25 to 220 AD) periods were produced with lead from isotopically distinct sources. That is, Han artefacts of unknown or uncertain attribution could be analysed and their lead isotope ratios would reveal or confirm their cultural origin. This approach has worked convincingly with the few Han Chinese bowls and mirrors analysed from Mainland Southeast Asia (Pryce et al., 2014: 290-291) but when we add the Pangkung Paruk example to the database we see that it does not fit (Figure 8). SEALIP/ID/PKP/2 was obviously produced with highly radiogenic lead and not that typically used for Han Dynasty Chinese metal artefacts. China does indeed host some highly radiogenic lead deposits (Zhu, 1995) but we are unaware of their association with Han period metal production. As such, we are unable to offer a more complete interpretation of this enigmatic mirror.

5.3 'Dong Son' and 'Pejeng' drums in Bali and Java

Finally, we turn to the Manikliyu drum, the first of the Pejeng-type to be subjected to laboratory analysis. It had been suggested (McConnell and Glover 1990; Calo 2014: 131) that the sharp angle between the tympanum and body of these drums (Figure 4) indicated a join between two separately produced elements rather than the continuously cast form of a Mainland Dong Son drum (hence two samples having been taken for chemical analysis, Table 1). A section cut through the shoulder of the Manikliyu drum did indeed reveal a discontinuity in this area but metallographic examination (Figure 9) revealed a continuous grain size either side, suggesting a post-production fissure rather than an original join. On the basis of this example at least, it is not possible to characterise Pejeng-type drum fabrication as technically distinct from that of a Dong Son drum, although the former seems to have employed reusable stone and the latter disposable ceramic moulds. In terms of alloy type and raw material sourcing, the Manikliyu drum's elemental and lead isotope composition are entirely comparable to most analysed Dong Son drums (Table 1, Figure 10) – a leaded bronze with a lead signature highly consistent with Mainland examples.

Many more Mainland and Island Southeast Asian drums could and should be studied from a technological and geochemical perspective but we by no means reject the predominant morpho-stylistic approach. The clear outlier in Figure 10, SEALIP/VN/DX/10, was noted, despite its north Vietnamese find spot, to be of the Yunnanese Dian rather than Dong Son decorative canon (Calo 2014: 45-46), and transpired to be made of an atypical alloy, unleaded bronze, with a completely different isotopic signature (Pryce et al. 2014: 290). Despite the limited size of the compositionally-analysed regional drum database, interesting divergences are being exposed between stylistically coherent examples through archaeological, geochemical, and/or technological data. What are traditionally assumed to be 'Dong Son' (northern Vietnamese) drums can actually be local imitations or variants. Ceramic drum moulds and Sepon style conical copper ingots have been found in Mukdahan province in northeast Thailand suggesting a drum foundry many hundreds of kilometres from the presumed epicentre of the Dong Son drum culture (Baonoed, 2016). Similarly, at Khao Sek in Chumphon province in peninsular Thailand, a porous and poorly-cast near-pure copper drum was found to be inconsistent with the 'Dong Son' technical tradition but was isotopically highly compatible with the central Lao Sepon production system (Pryce & Bellina, in press), suggestive of an ancient imitation of a Dong Son drum, even if the foundry location remains unknown.

What we propose for the Manikliyu drum is an interpretation that attempts to take into account the morpho-stylistic, technological and compositional data. Thus we seem to have a situation in which the one-piece fabrication technique and raw materials can be linked to Mainland Southeast Asian Iron Age Dong Son drums but there are clear differences in Pejeng-type drum morphology and decorative style, backed up with local foundry evidence. We recognise the limitations of a single sample but suggest that to explain the high degree of compositional compatibility between the Manikliyu drum and the Mainland drum corpus we might invoke not merely to the reuse of imported Mainland metal, but specifically to the breaking up and re-casting of imported Mainland drums. This has important implications for the development of a Bali/Java metallurgical tradition in that, in addition to it probably being ideologically stimulated by Mainland examples, there was a willingness not just to imitate foreign elite material culture but to entirely subsume and reorient both the form (techniques) and flow (materials) of imported metal for local needs (see Bray et al. 2015).

6. Conclusion

Twenty-seven copper-base artefacts from five Metal Age north Bali sites were selected for laboratory analysis in order to investigate metallurgical traditions and exchange networks. Preservation had not been kind to the assemblage, with two samples rejected and another 14 affected but capable of providing useful information. The predominant alloy was leaded bronze, with one instance of leaded high tin bronze, one high-tin bronze, and two unleaded bronzes. The leaded bronzes offer reasonable lead isotope ratio consistency with contemporary Mainland Southeast Asian consumption patterns and, in the absence of known lead production sites but comparability with the central Lao copper production signature, may correspond to sources in the Annam Cordillera bordering Laos and Vietnam. The leaded high-tin bronze, a typologically Han mirror, had a highly radiogenic signature that does not compare to previously studied Western or Eastern Han and is, for the time being, unexplained. The high-tin bronze, a thin-walled bowl of a type normally ascribed Indian origins, has an isotopic signature comparable to some Mainland Southeast Asian examples. Though not consistent with secondary production sites known on the Thai-Malay Peninsula, this bowl nevertheless indicates Bali's participation in exchange networks spanning the South China Sea and Bay of Bengal. Finally, the Pejeng-type drum from Manikliyu has, despite its clearly local (Bali and Java) typology and decorative style, an elemental and isotopic composition consistent with the most of the Dong Son-type drums known from Mainland Southeast Asia. This suggests the Pejeng drums may not have just been cast from melted down imported metal, but specifically from melted down imported drums; a significant reincarnation of a foreign elite material culture class.

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SEALIP ID	Site	Context
SEALIP/ID/BKH/1	Bangkah	BKH/87. TP1 (10)
SEALIP/ID/GLM/1	Gilimanuk	GLM/I/84.XXXIV/22TL. Cat 31032
SEALIP/ID/GLM/2	Gilimanuk	GLM/XI/92.XLVI.KOTAK III.SPIT 6
SEALIP/ID/GLM/3	Gilimanuk	GLM/XII/93. XLVII. 17
SEALIP/ID/GLM/4	Gilimanuk	GLM/XV/96.LV.9. Cat 81
SEALIP/ID/ML/1	Manikliyu	ML/97/6-9/105-140
SEALIP/ID/ML/2	Manikliyu	ML/97/6-9/105-140
SEALIP/ID/ML/3	Manikliyu	ML/97/6-9/105-140
SEALIP/ID/ML/4	Manikliyu	ML/97/6-9/105-140
SEALIP/ID/ML/5	Manikliyu	ML/97/6-9/105-140
SEALIP/ID/PCN/1	Pacung	PCN III. Spit 36
SEALIP/ID/PCN/2	Pacung	PCN IV. R VI
SEALIP/ID/PCN/3	Pacung	PCN IV. R VI. Cat 40
SEALIP/ID/PCN/4	Pacung	PCN IV. R VI. Cat 43
SEALIP/ID/PCN/5	Pacung	PCN 2008. VIII. Cat 29
SEALIP/ID/PCN/6	Pacung	PCN 2008. VIII. Cat 33
SEALIP/ID/PCN/7	Pacung	PCN 2012. IX. A2-40
SEALIP/ID/PCN/8	Pacung	PCN 2012. IX. B3-41
SEALIP/ID/PCN/9	Pacung	PCN 2012. IX. A2-42
SEALIP/ID/PCN/10	Pacung	PCN 2012. IX. E4-E5/SP.43
SEALIP/ID/PKP/1	Pangkung Paruk	PKP/04/2009/ A or B
SEALIP/ID/PKP/2	Pangkung Paruk	PKP/04/2009/ A or B
SEALIP/ID/PKP/3	Pangkung Paruk	PKP/04/2009/ A or B
SEALIP/ID/SBN/1	Sembiran	SBN XIX. A2-28
SEALIP/ID/SBN/2	Sembiran	SBN XIX. A2-28
SEALIP/ID/SBN/3	Sembiran	SBN XIX. A3-31
SEALIP/ID/SBN/4	Sembiran	SBN XIX. D4-30

Description	Corrosion	Cu %	Mn %	Fe %	Ni %	Zn %
hook	metal	91.5	0.0	1.1	0.1	<0.1
rod	completely corroded and not analysed					
-	metal	70.9	<0.01	0.2	0.1	<0.1
large swallow-tailed socketed point	corrosion	77.4	0.1	2.6	0.1	<0.1
platy fragment	corrosion	69.4	0.1	3.9	0.0	<0.1
wire spiral	metal	80.8	<0.01	<0.05	0.4	<0.1
flat spiral	metal	86.3	<0.01	<0.05	0.0	<0.1
ring spiral	metal	89.0	<0.01	<0.05	0.0	<0.1
drum body decoration	metal	87.1	<0.01	<0.05	0.0	<0.1
drum mid/lower mantle	metal	87.0	<0,005	0.0	0.4	<0,2
fragment	corrosion	67.2	0.0	0.8	0.1	<0.1
small bracelet by left ankle	metal	79.8	<0.01	0.0	0.1	<0.1
bracelet	metal & corrosion	71.8	0.0	0.6	0.1	<0.1
bracelet	metal	83.6	<0.01	0.1	0.1	<0.1
flat fragment	corrosion	52.5	0.0	2.1	0.0	<0.1
fragment	completely corroded and not analysed					
fragment	corrosion	61.8	0.2	11.9	0.0	<0.1
bracelet	metal & corrosion	78.8	0.2	2.2	0.2	<0.1
anklet	metal & corrosion	85.2	0.0	0.3	0.1	<0.1
socketed implement	metal & corrosion	73.0	0.2	6.2	0.0	<0.1
coiled wire	metal	86.6	<0.01	0.1	0.3	<0.1
Han mirror	metal	70.1	<0.01	0.1	0.0	<0.1
high tin bronze bowl	metal	72.0	na	0.0	0.0	na
point 1	corrosion	77.2	0.1	1.4	<0.01	<0.1
hollow point	corrosion	21.1	0.2	2.4	0.3	<0.1
ring with knobs	metal	90.9	<0.01	0.0	0.0	<0.1
hollow point	corrosion	39.2	0.6	5.7	0.0	<0.1

As %	Ag %	Sn %	Sb %	Pb %	Bi %	Alloy	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$
0.2	0.1	5.2	0.1	1.6		leaded bronze	2.1051±0.0001	0.85113±0.00001
0.5	0.1	18.3	0.3	9.6	0.1	leaded bronze	2.1191±0.0001	0.85443±0.00001
0.1	0.0	1.4	0.0	18.4	0.0	leaded bronze	2.1170±0.0001	0.85368±0.00001
0.7	0.1	8.9	0.1	16.7	0.1	leaded bronze	2.1155±0.0001	0.85248±0.00002
0.1	0.0	15.9	0.1	2.7	0.0	leaded bronze	2.1207±0.0001	0.85507±0.00001
0.1	0.1	11.2	0.0	2.2	0.1	leaded bronze	2.1161±0.0001	0.85265±0.00001
0.2	0.1	10.0	0.0	0.6	0.1	bronze	2.1166±0.0001	0.85274±0.00001
0.2	0.0	11.1	0.0	1.5	0.0	leaded bronze	2.1153±0.0001	0.85222±0.00001
<0,01	0.0	9.6	0.0	2.8	0.0	leaded bronze	2.1148±0.0003	0.85201±0.00001
0.3	0.1	24.7	0.3	6.4	0.0	leaded bronze	2.1279±0.0001	0.8586±0.00002
<0.1	0.1	8.9	0.2	10.7	<0.2	leaded bronze	2.1176±0.0001	0.85405±0.00002
<0.1	0.1	7.9	0.2	19.2	<0.2	leaded bronze	2.1195±0.0002	0.85452±0.00005
<0.1	0.1	9.1	0.2	6.7	<0.2	leaded bronze	2.1266±0.0002	0.85809±0.00003
0.1	0.0	20.6	0.1	24.4	0.0	leaded bronze	2.1123±0.0001	0.85144±0.00001
<0.1	0.0	15.4	0.1	10.4	<0.2	leaded bronze	2.1152±0.0001	0.85294±0.00006
<0.1	0.0	11.0	0.1	7.4	<0.2	leaded bronze	2.1162±0.0001	0.85324±0.00003
<0.1	0.0	8.0	0.2	6.1	<0.2	leaded bronze	2.1192±0.0002	0.85443±0.00005
0.2	0.0	10.8	0.2	9.3	<0.2	leaded bronze	2.1142±0.0002	0.8526±0.00003
0.1	0.0	11.9	0.1	1.0	<0.01	leaded bronze	2.1144±0.0001	0.85223±0.00002
0.4	0.0	23.5	0.0	5.7	<0.2	leaded bronze	1.9237±0.0001	0.76332±0.00003
0.1	0.1	24.0	0.0	0.0	0.0	high-tin bronze	2.4627±0.0004	0.84528±0.00013
<0.01	0.0	21.2	0.0	0.1	<0.01	bronze	2.0963±0.0001	0.84733±0.00002
0.6	0.0	59.8	0.4	15.0	0.0	leaded bronze	2.1267±0.0001	0.85792±0.00001
<0.01	0.0	9.0	0.0	<0.01	<0.01	bronze	2.0365±0.0001	0.82000±0.00002
<0.1	0.0	37.3	0.1	16.9	<0.2	leaded bronze	2.1135±0.0002	0.85191±0.00005

$^{206}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$
38.786±0.004	18.425±0.001	15.682±0.001
38.886±0.005	18.350±0.001	15.679±0.001
38.879±0.006	18.365±0.001	15.678±0.001
38.933±0.005	18.404±0.001	15.689±0.001
38.873±0.007	18.331±0.001	15.674±0.001
38.944±0.005	18.404±0.001	15.692±0.001
38.962±0.001	18.408±0.001	15.697±0.001
38.959±0.003	18.418±0.001	15.696±0.001
38.946±0.009	18.416±0.003	15.691±0.003
38.756±0.009	18.213±0.001	15.638±0.001
38.873±0.006	18.357±0.002	15.678±0.002
38.884±0.007	18.346±0.003	15.677±0.003
38.791±0.006	18.241±0.001	15.652±0.001
38.930±0.003	18.430±0.001	15.692±0.001
38.907±0.002	18.394±0.003	15.689±0.001
38.894±0.013	18.379±0.005	15.682±0.005
38.853±0.010	18.334±0.005	15.665±0.004
38.912±0.008	18.405±0.001	15.692±0.001
38.906±0.003	18.401±0.001	15.682±0.001
40.030±0.009	20.809±0.003	15.884±0.003
38.4	18.430±0.0125	*15.6*
38.746±0.004	18.483±0.002	15.661±0.001
38.819±0.002	18.253±0.001	15.660±0.001
38.905±0.007	19.104±0.003	15.665±0.003
38.937±0.008	18.423±0.003	15.695±0.003

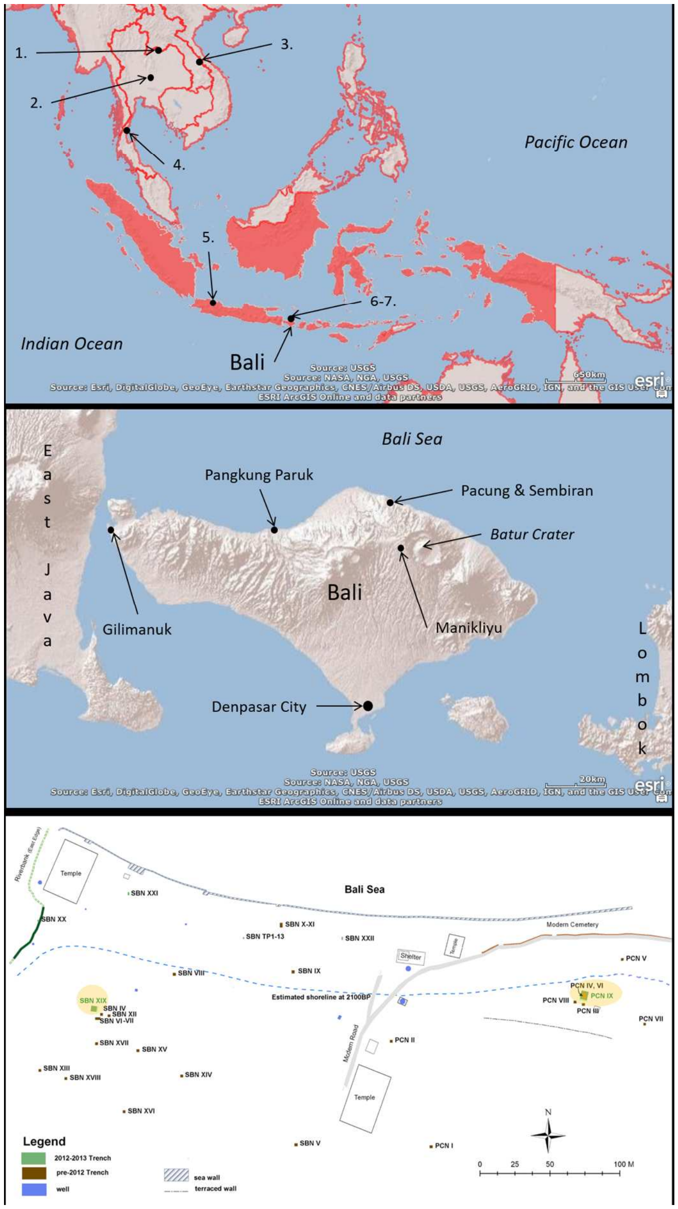


Figure 1: Regions, countries and sites mentioned in the text. Mainland Southeast Asia comprises Cambodia, Laos, peninsular Malaysia, Myanmar, Singapore, Thailand and Vietnam; Island Southeast Asia includes Brunei, East Malaysia, Indonesia, the Philippines and Timor Leste. Indonesia is shaded red and other nations outlined in red. The three known prehistoric Southeast Asian copper producing centres are: 1, Phu Lon; 2, Khao Wong Prachan Valley; and 3, Sepon. 4., Khao Sam Kaeo, is indicated as the most comprehensively studied Mainland site involved in early trans-Asian exchange systems. 5., is Batujaya and 6-7 are Sembiran and Pacung, though see detailed map below. Figure 2: Studied sites on the north coast of Bali. Figure 3: Plan of excavations as Pacung and Sembiran (Calo et al., 2015: Figure 2). Figure 3: Plan of excavations as Pacung and Sembiran (Calo et al., 2015: Figure 2).

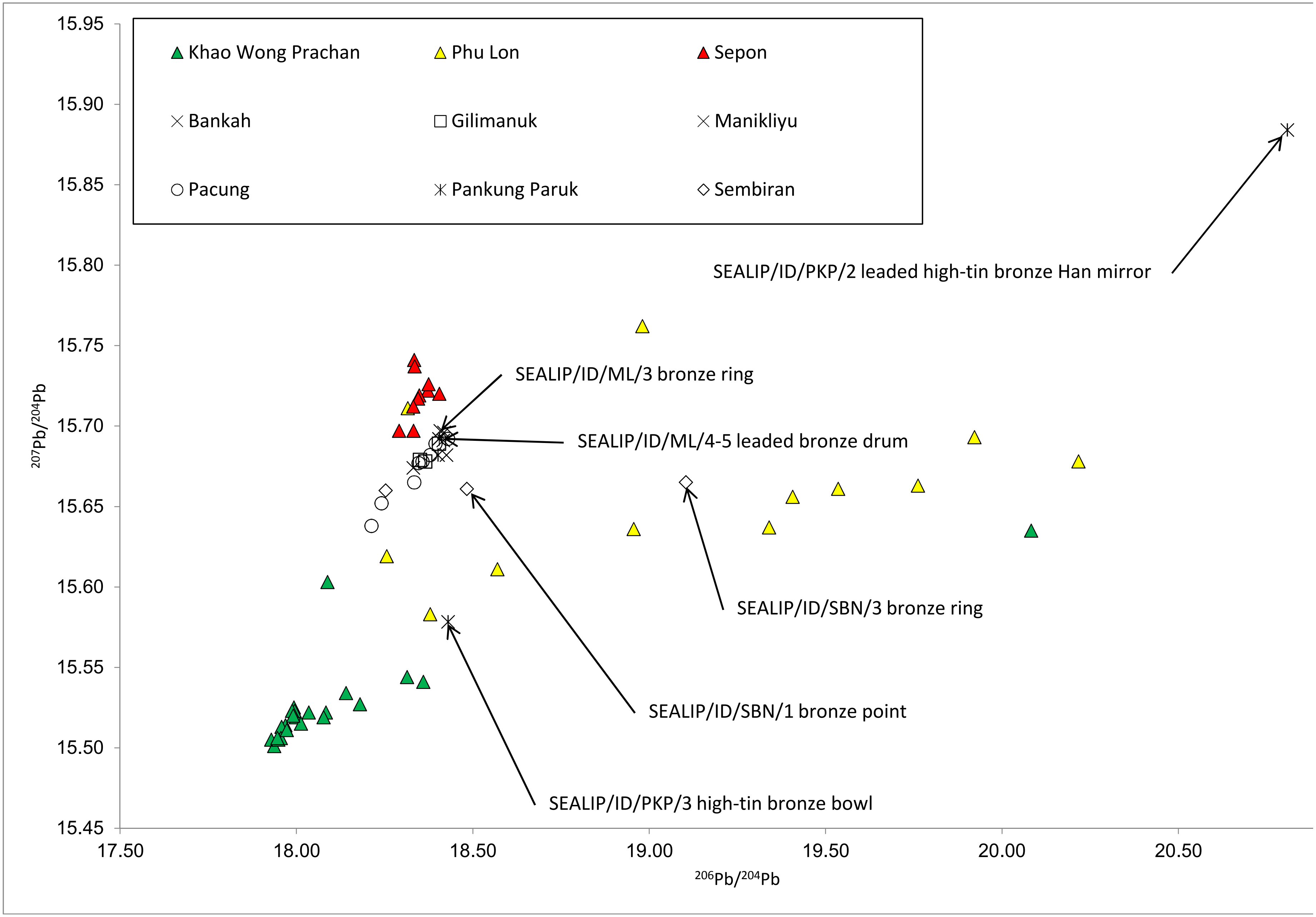
196x351mm (150 x 150 DPI)

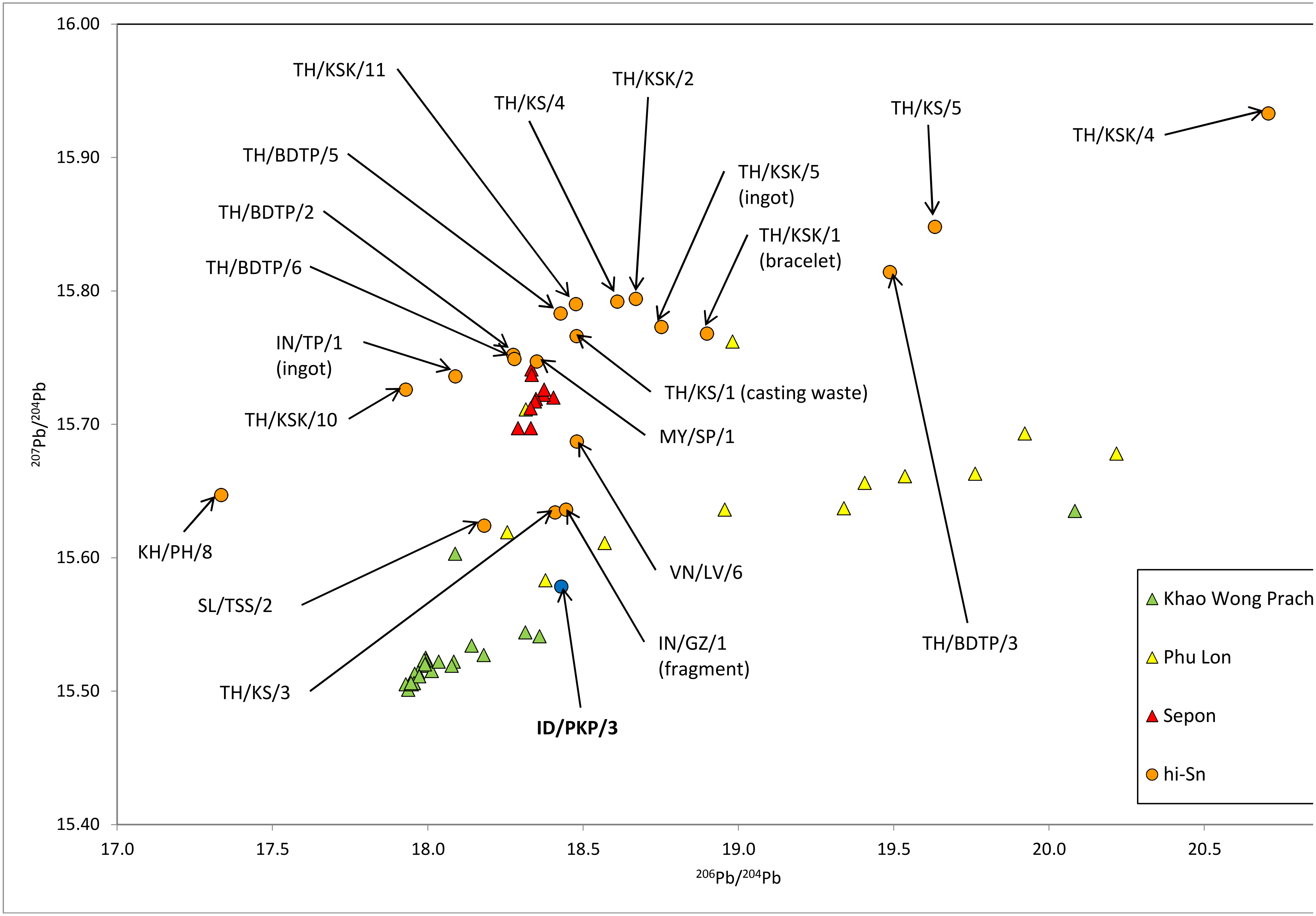
Manikliyu drum burial excavation in 1997 (Gede 1997-8 in Calo 2014).

368x179mm (150 x 150 DPI)

Images of the studied artefacts, where available, from the north coast of Bali.

880x511mm (150 x 150 DPI)


Khao Wong Prachan
Phu Lon
Sepon
Bankah
Gilimanuk
Manikliyu
Pacung
Pankung Paruk
Sembiran
SEALIP/ID/PKP/2 leaded high-tin bronze Han mirror
SEALIP/ID/ML/3 bronze ring
SEALIP/ID/ML/4-5 leaded bronze drum
SEALIP/ID/SBN/3 bronze ring
SEALIP/ID/SBN/1 bronze point
SEALIP/ID/PKP/3 high-tin bronze bowl
15.95
15.90
15.85
15.80
15.75
15.70
15.65
15.60
15.55
15.50
15.45
17.50
18.00
18.50
19.00
19.50
20.00
20.50
$^{207}Pb/^{204}Pb$
$^{206}Pb/^{204}Pb$


TH/KSK/11
TH/KSK/2
TH/KS/4
TH/KS/5
TH/KSK/4
TH/BDTP/5
TH/KSK/5
(ingot)
TH/BDTP/2
TH/KSK/1
(bracelet)
TH/BDTP/6
IN/TP/1
(ingot)
TH/KS/1 (casting waste)
TH/KSK/10
MY/SP/1
KH/PH/8
VN/LV/6
SL/TSS/2
IN/GZ/1
(fragment)
TH/BDTP/3
TH/KS/3
ID/PKP/3
Khao Wong Prach
Phu Lon
Sepon
hi-Sn
16.00
15.90
15.80
15.70
15.60
15.50
15.40
17.0
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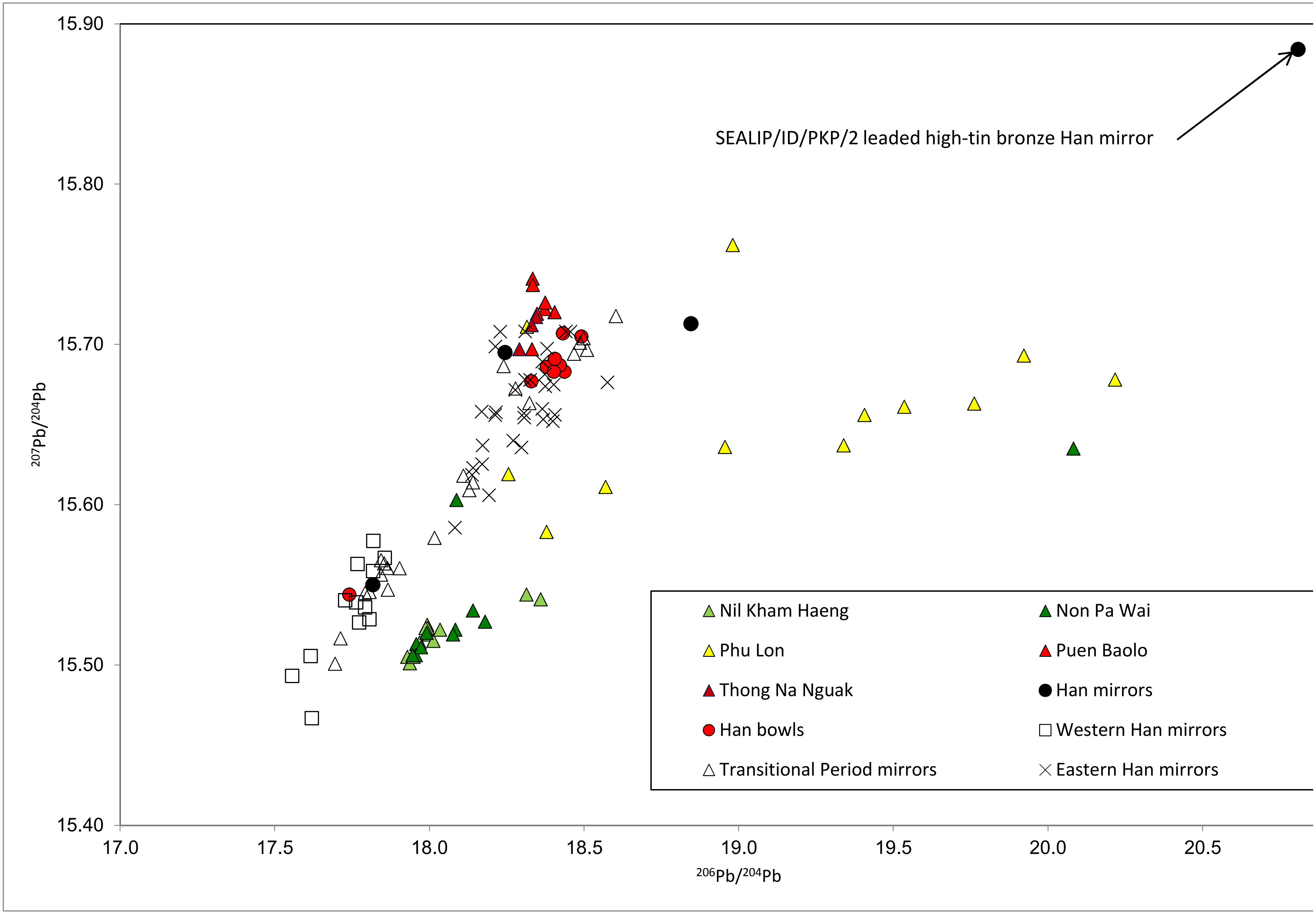
$^{207}Pb/^{204}Pb$
$^{206}Pb/^{204}Pb$


15.90
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15.40
$^{207}Pb/^{204}Pb$
17.0
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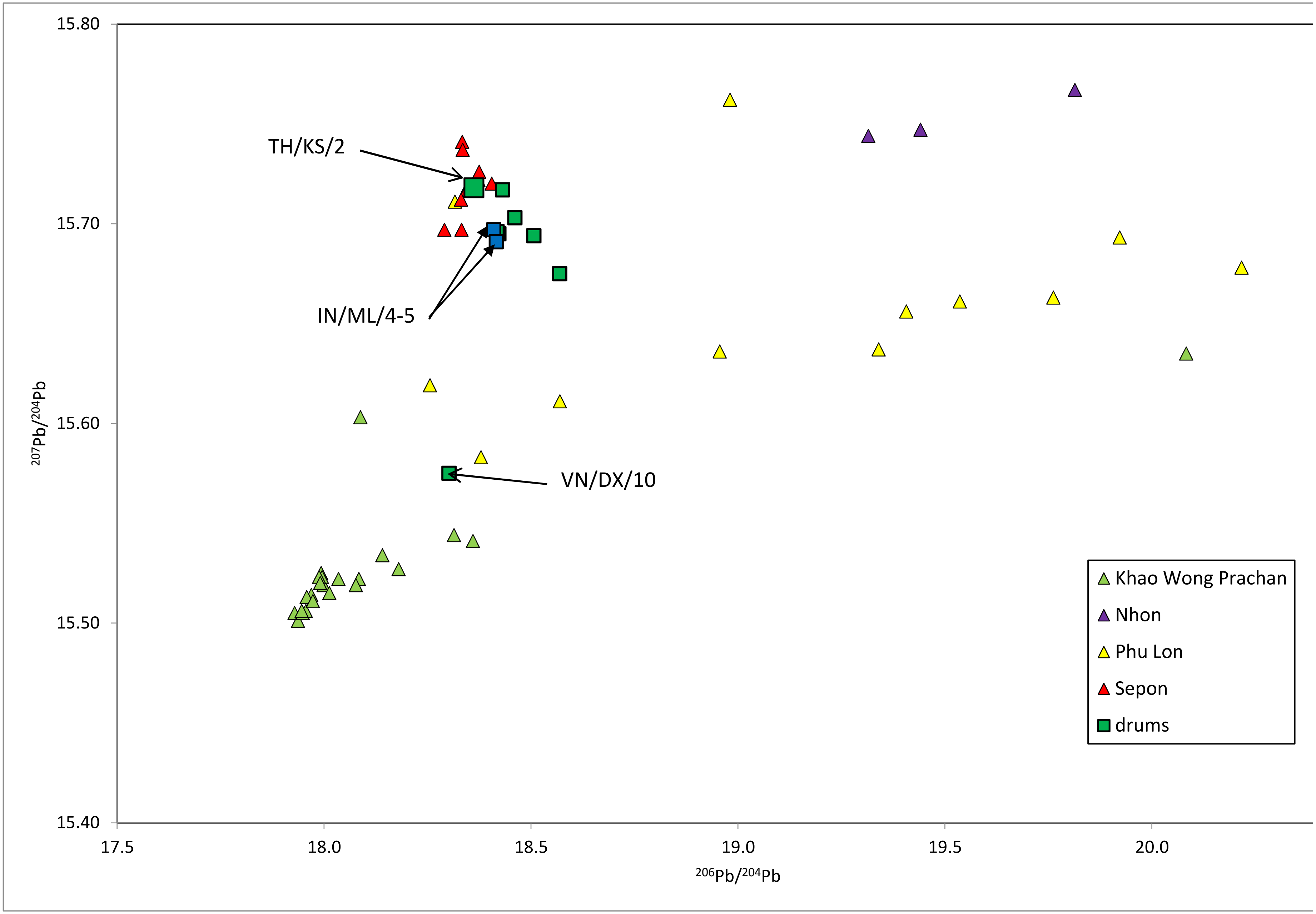
19.0
19.5
20.0
20.5
$^{206}Pb/^{204}Pb$
SEALIP/ID/PKP/2 leaded high-tin bronze Han mirror
Nil Kham Haeng
Non Pa Wai
Phu Lon
Puen Baolo
Thong Na Nguak
Han mirrors
Han bowls
Western Han mirrors
Transitional Period mirrors
Eastern Han mirrors


15.80
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15.60
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15.40
$^{207}Pb/^{204}Pb$
17.5
18.0
18.5
19.0
19.5
20.0
$^{206}Pb/^{204}Pb$
TH/KS/2
IN/ML/4-5
VN/DX/10
Khao Wong Prachan
Nhon
Phu Lon
Sepon
drums

Micrograph mosaic of drum mantle, SEALIP/ID/ML/5, showing complete cut through the shoulder at 50 x magnification and detail of the 'joint' at 100 and 200 x magnification. The consistent grain size either side shows the 'joint' to be a crack or fissure.

209x158mm (150 x 150 DPI)