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Separation or integration? Further insights from a study on chemical datasets of ancient bronze drums from South and Southeast Guangxi, China

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Abstract

Bronze drums of Types Beiliu and Lingshan, two of the eight types of bronze drums in China, represent the highest level of bronze industry in Guangxi during the Han and Tang dynasties. Because of their distinctive ethnic features and generous size, they have received significant attention. Through the study of 12 drums of Type Beiliu and 7 drums of Type Lingshan, the provenance of ore sources, ethnic characteristics, and their correlations are further discussed. According to the analysis results, the above two types of bronze drum share some common features in alloying patterns, lead isotope ratios, and trace elements. However, they exhibit differences in decorative traditions. This research concludes that although the above two types of bronze drums belong to different local powers, extensive communication existed regarding the boundary. A complex relationship of integration, separation, and confrontation existed among them, which was typical of ancient ethnic society.

Keywords: Bronze drums, Alloying pattern, Lead isotope, Trace elements, Guangxi

Introduction

Bronze drums are single-headed, body-decorated bronze ware. Originating in central and western Yunnan in the eighth century BC, they widely spread as spiritual, sacrificial, and musical instruments in the provinces of South China (such as Yunnan, Guangxi, Sichuan, Guizhou, Guangdong, Hainan, and Hunan), as well as Southeast Asia. With the spread of colonialism in the above-mentioned areas in the late nineteenth century, the study of bronze drums emerged in the west. Especially before World War II, western scholars conducted significant research [1–4] and bronze drums remain a hot research topic in the field of archaeology and heritage [5–11]. In China, ancient bronze drums are divided into eight types, each named after their respective excavation locations. Among them, Type Beiliu (Type BL) and Type Lingshan (Type LS) are mainly distributed in Southeast and South Guangxi province; 107 and 99 specimens, respectively, have been found, all with a diameter of over 50 cm. Type BL drums were also discovered in Southwest Guangdong province, along the Yunkai Mountain, and in Hainan Province. With a diameter of 165 cm and a weight of 299 kg, the no.101 Type BL bronze drum with cloud and thunder patterns, preserved at the Anthropology Museum of Guangxi, is the largest ancient bronze drum discovered thus far. With their immense form and elaborate decorations, Types BL and LS drums occupy a prominent place in the bronze drum family. In addition, the wall of the drums' cylinder is very thin; the thinnest of which is no more than 0.3 mm. Existing studies have suggested that they were cast from complex clay molds. In most cases, a fan-shaped pattern, which conforms to the diffusion rule of sound waves for the sake of a sonorous

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tum, appears on the reverse side of the drumhead. It is no exaggeration to say that they represent the top rank of the bronze manufacturing industry in Guangxi during the Han and Tang dynasties [12].

Large size, elaborate decorations, complicated casting technology, and copious quantities have brought Types BL and LS drums widespread attention in terms of ethnicity, typology, chronology, and casting technology. However, both types were discovered by accident and, thus, lacked scientific excavation. Therefore, almost all the above issues remain a mystery. Chronology was established using a few accompanying wares occasionally found with the drums. For example, fragments of pottery with yellow glaze can be traced back from the Eastern Han to the Western Jin Period. In addition, the decorative motifs of cloud and thunder patterns were discovered in the tombs assigned to the Southern Dynasties. The Wuzhu coin pattern (五铢钱 in Chinese, prevailing from the Western Han to the Southern Dynasties) was also discovered on a drumhead. According to these references of archaeological typology, the dates for Types BL and LS drums encompass a long historical period from the Han to the Tang Dynasty (ca. 200BC–800AC) [13]. A wide range of scholars support this conclusion.

The provenance of the above two types of giant bronze drums is of great significance for revealing the casting pot, cast tradition, and circulation of ore resources of ancient bronze industry, as well as for facilitating an in-depth understanding of the political and economic background of contemporary Guangxi. With great progress in lead isotope analysis since the 1990s, the Tongshiling ancient copper mine in Beiliu City was identified as a copper source for bronze drum casting, especially for Type BL [14]. In addition, lead isotope implies the possibility of other ore sources, thus, the above questions broached by researchers cannot be resolved. Not to mention that the disputes and doubts about lead isotopes have not yet ended, because their determination and interpretation requires a certain degree of caution [15–18]. Compared to finding the exact origin of the ore source, it is more imperative to clarify the relationship between Types BL and LS, which is crucial for understanding the entire system of the ancient bronze industry in Guangxi, Southwest China.

Thus, a novel method combined with new chemical data should be developed to re-valuate the published data on Types BL and LS drums to conduct a further investigation on the above issues. Trace element analysis is an effective assistant method as it preserves some chemical information from its ores [19–21]. Although the main purpose of the trace element method is to exclude possible sources under consideration, it can sometimes distinguish sources of isotopic overlap [22]. During the research process in the past few years in China, the trace element analysis method has been applied to ascertain the provenance of ancient bronze [23].

In addition to comparing the LI ratios and chemical composition, it is also important to assess the provenance hypothesis against archaeological and archeometallurgical information from the region of interest [24–27]. Consequently, the following question arises: why are Types BL and LS selected as the research examples out of eight types of bronze drums? Southeast and South Guangxi comprise the areas where the Central Plains culture was first developed and influenced. During the prosperous period of these two types of bronze drums, the local separatist powers of big clans managed these regions. According to existing studies [14, 28], Types BL and LS drums most likely share the same ore source and similar immense form, but exhibit different or diverse decorations. Can the two types of drums be attributed to different local powers? Do they originate from the same ore source for certain? This study aims to conduct a further investigation on the above enticing questions. Therefore, the objective of this study is to characterize these two types of drums and further discuss their relationship through chemical, isotopic, or typological means, rather than establish a hypothesis of the exact or broader provenance regions (Figs. 1, 2).

Materials and methods

Sample information

All bronze drum samples collected in this study originate from the 2014 Bronze Drum Investigation Program of Guangxi. A total of 12 samples of Type BL were obtained from 11 drums (samples TG-54 and TG-55 are from the same drum), and 7 samples of Type LS from 6 drums (samples TG-7 and TG-8 are from the same drum). The samples were collected from museums or cultural heritage conservation institutes in counties in Southeast and South Guangxi, such as Pingnan, Guiping, Tengxian, Cangwu, Rongxian, Beiliu, Yulin, Luchuan, Qinzhou, Beihai, and Nanning (Additional file 1: Table S1). It should be noted that the two samples of the same drum can definitively identify the provenance of the cast shims and the drum body, as TG-54 and TG-7 are shims from the drums of Types BL and LS, respectively. Based on the analysis results of chemical composition, lead isotope, and trace elements, very few distinctions were evident between the samples of shims and drum bodies (Fig. 3).

Analytical methods

Alloying elements

Every sample was divided into two pieces in the laboratory. Of these, one was cold-mounted in epoxy and then polished with a 1 mμ polishing paste for metallographic

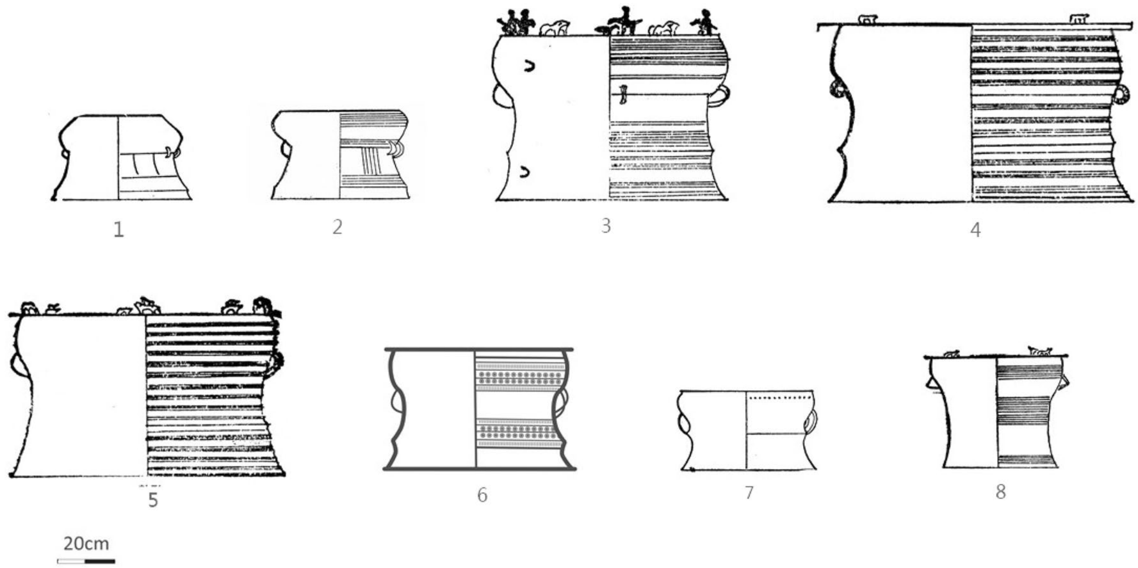

Fig. 1 Sketch of the eight types of bronze drums named after their excavation locations in China. 4. Type Beiliu (Type BL) and 5. Type Lingshan (Type LS) are analyzed in this article. The other types are 1. Type Wanjiaba; 2. Type Shizhaishan; 3. Type Lengshuichong; 6. Type Zunyi; 7. Type Majiang; and 8. Type Ximeng

inspection and compositional analysis. The other piece was for trace element and lead isotope analysis. Under the operating conditions of an accelerating voltage of 20 kv, working distance of 10–15 mm, and acquisition time of 60 s, SEM–EDS was used for component analysis. To ensure the precision and accuracy of the examination, standard samples of pure copper (Series No. 12436, made by Micro-Analysis Consultants Company, Britain) were used for the system factor calibration before the analysis, and seven pieces of tin–lead bronze alloys made by the Getty Research Institute were tested. The experimental results show that the accuracy of the detection of the composition of Cu and Sn was stable, and the relative error was less than 10%. To reduce the error caused by sample heterogeneity, five to seven micro areas were analyzed in the respective sample under different magnification powers in the laboratory of the Institute of Cultural Heritage and History of Science & Technology, University of Science & Technology Beijing, to obtain the average value of the above-mentioned micro areas as the quantitative value of the sample.

Trace elements

The analysis was conducted at the School of Archaeology and Museology, Peking University in Beijing. All samples were strictly subjected to surface rust removal treatment until the metal matrix was exposed. After washing, they were weighed using an electronic balance and recorded, then added to a certain volume of HCl and HNO_3 and completely dissolved using heat. Subsequently, the fixed volume of the dissolved sample was transferred to a 100 ml volumetric flask and shaken well before being tested by an inductive couple plasma-atomic emission spectrometer (ICP-AES; PHD, Leeman Labs Inc, C.A, USA). The experimental conditions were: RF power 1.1 Kw; argon flow rate 20 l/min; atomizer pressure 30 psig, peristaltic pump rate 1.2 ml/min; integration time 30 s/time. The relative error of each of the three tests was below 1%. The standard solution used in the experiment was made from a single national standard solution developed by the General Iron and Steel Research Institute. The final results are shown in Additional file 1: Table S4.

Lead isotope

This analysis was conducted at the School of Archaeology and Museology, Peking University in Beijing. Initially, the sample pieces were polished to remove rust and subsequently dissolved in 6 ml of HCL and 2 ml of HNO_3. Then, the leached solution was diluted to 20 ml with deionized water. An inductively coupled plasma-atomic emission spectrometer (ICP-AES; PHD, Leeman Labs Inc, C.A, USA) was employed to detect lead content and trace elements in the solution. Subsequently, the respective solution was diluted with deionized water again to 500 ppb and Tl Standard SRM997 was added to it. Lead isotope analysis was performed by MC-ICP-MS (Type: VG Elemental) in the laboratory of the School of

Earth and Space Sciences. Through the repeated analysis of SRM981, the overall analytical 2-σ error of all lead isotope ratios was recorded to be less than 0.06%. The results are shown in Additional file 1: Table S2.

Results

According to published data, more than 95% of ancient bronze drums were copper-based ternary alloys, and very few were pure-Cu. Various other elements (such as Sb, As, or Fe) were detected in the alloy [29] with content exceeding 1 wt.%. SEM–EDS analysis determined that the main alloying elements of all samples of Types BL and LS were Cu, Sn, and Pb, exhibiting the alloying tendency of higher Pb and lower Sn (Fig. 4). The alloying features of the above two types were slightly different. In more detail, Type BL exhibited a higher Pb content of 15.5 wt.%, while Type LS exhibited a 9.9 wt.% Pb content on average. The Sn and Cu contents of Type LS were higher, averaging 9.6 wt.% and 78.4 wt.%, respectively, while those of Type BL were 8.3 wt.% and 73.1 wt.%, respectively, as obtained by the statistics of the published data. Because the samples of bronze drums originated from two different areas in Southern and Southeastern Guangxi, this diversity of alloying trends can also be considered as an inter-regional diversity (Fig. 5). Of course, the quantities of bronze drum samples in this article are not sufficient to characterize the alloying features of the entire assemblage of Types BL and LS drums, which needs to be further discussed on the basis of more alloying pattern data.

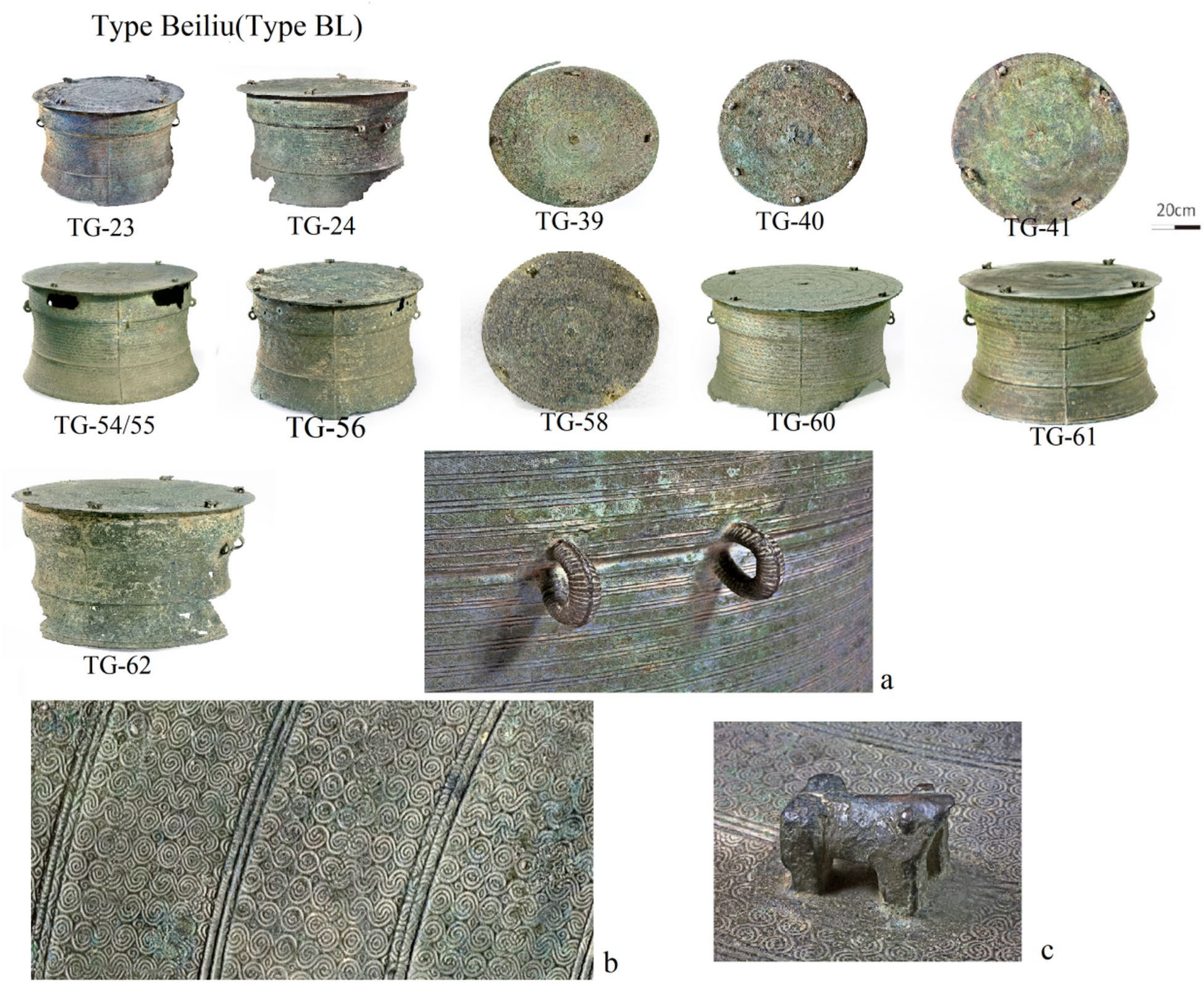

Fig. 2 Pictures of the samples from Types BL and LS drums. 12 samples of Type BL from 11 drums are TG-23, D 68.4–75.8 cm; TG-24, D 86–92.7 cm; TG-39, D 83–87.7 cm; TG-40, D 62.4–91 cm; TG-41, D87–89 cm; TG-54/55, D 88.5–93.9 cm; TG-56, D 86.3–93.3 cm; TG-58, D 69 cm; TG-60, D 63.4–72 cm; TG-61, D 63–67.2 cm; and TG-62, D 66–73 cm. 7 samples of Type LS from 6 drums are TG-7/8, D 78–79; TG-10, D 80–81 cm; TG-11, D 62.1–72.8 cm; TG-12, D 117–120CM; TG-44, D 76.4–90.8 cm; and TG-52, D 64.3–73.6 cm

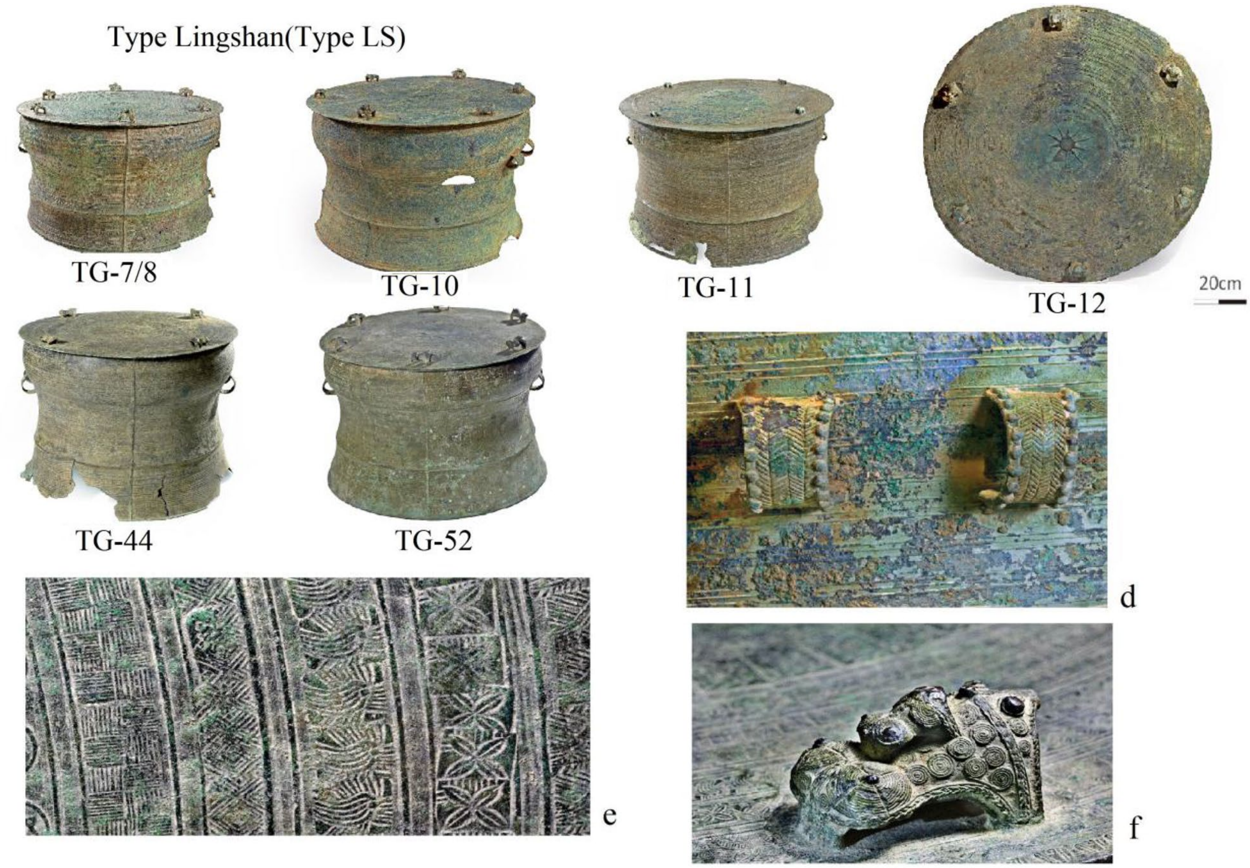

Fig. 2 continued

The 19 samples of bronze drums demonstrate a good linear distribution on the scatter plots (Fig. 6a, b). To avoid possible bias due to the small number of samples, new samples were compared with the published data (Additional file 1: Table S3) of 33 samples from Types BL and LS (Fig. 6c, d). Type LS still exhibited a good linear distribution and a close correlation with Type BL, which had a larger coverage. Ratios of most samples were within a range of $^{206}Pb/^{204}Pb$: 18.3–18.7, $^{207}Pb/^{204}Pb$: 15.4–15.8, and $^{208}Pb/^{204}Pb$: 38.25–39.25. Because all samples had lead concentrations over 1 wt.%, all ratio data was regarded as the indicator of lead or leaded deposits, and lead–zinc deposits were usually of those in Guangxi. The proportion of lead–zinc ores from Southeast, South, and northwest of Guangxi were introduced into the scatter plot and compared with the bronze drums. It was determined that the ore sources from Southeast and South Guangxi highly corresponded to Types BL and LS drums excavated intensively in the above two regions (Fig. 8). Although the ratios of lead–zinc deposits from northwest Guangxi were within the range of $^{206}Pb/^{204}Pb$: 17.5–18.6, $^{207}Pb/^{204}Pb$: 14.9–15.7, and $^{208}Pb/^{204}Pb$: 38–39.2, which were also the range of most ores and bronze drums from southeast and South Guangxi, no significant overlap was evident between the NW deposits and the drums analyzed in this article.

Arsenic (As), antimony (Sb), silver (Ag), and nickel (Ni) are the four most common trace elements that are relevant to the ore source, which tend to be either present or absent in the ores that have been employed in antiquity. The Oxford Group Bray and Pollard conducted a series of studies on the presence/absence classification system based on the above four elements [30–32] and classified them into 16 copper groups based on the content of each element: > 0.1% (presence), or < 0.1% (absent), arguing that this approach presents the full potential of the chemical space that these elements afford [33]. Moreover, it is shown to be equally applicable to any set of analytical data for copper alloys regardless of region and time period [34–40]. Characterization, rather than provenance of archaeological alloys, is the most important reason for the choice of analytical method in our paper, although there seems to be much controversy over the choice of elements and their fixed threshold of 0.1 wt.% [16, 18].

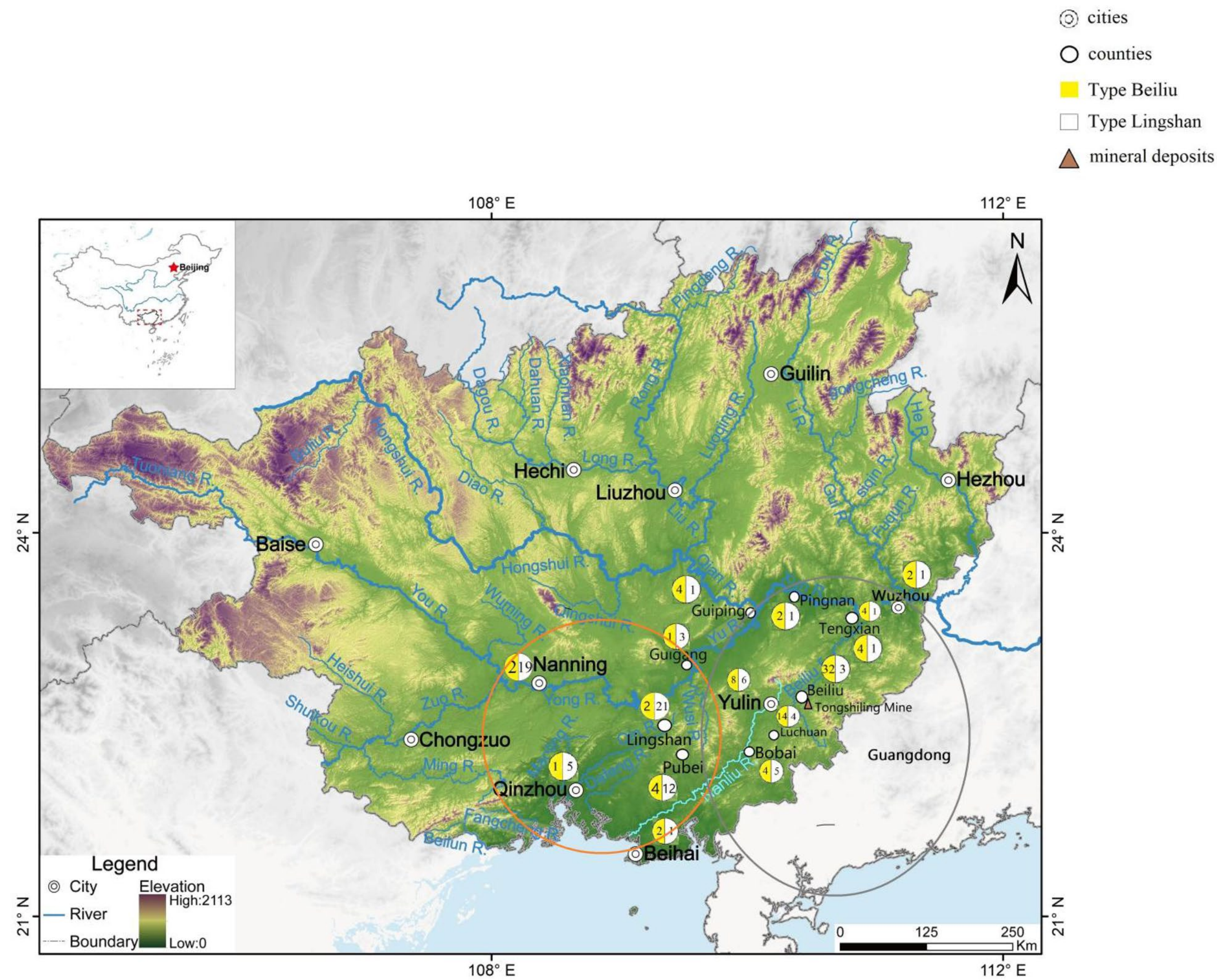

Fig. 3 Distribution of Types BL and LS drums in Guangxi. Type LS drums are mainly distributed in the districts inside the orange ring in south Guangxi and centered in Lingshan county. Type BL drums are mainly distributed in the districts inside the gray circle in southeast Guangxi and southwest Guangdong

Trace elements of Types BL and LS drums have distinct characteristics of containing high content of Sb and Ag (Fig. 7), with a highest content of 4.43 wt.% Sb and 1.84 wt.% Ag of samples TG-40 and TG-61, respectively (both of which are Type BL from Southeast Guangxi). The content of As is lower than that of Sb and Ag, and Ni is absent in all samples. Sample TG-11 (Type LS from South Guangxi) exhibits an unusual feature of far lower content of 0.1 wt.% of every trace element except Fe (0.44wt%). In accordance with the classification method of Bray, except sample TG-11 which presents a feature with all eight elements detected below 0.1 wt.% (CG 1, None), the total samples from both types can be classified into two copper groups: CG6 (As + Sb) and CG7 (Sb + Ag) (Table 1). All three drums in CG6 are Type BL, and the other samples are all in CG7, including nine of Type BL and six of Type LS. This classification is consistent with the results of the lead isotope ratio analysis that a close correlation exists between the ore sources of Types BL and LS. Therefore, it can be inferred that they may share the same ore sources. In addition, Type BL might have exploited more ore deposits during the same period.

Discussion

Alloying patterns

As revealed by the results of the chemical composition analysis of Types BL and LS drums, an inherent tendency of copper-based lead–tin combination was evident during the alloying process. The contents of both lead and tin in all samples are > 2% whereas more

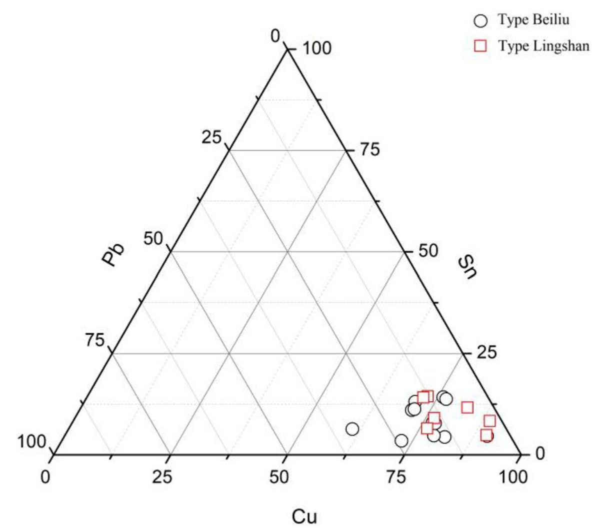

Fig. 4 The triangle figure of alloy compositions of Types BL and LS drums

than 70% of samples are >7%, indicating that they were deliberately added for the purpose of casting ternary bronze. The alloying ratios are the result of the accumulation of craftsmen's experiences [29]. Both types are all leaded tin cast bronzes with similar but slightly different Pb–Sn composition ratios (the average contents of Type BL are Cu73.1 wt.%, Sn 8.3 wt.%, Pb 15.5 wt.%, n = 29; The average contents of Type LS are Cu 78.4 wt.%, Sn 9.6 wt.%, Pb 9.9 wt.%, n = 23). As revealed by their differences in motifs and statue decoration, as well as in size and form, two casting and aesthetic traditions were identified for Types BL and LS, respectively. As shown in Fig. 2, the prevailing patterns on Type BL drums are thunder and cloud motifs (double squares and spircles), always with four clumsy four-legged frogs decorated on the corner of the drumhead. Nevertheless, the patterns on Type LS drums are more elaborate and diverse (such as birds, animals, equestrians, flowers, and various geometric patterns), with six or eight plumper and larger three-legged frogs situated anticlockwise on the drum face.

In accordance with Chinese historical records, from the Han to the Tang dynasty, especially the Wei, Jin, Southern, and Northern Dynasties (3 c.AC–6 c.AC), ethnic groups of the Li (俚) and Liao (僚) people (a joint name of ethnic groups), living in Lingnan (岭南) (including provinces of Guangxi, Guangdong, Hainan, and northern Vietnam at that time) were the owners and casters of giant bronze drums. These records are supported by accompanying objects occasionally found with Types BL and LS drums. Existing ethnic studies conducted in-depth investigations on the two large clans of Feng and Ning. It is believed that Clan Feng, who managed western Guangdong and Southeastern Guangxi, owned the Type BL bronze drums, while Clan Ning, who occupied Southern Guangxi, owned the Type LS bronze drums [13]. Accordingly, the casting alloys are similar but slightly different, with similar forms but different decorative traditions. It can be considered that Types BL and LS drums belonged to two local powers in Southeastern and Southern Guangxi, as well as southwestern Guangdong, for centuries.

The distribution centers can be easily deduced from the names of Types BL and LS. Type BL is named after Beiliu City, where 32 bronze drums of this type were excavated in Southeast Guangxi, and Type LS is named after Lingshan County in South Guangxi, where 21 drums of this type were excavated (Fig. 3). However, the traditional junction area of the above two types of bronze drums can be determined based on the number of unearthed and decorative styles in each administrative area. The spheres of effect of Types BL and LS are divided by the Nanliu River, the upper portion of which, called the Beiliu River, runs through Beiliu City.

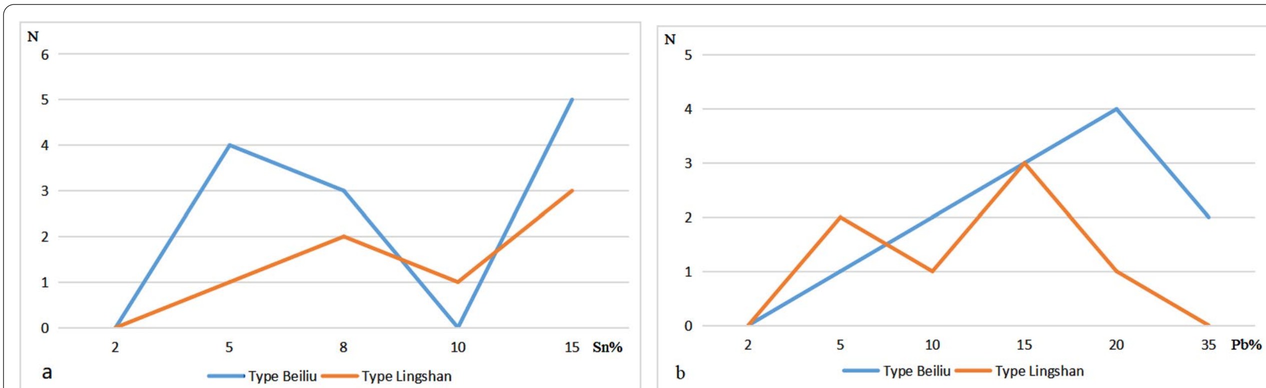

Fig. 5 Diagram of different Sn and Pb concentrations in samples of Types BL and LS drums

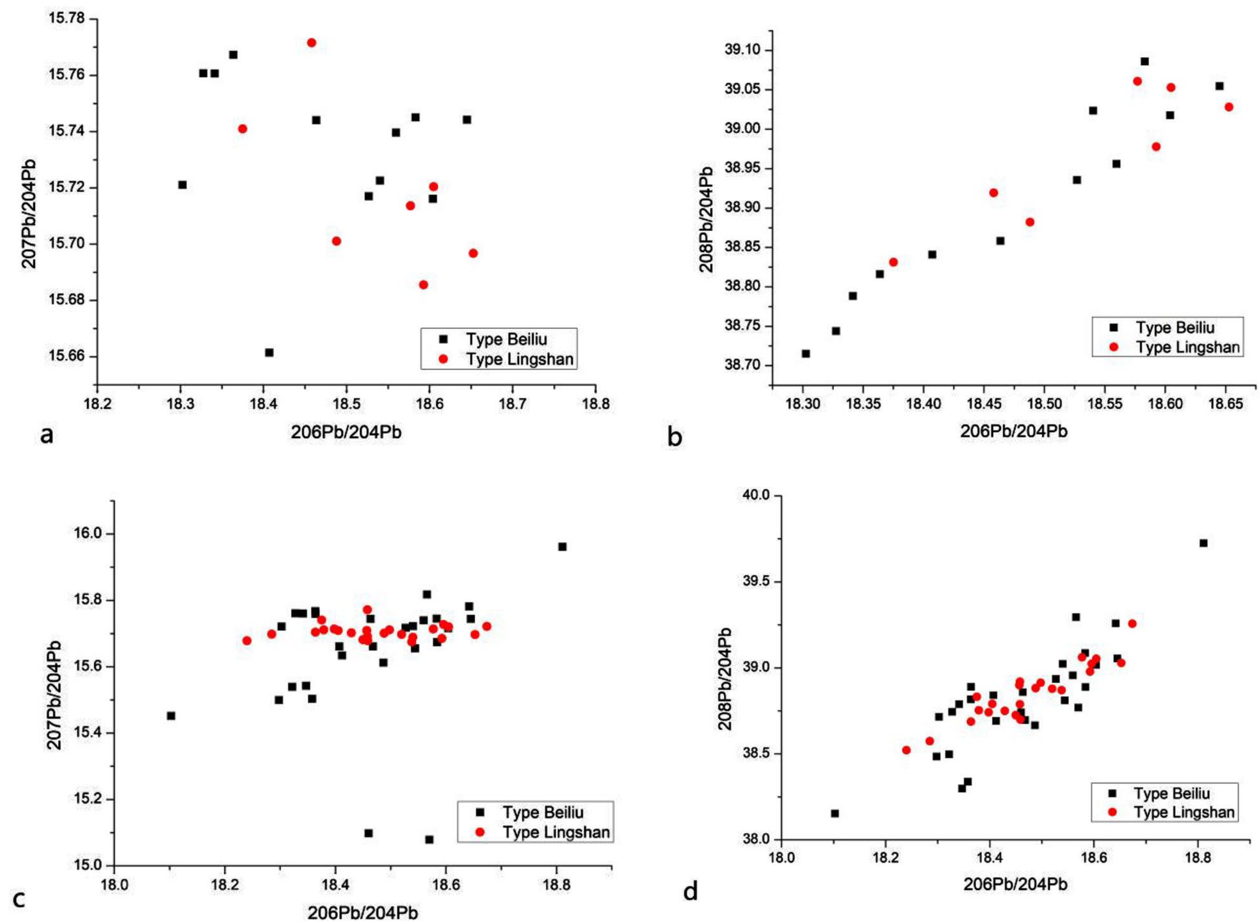

Fig. 6 Plots of lead isotopic ratios of samples of Types BL and LS drums. **a**, **b** data of the 19 new samples in this article (Additional file 1: Table S2); **c**, **d** new and published data (Additional file 1: Table S3)

Drums of multiple styles of the above two types are found on the east bank of the Nanliu River (e.g., Yulin and Bobai), with some popular motifs and flat drum ears that were usually decorated on Type LS being found on Type BL. Moreover, the quantities of Types BL and LS drums unearthed in Yulin and Bobai are close to 50%:50%, which is consistent with the quantities in Hepu and Beihai in the downstream area of the Nanliu River, South Guangxi. Pubei county, located on the west bank of the Nanliu River, may be on the sphere rim of the effect of Type BL as five drums were found there, accounting for 31% of the sum (Fig. 3). Research indicates that along the Nanliu River, two traditional exchanges of bronze drums occurred, suggesting the existence of two local powers, namely, the holders of Types BL and LS drums.

Lead isotope

As depicted in Fig. 6, whether it is a scatter plot of ^{206}Pb/^{204}Pb versus ^{207}Pb/^{204}Pb or ^{208}Pb/^{204}Pb, lead isotope ratios of Type LS are within the range of Type BL. Furthermore, significant overlap exists, indicating a close correlation between the above two types, especially when a bigger quantity of samples was considered (Fig. 6c, d).

By analyzing the LI ratios of lead–zinc deposits in Guangxi, the correlations of ore sources and bronze drums were directly observed. Lead–zinc deposits from Southeast and South Guangxi have distinct overlap with Types BL and LS drums, indicating a close relationship between the ores and drums. Interestingly, for specific individual samples of ore and drums, the correlation between each drum type and its ore sources is easily drawn. For instance, in Fig. 8a, sample TG-44, a drum

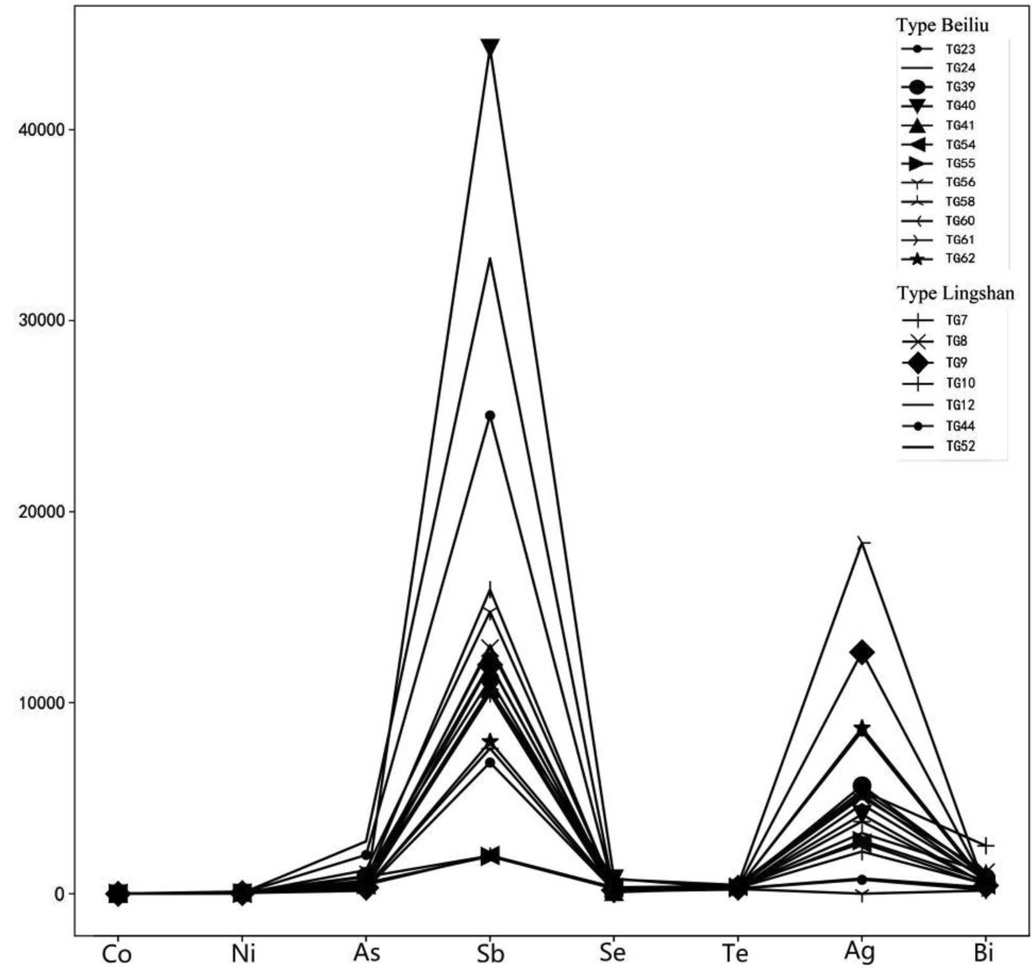

Fig. 7 Curve of trace element content in samples of Types BL and LS drums

Table 1 Distribution of copper groups for the samples of Types BL and LS drums (for definition of copper groups see [33])

Type	CG1 (None)	CG6 (As + Sb)	CG7 (Sb + Ag)
Beiliu	0	3 (TG-23/24/56)	9 (TG-39/40/41/54/55/58/60/61/62)
Lingshan	1 (TG-11)	0	6 (TG-7/8/10/12/44/52)

of Type LS excavated in Nanning, south Guangxi seems to be using the ore source from its deposition area. Furthermore, deposits and source locations are not always aligned, which may reveal more information about social resource flows. For example, samples TG-41, TG-56, and TG-60 of Type BL excavated in Southeast Guangxi share the ore sources from Hengxian, Yongning, and Fusui in South Guangxi. Among them, samples TG-61 (Type BL) and TG-11 (Type LS) share the ores from Gui county in the Southeast, while TG-58 (Type BL) and TG-8 (Type LS) share the ores from Pubei county in the South (Fig. 8).

The above information expresses that territorial restrictions of mining were not as strict as speculated. The exchange of ore resources between Southeast and South Guangxi was frequent. Moreover, based on the discussion on the aforementioned alloying patterns, Types BL and LS might have co-existed for an extended period. Except for mineral exchanging and communicating, the principle of proximity was primary when working with mineral sources. For the highly developed copper drum casting alloying technology, purposeful and targeted exchange was not excluded.

It is worth noting that the above lead isotope analysis suggests that many ore sources of Type BL drums derived from Yulin, Guigang, and Wuzhou of Southeast Guangxi as well as from Naning, Qinzhou of South Guangxi. Due to the abundant mineral resources in Guangxi, no lack

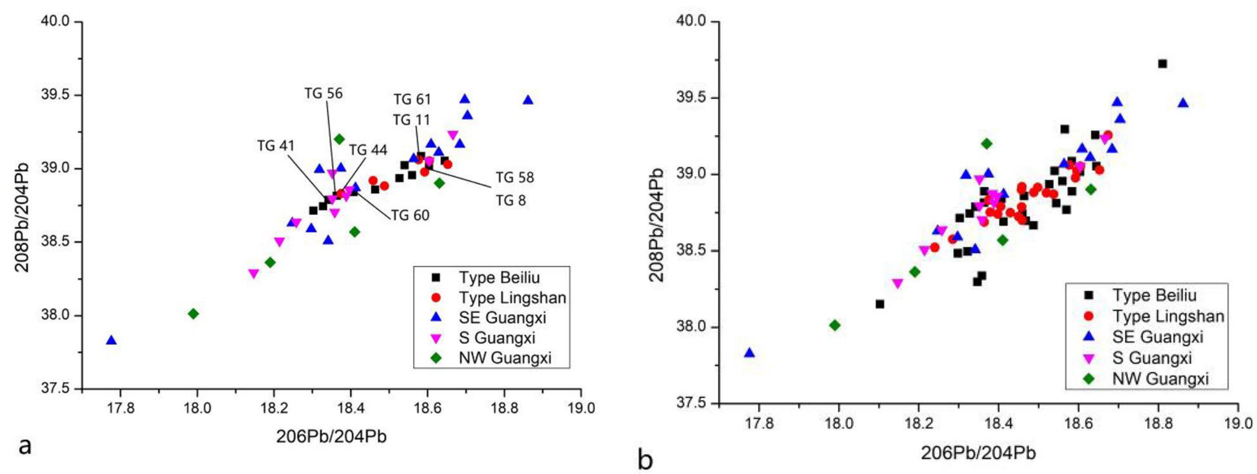

Fig. 8 Plots of lead isotopic ratios of Types BL and LS drums compared with the published data [14] of lead–zinc deposits in southeast, south, and northwest Guangxi (the blue, pink, and green symbols, respectively). **a** Data of the 19 new samples of bronze drums in this article (Additional file 1: Table S2); **b** New and published data of bronze drums (Additional file 1: Table S3)

of polymetallic deposits were found in the areas where they intensively excavated and employed bronze drums. In most cases, the scale of the polymetallic deposits deeply affected the cast scale of bronze drums. That is to say, the more sizable the deposit, the more drums may be present, and vice versa. It is now certain that the above mentioned giant bronze drums were manufactured based on the local ore sources largely in accordance with the principle of proximity. Distance and transportation costs were more important to the makers and owners of bronze drums. Accordingly, it is unlikely that the above giant bronzes were imported from outer Guangxi. Also, no records have been found indicating a drum trade or exchange for a large quantity, nor have signs of the origin of the giant bronzes been identified in other areas.

Interestingly, lead isotope ratios of Type BL drums span a larger range from 18.3–18.7 for $^{206}Pb/^{204}Pb$, 15.6–15.8 for $^{207}Pb/^{204}Pb$, and 38.7–39.1 for $^{208}Pb/^{204}Pb$, versus those of Type LS drums of $^{206}Pb/^{204}Pb$: 18.3–18.7, $^{207}Pb/^{204}Pb$: 15.7–15.8, and $^{208}Pb/^{204}Pb$: 38.8–39.1. Thus, more ore deposits might have been employed to cast Type BL drums, for their larger unearthed quantity than Type LS, or because Type BL has existed for a longer time. Over 300 drums of Types BL and LS drums (166 and 136, respectively) have been unearthed in China thus far, the former with a slightly larger quantity than the latter in the areas pertaining to ancient Lingnan. The effect of Type LS is weaker in the areas further away from its distribution center, South Guangxi, for the unearthed number compared to Type BL is 99:107 in Guangxi, 18:43 in Guangdong, and 2:6 in Hainan province. Therefore, concluding that Types LS and BL were manufactured by the chief powers of Clan Ning and Clan Feng managed in South, Southeast Guangxi, and Southwest Guangdong from early 6c.AC–8c.AC are reasonable to some extent. However, it is clear that local clans were not the inventors of the above types of bronze drums, for they had been seen in the historical records earlier before the Clans of Ning and Feng emerged. Perhaps Type BL existed for a longer time (from the mid-Western Han, but Type LS from the Eastern Han, according to archaeological typology and the associated objects), or simply because Clan Feng had a larger territorial extent than Clan Ning.

Trace elements

When the basic composition and alloy elements are highly consistent, the features of trace elements become an important reference index for distinguishing mineral sources. Trace elements of Types BL and LS drums have a significantly higher content of Sb and Ag, for which the content of the former is generally higher than that of the latter (Fig. 7).

When classifying all trace elements of the sample according to the copper group method, the homogeneity of Types BL and LS is more distinct. Fifteen of 19 samples are classified as CG7(Sb + Ag), three samples of Type BL are identified as CG6(As + Sb), and one sample of Type LS is attributed to CG1(None). The high amounts of Sb in the entire assemblage of samples are distinct from 1956–44,262 μg/g, with 13,484 μg/g on average. Ag is the second highest of elements, with amounts from 738–18,371 μg/g, with 5131 μg/g on average, and As is the third from 115–2740 μg/g, with 754 μg/g on average (Additional file 1: Table S4).

Guangxi has rich and widespread polymetallic deposits of lead, zinc, and antimony, yielding approximately 40% of antimony production in China. Therefore, the trace element characteristics of high concentrations of Sb and Ag provide additional evidence for the adjacent mining principle of copper drum casting. For example, a Dachongkeng deposit of Ag-Pb–Zn and Si'de deposit of Cu-Pb–Zn in Guiping are characterized by associated minerals of Ag and Sb [41]. Guiping is located at the delta where the three rivers of Yu, Qian, and Xun meet. It extends to Nanning and Baise in the west, Qinzhou, Beihai, and Fangchenggang in the South, Hechi in the north, and Wuzhou in the east. Moreover, it is connected to Guigang and Yulin by water transportation. Minerals exploited from the Qian-Xun-Yu River Basin can be delivered conveniently and efficiently to each district of Guangxi, especially to the Southeast and South through the complex river system.

By introducing the sociological analysis method of SPSS (Statistical Product Service Solutions), factor analysis of trace elements was conducted. With eight elements of different concentrations as variables for each sample, the correlation between them can be visually observed when all samples with different element characteristics are analyzed in a scatter plot. The analysis demonstrated that the correlation between the samples of Types BL and LS drums are presenting clusters on the plot (Fig. 9), corresponding to the different areas of the distribution of these two types. However, the boundary is not so absolute, as several samples mix in the other cluster, demonstrating that these two types of drums had both their own ore sources and shared sources.

Conclusion

Bronze drums remain a hot and enticing research topic in archaeological bronze studies, as many issues such as their transformation, propagation paths, and chronological order are still unknown. Using the analysis method of alloying composition, lead isotope, and trace elements, as well as typology and archaeological social background, this study investigates 19 samples from Types BL and LS bronze drums.

The results suggest that Types BL and LS share a similar but slightly different alloying pattern of copper-based and Cu-Sn–Pb ternary alloy. Through a comparison of decorative traditions, it can be easily deduced that the above two types of bronze drums belong to the same bronze casting tradition, but with their own choices in alloying techniques and aesthetics, suggesting that they likely belonged to two local powers occupying Southeast

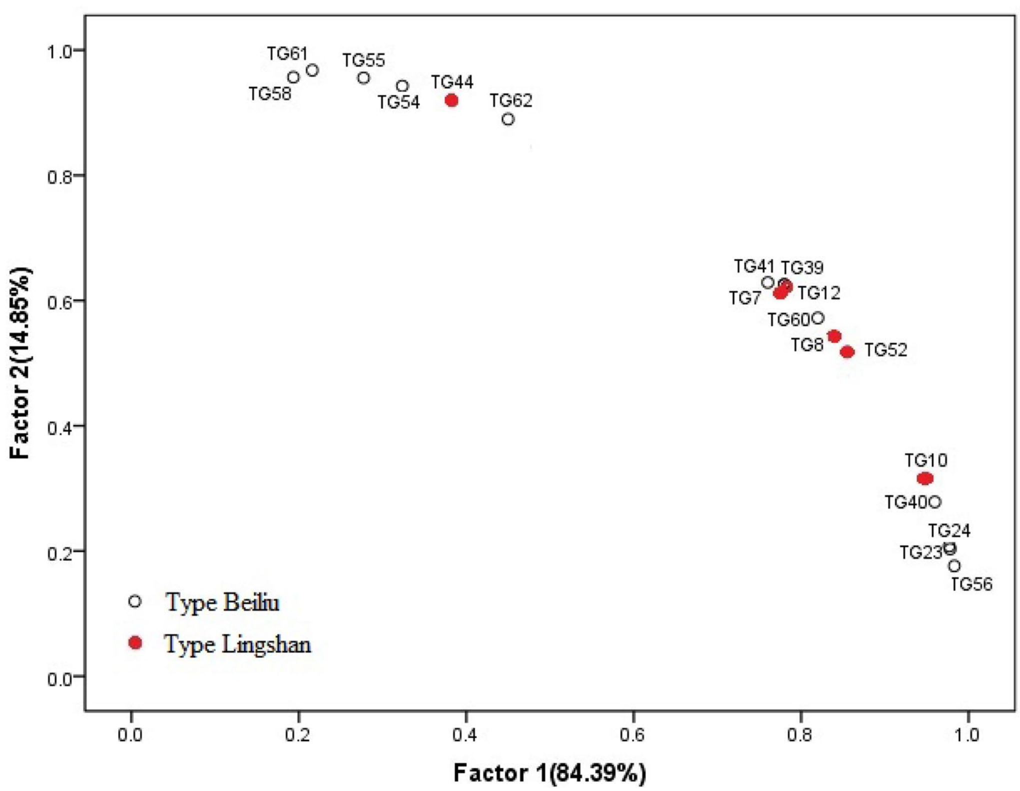

Fig. 9 Scatter plot of factor analysis of trace elements of Types BL and LS drums

and South Guangxi bounded by the Nanliu River. Significant overlap of LI ratios between Types BL and LS implies they might be cast of the same or similar ore sources. Thus, it is evident that the principle of proximity of mineral mining is not the only rule. The goal was to obtain the required bronze minerals through exchange or communication. Analysis on trace elements in this study completely support this conclusion, due to the high content of Sb and Ag of trace elements, and most of the samples share the same copper group (CG 7, Sb+Ag).

Clarification of what happened between the production and deposition of the bronze drums could reveal more about the societies and more comprehensively reflect past realities. This study raised the following question: How could the giant bronze drums of Types BL and LS be extensively cast and employed in Southeast and South of Guangxi? The reason may be that the Southeast area was one of the earliest developed regions of Guangxi after the Xiao-He Ancient Road was constructed to connect the north of the Five Ridges during the Qin Dynasty (3c. BC). Twenty-four copper deposits are distributed in the districts (such as Guigang, Pingnan, Guiping, Rongxian, Luchuan, Bobai, and Xingye), including the Tongshiling ancient copper mine in Beiliu. At the same time, deposits in Southern Guangxi were also exploited. Accordingly, the extensive exchange and communication of minerals existed among the different spheres of local ethnic chieftains. Local people exploited these deposits for a long time, using only pre-industrial mining methods. Historical records of the casting and use of giant bronze drums by the Li and Liao peoples frequently appeared in past dynasties' books such as Guangzhou Ji (广州记), Taiping Huanyuji (太平寰宇记), and Lingbiao Luyi (岭表录异).

The above analyses reveal the fact that although Types BL and LS drums were closely associated with different influences of local power, separation and confrontation were not the mainstream over the long history of ethnic societies. Accordingly, they integrated into larger cultural traditions and developed into different subcultures.

Abbreviations

SEM: Scanning electron microscope; EDS: Energy dispersive spectrometry; ICP: Inductive couple plasma; AES: Atomic emission spectrometer; MS: Mass spectrometry; Type BL: Type Beiliu; Type LS: Type Lingshan.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40494-022-00808-0.

Additional file 1: Table S1. Archaeological and sampling information of bronze drum samples. **Table S2.** Lead isotope and alloying composition of the bronze drum samples. **Table S3.** Published data of lead isotope of the bronze drum samples. **Table S4.** Trace elemental data by ICP-AES of the bronze drum samples (μg g−1).

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Author contributions

LQ: conceptualization, analysis, and drafting the manuscript; ZG: methodology, data collection, and manuscript revision; LY: methodology and manuscript revision; GS: manuscript revision. All authors read and approved the final manuscript.

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Availability of data and materials

Additional file 1 contains details regarding the archaeological and sampling information of bronze drum samples, the chemical compositions by SEM–EDS, the trace elements by ICP-AES, and the lead isotope ratios by MC-ICP-MS.

Declarations

Competing interests

We declare that the authors have no financial or personal relationships with other people or organizations that can inappropriately influence our work. There is no professional or other personal interest of any nature or kind in any product, service, and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

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References

1. Meyer AB, Foy W. Bronyepauken aus Südostasien. New York: Dresden; 1897.
2. Heger F. Alte Metalltrommeln aus SÜdostasien. Leipzig: K. von Hiesemann; 1902.
3. Kirby PR. The kettle-drums: an historical survey. Oxford Univ Press Music Lett. 1928;9(1):34–43.
4. Goloubew V. Recherches de M. Goloubew dans Ankor Thom (Chronique). Bulletin de l'Ecole française d'Extrême-Orient. 1937;37:651–5.
5. Bunker E. The Tien-culture and some aspects of its relation to the Dong Son Culture. In: Barnard N, editor. Early Chinese art and its possible influence into the Pacific basin. New York: Intercultural Arts Press; 1972. p. 291–328.
6. Kempers B. The kettledrums of Southeast Asia: a bronze age world and its aftermath. Rotterdam/Brookfield: A A Balkema Publishers; 1988.
7. Loofs-Wissowa HHE. Dongson drums: instruments of shamanism or regalia? Arts Asiatiues Tome. 1991;46:39–49.
8. Cooler RM. The Karen bronze drums of Burma: types, iconography, manufacture and use. Leiden: E J Brill; 1995.
9. Han XR. Who invented the bronze drum: nationalism, politics, and a sino-Vietnamese archaeological debate of the 1970s and 1980s. Asian Perspect. 2004;43(1):7–33.

10. Calò A. The distribution of bronze drums in early Southeast Asia: trade routes and cultural spheres. Oxford: Archaeo Press; 2009.
11. Calò A. Trails of bronze drums across early Southeast Asia: exchange routes and connected cultural spheres. Singapore: Institute of Southeast Asian Studies Press; 2014.
12. Jiang Y. The casting technology of ancient bronze drums in South China and Southeast Asia 中国西南和东南亚古代铜鼓铸造技术.考古. Kao Gu. 2008;6:85–90.
13. Yao SA, Jiang TY, Wan FB. Discussion on Lingshan type bronze drums论灵山型铜鼓.考古. Kao Gu. 1990;10:929–42.
14. Wan FB. The scientific researches on the ancient bronze drums of China 中国古代铜鼓科学研究. Nanning: Guangxi Nationalities Publishing House; 1992.
15. Pernicka E, Begemann F, Schmitt-Strecker S, Grimanis AP. On the composition and provenance of metal artefacts from Poliochni on Lemnos. Oxf J Archaeol. 1990;9:263–98.
16. Pernicka E. Provenance determination of archaeological metal objects. In: Roberts BW, Thornton CP, editors. Archaeometallurgy in global perspective: methods and syntheses. New York: Springer; 2014. p. 239–68.
17. Stos-Gale ZA. Bronze Age metal sources and the movement of metals between the Aegean and Anatolia. In: Bartelheim M, Horejs B, Krauss R, editors. Von Baden bis Troja, Ressourcennutzung, Metallurgie und Wissenstransfer: Eine Jubiläumsschrift für Ernst Pernicka, Oriental and European Archaeology, vol. 3. Rahden/Westf.: Verlag Marie Leidorf GmbH; 2016. p. 375–98.
18. Radivojevic M, Roberts B, Pernicka E, Stos-Gale Z, Martinón-Torres M, et al. The provenance, use, and circulation of metals in the European bronze age: the state of debate. J Archaeol Res. 2019;27:131–218.
19. Tylecote RF, Boydell PJ. Experiments on copper smelting. In: Rothenberg B, Tylecote RF, Boydell PJ, editors. Chalcolithic copper smelting. London: Institute for Archaeo-Metallurgical Studies; 1978. p. 27–49.
20. Merkel J. Experimental reconstruction of Bronze Age copper smelting based on archaeological evidence from Timna. In: Rothenberg B, editor. The ancient metallurgy of copper: archaeology. London: Experiment, Theory, Institute for Archaeo-Metallurgical Studies and UCL Institute of Archaeology; 1990. p. 78–122.
21. Pernicka E. Trace element fingerprinting of ancient copper: a guide to technology or provenance? In: Young SMM, Pollard AM, Budd P, Ixer RA, editors. Metals in Antiquity, BAR International Series 792. Oxford: Archaeo Press; 1999. p. 163–71.
22. Rohl BM, Needham SP. The circulation of metal in the British bronze age: the application of lead isotope analysis, British museum occasional papers 102. London: British Museum; 1998.
23. Wei GF, Qin Y, Yang LX, Zhang GM, Gong CG, et al. Primary study on the exporting route of ancient output copper ores and the smelting output by analysis of the symbolic trace elements若干古铜矿及其冶炼产物输出方向判别标志的初步研究. 考古. Kao Gu. 2009;01:85–95.
24. Pernicka E, Begemann F, Schmitt-Strecker S, Todorova H, Kuleffff I. Prehistoric copper in Bulgaria: its composition and provenance. Eurasia Antiqua. 1997;3:41–180.
25. Hunt Ortiz MA. Prehistoric mining and metallurgy in south west Iberian peninsula. Michigan: University of Michigan Press; 2020.
26. Höppner B, Bartelheim M, Huijsmans M, Krauss R, Martinek KP, Pernicka E, Schwab R. Prehistoric copper production in the Inn Valley (Austria), and the earliest copper in Central Europe. Archaeometry. 2005;47:293–315.
27. Artioli G, Angelini I, Nimis P, Villa IM. A lead-isotope database of copper ores from the southeastern Alps: a tool for the investigation of prehistoric copper metallurgy. J Archaeol Sci. 2016;75:27–39.
28. Yao SA, Jiang TY, Wan FB. Discussion on Lingshan type bronze drums. Kao Gu (Archaeology). 1990;10:929–42.
29. Lu QY, Zou GS, Li YX, Zheng L, Wang W. Provenance study on 'Big bronze drums': a method to investigate the ancient bronze industry of Guangxi, Southwest China from Han to Tang dynasty (around 200 BC–900 AC). J Cult Herit. 2020;44:15–26.
30. Bray P. J. Exploring the social basis of technology re-analysing regional archaeometric studies of the first copper and tin-bronze use in Britain and Ireland, PhD thesis. University of Oxford; 2009.
31. Bray PJ, Pollard AM. A new interpretative approach to the chemistry of copper-alloy objects: source, recycling and technology. Antiquity. 2012;86:853–67.
32. Pollard AM, Bray PJ. A new method for combining lead isotope and lead abundance data to characterize archaeological copper alloys. Archaeometry. 2015;57:996–1008.
33. Bray PJ, Cueod A, Gosden C, Hommel P, Liu R, Pollard AM. Form and flow: the 'karmic cycle' of copper. J Archaeol Sci. 2015;56:202–9.
34. Bray P. Metal metalwork and specialisation The chemical composition of british bronze age swords in context. In: Koch J, (Editor). Celts from the West III Proceedings of the AEMA Conference, Cardiff; 2016
35. Cuénod A, Bray P, Pollard AM. The "tin problem" in the prehistoric Near East: further insights from a study of chemical datasets on copper alloys from Iran and Mesopotamia. Iran. 2015;53:29–48.
36. Hsu Y-K, Bray PJ, Hommel P, Pollard AM, Rawson J. Tracing the flflows of cop per and copper alloys in the early Iron age societies of the Eastern Eurasian steppe. Antiquity. 2016;90:357–75.
37. Perucchetti L, Bray P, Dolfini A, Pollard AM. Physical barriers, cultural connections: prehistoric metallurgy across the alpine region. Eur J Archaeol. 2015;18:599–632.
38. Pollard AM, Bray P, Hommel P, Hsu CY, Liu R, Rawson J. Applying the Oxford System to further understand bronzes in China. Kaogu. 2017;1:95–106.
39. Pollard AM, Bray P, Hommel P, Hsu YK, Liu R, Rawson J. Bronze Age metal circulation in China. Antiquity. 2017;91:674–87.
40. Liu C, Liu RL, Zhu SY, Wu J, Pollard AM, Cui JF, et al. New scientific analyses reveal mixing of copper sources in the early Iron Age metal production at Ili, western China. Archaeometry. 2022;64(1):98–115.
41. Administration of the exploration and development of Geology and Mineral Resources of Guangxi. Copper ores in Guangxi, Ann Geol Min Res China. 2022 (**In press**).

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