A REVIEW OF GLASS COMPOSITIONS AROUND THE SOUTH CHINA SEA REGION (THE LATE 1ST MILLENNIUM BC TO THE 1ST MILLENNIUM AD): PLACING IRON AGE GLASS BEADS FROM TAIWAN IN CONTEXT

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ABSTRACT

With more published chemical analyses of glass beads in Southeast Asia and southern China in the last decade, it is becoming possible to discuss the regional and temporal patterns of prehistoric glass in these areas. This article focuses on the late 1st millennium BC to the 1st millennium AD, reviewing the chemical compositions of glass in Taiwan, Southeast Asia and southern China, in an attempt to understand the potential relationships between the three regions.

INTRODUCTION

Prehistoric Taiwan witnessed the emergence of glass artefacts, in the form of beads, bracelets or earrings, during the Iron Age (from the late 1st millennium BC onwards). Prior to the Iron Age, it is common that inhabitants of prehistoric Taiwan used nephrite as a raw material for the manufacture of either prestige items or daily tools. Nephrite is indigenous to the island, and research has shown that it was exported from Taiwan to Southeast Asia via the South China Sea from as early as the middle Neolithic period (Hung et al. 2007). However, from the late 1st millennium BC onwards the use of nephrite declined, gradually being replaced by increasing numbers of 'exotic' glass beads, as religious and decorative items (Liu 2005). These are mostly found in funerary contexts in Taiwan. The substitution is seen first to occur in coastal areas rather than in the more mountainous regions, and is more prevalent in eastern and northern Taiwan than in central-western and southern Taiwan (Liu 2005). This has led archaeologists to suggest that glass beads were brought into Taiwan through the maritime nephrite networks established since the Neolithic Age (Hung and Bellwood 2010).

This article reviews the more recent research into glass compositions before the 1st millennium AD in Iron Age Taiwan, when very few polychrome and complex-shaped glass beads have been found; the majority of finds comprising plain beads (Figure 1). These simple monochrome glass beads resemble beads in contemporary Southeast Asia; because of this it is difficult to establish a temporal and regional pattern using the geometric shape and decorative style of glass beads, as most of the superficial marks on the beads may be unintentionally produced during manufacture. Similarly, the lack of extensive evidence of glass production in Southeast Asia means that their manufacturing methods cannot be linked to specific production locations. Therefore an understanding of the provenance and exchange of 'exotic' glass beads within Taiwan and between Taiwan and the adjacent countries may rely more on compositional information than stylistic analysis.

In the last decade many compositional studies of prehistoric glass beads around the South China Sea have been published, which allows glasses to be grouped regionally using compositional similarities or differences (e.g. Lankton and Dussubieux 2006; Lankton et al. 2008; Dussubieux and Gratuze 2010; Dussubieux et al. 2010; Lankton and Dussubieux 2013). This paper uses these publications and other reported chemical analyses of glass in early Iron Age Taiwan, Southeast Asia and southern China to try to shed light on any potential relationship relating to the raw materials used and the provenance of beads between these regions. The regions and sites mentioned in this paper are labelled in Figure 2.

THE RAW MATERIALS AND CHEMICAL COMPOSITION OF GLASS IN SOUTHEAST ASIA

Silicate glass, made using silica sands or quartz pebbles, is the most common compositional type of glass found in ancient Asian contexts (Sayre 1961; Brill 1995). Alkalis, as flux, can be derived from minerals or plant ashes which are either high in soda or potash (Henderson 1985).

However, within this broad soda-lime-silica tradition, research in the 1990s by Basa et al. (1991), Brill (1993; 1995), Brill et al. (1995) and Glover and Henderson (1995) have identified some glass

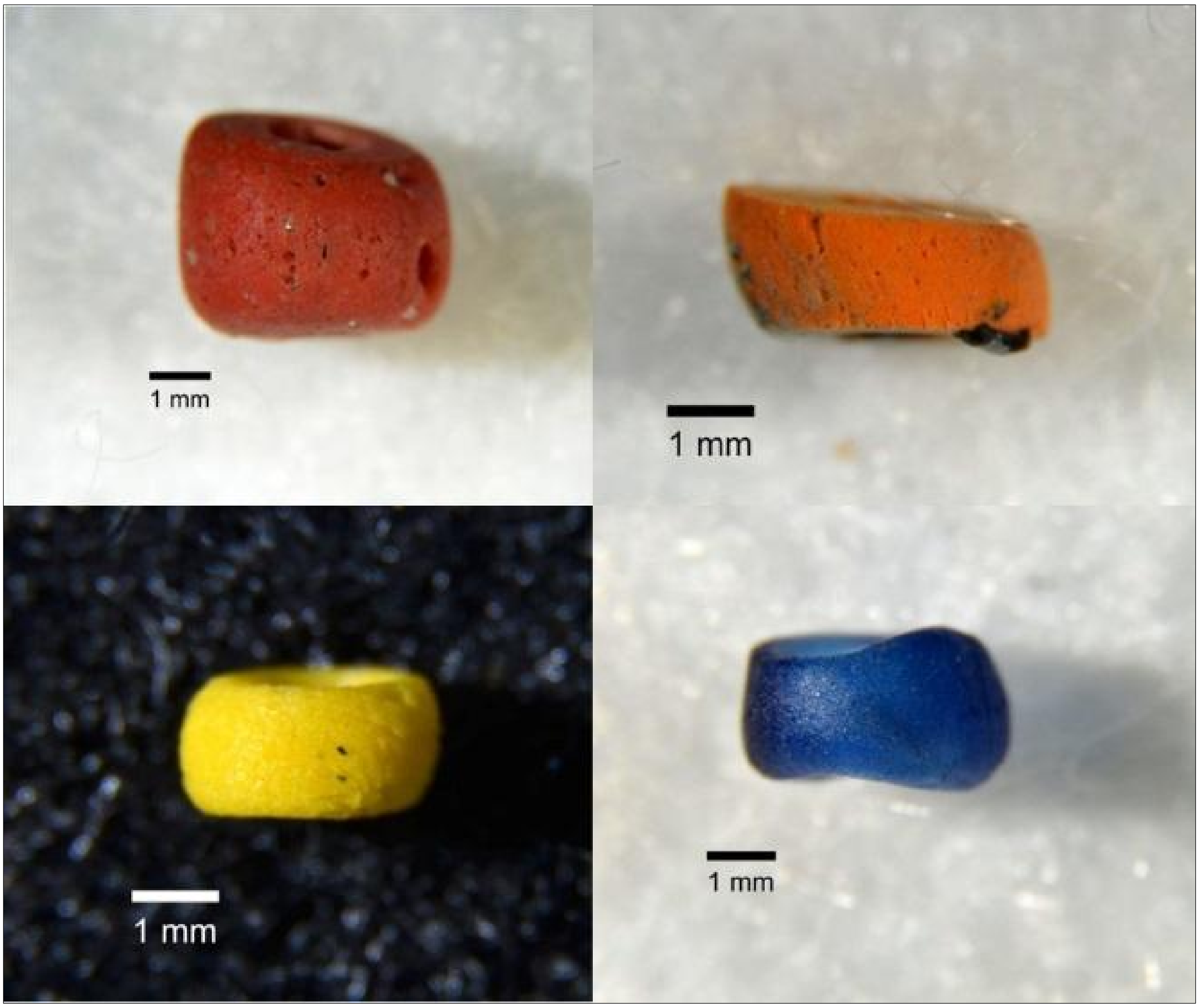

Figure 1: some examples of glass beads excavated from Kiwulan, Taiwan.

compositions which are typical of Southeast Asia and South Asia. The two most frequent types are alumina soda glass and potash glass, both produced with mineral alkalis (Brill 1995). These two groups have now been further refined and sub-groups established based on minor and trace elements in the glass (Dussubieux 2001; Dussubieux and Lankton 2006, 2013; Dussubieux et al. 2010; Dussubieux and Gratuze 2010; Carter 2013; Dussubieux and Allen 2014). These sub-groups can frequently be related to specific regions and chronological periods.

m-Na-Al glass

'Mineral soda' glass, named m-Na-Al glass (m refers to mineral), is a predominant compositional type that covers a wide geographical and chronological range in South Asia, Southeast Asia, East Africa and Turkey from the 4th century BC to 19th century AD (Dussubieux et al. 2010). It differs from the evaporate soda 'natron' glass, particularly typical of the Roman period in Western Europe, by its higher concentration of alumina, which is thought to be contributed from less-refined sand. South Asia is the major area for the production of m-Na-Al glass in the Indo-Pacific region. In South Asia, minerals such as *reh*, an efflorescence composed of sodium carbonate, sodium chloride and sodium sulphate, are suggested as one possible raw material (Brill 1987). In Southeast Asia, Dussubieux et al. (2010) suggested a particular type of m-Na-Al glass (m-Na-Al 3, see below) was probably made in the upper Thai-Malay peninsula, but latterly suggests that this type of mineral soda glass shows a compositional similarity to glass in northern India (Lankton and Dussubieux 2013: 431). Issues concerning the local procurement of raw materials for mineral soda glass in Southeast Asia or the possible South Asian influence on glassmaking in Southeast Asia therefore still remain unclear.

M-Na-Al glass is rich in soda (>10%) and alumina (>5%, average nearly 10%) but low in magnesia (<1.5%). The low magnesia concentration suggests the use of a mineral soda flux (Brill 1987). Recently, Dussubieux et al. (2010) reported 5 m-Na-Al glass subgroups based upon Ca and Mg, and the trace elements U, Ba, Sr, Zr and Cs. Two of these types, m-Na-Al 1

Figure 2: map showing the sites and regions mentioned in the text (from d-maps.com with additions). The number behind the region or site indicates the type of glass composition which had been identified. The number in the parentheses indicates the specific sub-group mentioned in the text. For example, Ban Don Ta Phet$^{2(2)}$ refers to potash glass (m-K-Ca) in Ban Don Ta Phet. Please note that the label of chemical composition does not show the percentage and chronological sequence of each group, and therefore is only provided for clearer visualisation.

and m-Na-Al 3, were found in Southeast Asia. M-Na-Al 1 is relatively low in U and high in Ba, Sr and Zr, while m-Na-Al 3 is high in U and low in Ba, Sr and Zr. M-Na-Al 1 was found to be earlier in southern India and Sri Lanka from the 4th century BC and later in Southeast Asia, with the possible primary production in Sri Lanka (Dussubieux 2001: 121-124; Dussubieux et al. 2010). M-Na-Al 3, however, was mostly found in Thailand, southern Vietnam and Cambodia, dating from the 4th to 2nd century BC (Dussubieux et al. 2010).

Potash glass

Potash glass is another common chemical group in Southeast Asia, and is also found in South Asia, China, Japan and Korea. Lankton and Dussubieux (2013, Figure 5.7.3) imply that there is a transition from the dominance of potash glass to that of m-Na-Al glass in Southeast Asia during the turn of the Christian era, but the actual picture is still ambiguous. The flux for mineral potash glass may come from substances such as saltpetre (KNO_3). Potential production regions have been suggested in South Asia, Southeast Asia and southern

China, but the production and provenance remain even more unclear than that of m-Na-Al glass.

Mineral potash glass generally has a potash concentration higher than 15% and soda and magnesia concentrations lower than 1.5%. Despite the difficulty of establishing a provenance for this glass, at least 3 chemical sub-groups, possibly associated with different production regions, can be distinguished: (1) low alumina and high lime ($Al_2O_3 \leq 1\%$, m-K-Ca), (2) high alumina and low lime ($CaO \leq 1\%$, m-K-Al) and (3) moderate alumina and moderate lime (CaO and Al_2O_3 in 1-4%, m-K-Ca-Al) (Lankton and Dussubieux 2006; Dussubieux and Gratuze 2010).

All the three sub-groups can be found in Southeast Asia, but there is a geographical difference in their occurrence. M-K-Ca glass was identified particularly in Ban Don Ta Phet, an Iron Age site in central Thailand (Glover and Henderson 1995). It is rare in South Asia and East Asia, therefore Glover and Henderson (1995) suggested that it may be a local product in Southeast Asia or southern China. This composition is also identified in Vietnam, and Lankton and Dussubieux (2006) suggest that there may be primary production in Giong Ca Vo in southern Vietnam based on the potential archaeological findings of glassmaking at the site. M-K-Al glass is more widely spread in Thailand (Lankton et al. 2006), northern Vietnam (Lankton and Dussubieux, 2006), south-eastern Cambodia (Carter 2010) and southern China (Fu and Gan 2006; Gan 2007; Xiong and Li 2011: pp79-96). Potential manufacturing evidence (probably secondary production) was found in Khao Sam Kaeo in Thailand (Lankton and Dussubieux 2013). It is suggested that primary production is likely to be somewhere in the northern regions of mainland Southeast Asia and southern China due to its predominant distribution there (Lankton and Dussubieux 2006). M-K-Ca-Al glass, on the other hand, is more abundant in South Asia than in Southeast Asia and southern China. The site Arikamedu in southern India was originally thought to be one of the production centres based on the abundant numbers of m-K-Ca-Al glass artefacts and associated residues (Lankton and Dussubieux 2006), although the authors now suggest this is not the case, and the glass in Arikamedu was imported (Dussubieux et al. 2012). Where it originated is far from clear at the moment, although it has been found in India, Southeast Asia and particularly in Vietnam (Lankton and Dussubieux 2006; Lankton et al. 2008; Dussubieux et al. 2012; Lankton and Dussubieux 2013). Recently, glass debris unearthed at Khao Sam Kaeo suggests the possibility of glassworking using m-K-Ca-Al glass in Southeast Asia, and the potential contact between the Khao Sam Kaeo and Sa-Huynh culture sites in southern Vietnam is suggested due to the compositional similarities of glass artefacts (Lankton et al. 2008).

Soda plant ash glass

Soda plant ash glass, known as v-Na-Ca glass (v for vegetal, e.g. Lankton and Dussubieux 2006), contains more magnesia and lime than mineral soda glass, and is also found in Southeast Asia. Dussubieux and Gratuze (2010) noticed that only beads were produced in soda plant ash glass in the early 1^{st} millennium AD. These early glasses are found in Sri Lanka in South Asia and in Cambodia, Thailand and Vietnam in Southeast Asia. Using soda plant ash as a flux in glassmaking is a tradition in Western Asia in the Sasanian (3^{rd} –7^{th} century AD) and Islamic periods (ca. 8^{th} – 13^{th} century AD) (Freestone and Gorin-Rosen 1999; Mirti et al. 2008). However, the early contact between Southeast Asia and Western Asia at such an early period was thought to be less likely, and therefore there is less possibility of a direct Western Asian origin of the glass (Dussubieux and Gratuze 2010). After the early 1^{st} millennium AD, both beads and vessels made from soda plant ash glass were found. A large number of plant ash glass artefacts were found in Sumatra and Peninsular Malaysia after the late 1^{st} millennium AD (Brill 1999: 376-387; Lankton and Dussubieux 2006; Dussubieux 2009; Dussubieux and Allen 2014). Within this period, glasses are lime-rich from the 9^{th} to 10^{th} century AD, and then alumina rich from the 12^{th} to 13^{th} century AD (Dussubieux and Allen 2014). Both the lime-rich and alumina-rich plant ash glass are tentatively thought to be imported from the Near East and the Middle East, but firm patterns and provenance remain to be elucidated (Dussubieux, pers. comm., 2014).

THE RAW MATERIALS AND CHEMICAL COMPOSITION OF GLASS IN SOUTHERN CHINA

Early glass, mostly of non-vessel types, in southern China predates the Warring States (476 - 221 BC) and Western Han (206 BC – 9AD) (Huang 2005; Gan 2007). From the Eastern Han period (25-220AD) onwards, more glass vessels were unearthed; their style and composition suggests they were mostly Western imports (An 1991; Xiong and Li 2011: 136-138). Among the early glass found in the Warring State and the Han Dynasty, barium-lead-silicate glass and potash glass are the two common chemical compositions (Shi et al. 1986; Brill et al. 1991b; Brill 1995; Li et al. 2003). Later, lead silicate glass and potassium-lead-silicate glass dominated in China (Brill et al. 1991b; Gan 2007).

High lead glass

Barium-lead-silicate glass is believed to be locally manufactured in southern China during the Warring States and the Han Dynasty. Distinct concentrations of PbO and BaO can be identified, with BaO > 9%, PbO > 20% and a variable PbO/BaO ratio (0.68-4.87 in Brill et al. (1991b), but 2-2.5 in Gan (2005)).

The Six Dynasties (220-589 AD) witnessed the decline of barium-lead-silicate glass. Lead silicate glass and potassium-lead-silicate dominated during the Six Dynasties to the Northern Song Dynasty (220-1127AD), although a few lead silicate glass objects date back to the Warring States Period (Brill et al. 1991b; Gan 2007). Lead silicate glass contains PbO generally at 35-75%, and potassium-lead-silicate glass has K_2O at 7-15% and PbO at 35-50%. Both the glass types have been found in southern China (Huang 2003; Li et al. 2003), but their abundance and distribution is less clear.

It is believed that high lead glasses in East Asia and Southeast Asia are products from southern China (Dussubieux and Gratuze 2010; Brill 1993; Gan 2007), although Japan and Korea are also suggested as sources for lead silicate glass (Brill 1993). The manufacture of barium-lead-silicate and potassium-lead-silicate glass emerged along the Yangtze Valley in the Warring State period (476 - 221 BC), and then spread southward and south-westward, among which Guangdong (廣東) and Guangxi(廣西) are thought to be important regions for producing potassium-lead-silicate glass (Gan 2007). Zhao (1991) noted that galena (PbS) deposits often occur with barite ($BaSO_4$) in the Yangtze River Valley, especially Hunan province. This might support the assumption of local development of barium-lead-silicate glass in southern China, although Brill et al. (1991b) suggests that the varied PbO/BaO ratio indicates lead and barium did not come from a single source. The lead isotope ratio reported by Brill et al. (1991a), however, does indicate that barium-lead-silicate glasses from China show Pb isotopes with a low ratio cluster, and they suggest that the raw materials were probably procured in Yunnan in south-western China, which is the only area in China where this low ratio ore occurs (Li 1996). Other lead glasses in the area also indicate the use of southern Chinese lead (Zhu 1995; Li 1999: pp111-113), although Dussubieux and Gratuze (2010) suggest more research is needed on Southeast Asian ores.

Potash glass

Potash glass is another predominant type. In southern China it intertwines compositionally with those in Southeast Asia and South Asia. Most of the potash glasses found in southern China are m-K-Al glass or m-K-Ca-Al glass (e.g. Shi et al. 1986; Huang 1988; Xiong and Li 2011: pp152-153). Some m-K-Al glasses are reported to have high Rb/Sr ratios (10-30), while in some m-K-Ca-Al glasses the Rb/Sr ratio is usually lower than 4 (Xiong and Li 2011: 86-96). Similar patterns can also be seen in the potash glass from Khao Sam Kaeo in Thailand (Lankton and Dussubieux 2013, Table 5.7.2). In addition to these two types, Li et al. (2003) and Fu and Gan (2006) reported a group, mainly in the Warring States period and the Han Dynasty, which has higher lime (~10%) than the typical m-K-Ca (< 7%) glass in Southeast Asia. On the other hand, Brill et al. (1991b) analysed a few Chinese potash-lime-silica glasses, dated later than the 7th century AD, and suggested that lime could be intentionally added as a stabiliser. Another potential group in China was suggested by Dussubieux and Gratuze (2010) to have both high alumina and high lime concentrations.

Chinese scholars believe that potash glass was a local product in southern China. Zhao (1991) suggested that saltpetre (KNO_3) was used as a flux in local glass production, based upon the use of this material in medicine from the Western Han period, its mention in ancient literature and the favourable environmental conditions for its formation (although sources are not known) (Zhao 1991; Gan 2007). This has led to the acceptance that southern China is one of the production centres of potash glass throughout China, Southeast Asia and South Asia. However, with increasing research into glasses of the wider region, Chinese researchers have started to acknowledge that some potash glasses were imported from, instead of exported to, South Asia and Southeast Asia (Xiong and Li 2011: 124-126, 133-136).

GLASS COMPOSITION IN EARLY IRON AGE TAIWAN

The earliest published compositional studies of glass beads in Taiwan were reported by Japanese and Taiwanese anthropologists in the mid-20th century (Sato 1988[1944]; Chen 1966). These studies were conducted on glass beads used as heirlooms by aborigines in Taiwan, rather than archaeological samples. The results revealed a lead silicate glass, and these authors suggested, using ethnographic records from Borneo, that the beads had a Southeast Asian origin, as they did not show the typical composition of glass beads known in China and South Asia. Chen (1966) further suggested that the glass beads were introduced with the migration of Paiwan (排灣) aborigines, who have the tradition of using polychrome glass beads as heirlooms, from Southeast Asia to Taiwan after the early 1st millennium AD.

Further research in later decades has shown these suggestions may be questioned, especially because of the chemical similarities to glass of the 1st millennium AD in Southeast Asia and of the relationship between these heirloom beads and excavated archaeological beads. Specifically, these lead silicate glasses are now known to be uncommon in contemporary Southeast Asia. Besides, most of the Paiwan heirloom glass beads are polychrome beads which are rarely found in prehistoric Taiwan and may not necessarily have a direct relationship with the abundant monochrome, and smaller, glass beads from early Iron Age contexts in Taiwan.

The first compositional analyses of archaeological beads unearthed in Taiwan have only taken place during the last decade. The integrated results of these analyses are given in Table 1, which shows that m-Na-Al and soda plant ash glass are the two most common types in prehistoric Taiwan. The presence of m-Na-Al glass is not surprising as it is the most common glass compositions in contemporary Southeast and South Asia, and Taiwan is thought to be involved in the interaction network with Southeast Asia for the exchange of nephrite, siliceous stone beads, glass beads and metalwork in this period (Hung and Bellwood 2010). The soda plant ash glass, however, is a less well known type in contemporary Southeast Asia, being a more common tradition in Western Asia. The increasing proportion of soda plant ash glass can be seen in some Southeast Asian sites 2013 Figure 5.7.3), and it is predominantly associated with a Western Asian, possibly Sasanian, origin (Dussubieux 2001; Lankton and Dussubieux 2006). Nevertheless, no archaeological records suggesting potential interaction between Western Asia and Taiwan are known during this period. The high percentage of soda plant ash glass in Taiwan in the 1st millennium AD therefore brings into question the provenance of the beads and trade/exchange activities in this period.

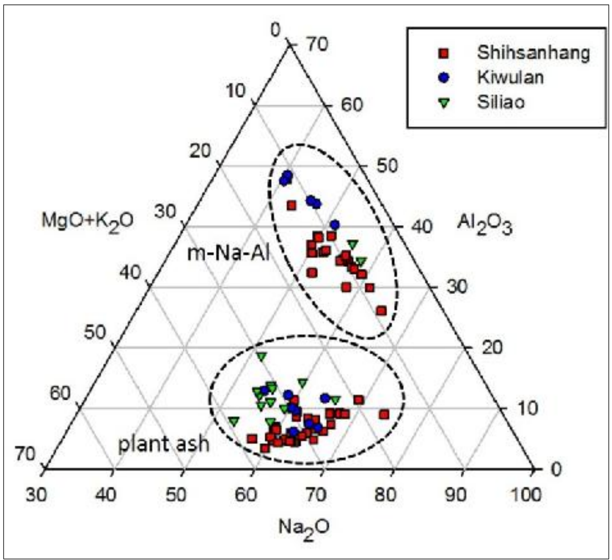

Figure 3: Ternary diagram showing m-Na-Al glass and soda plant ash glass in Shihsanhang, Kiwulan and Siliao.

Figure 3 shows the Na_2O-Al_2O_3-(MgO+K_2O) diagram of m-Na-Al glass and soda plant ash glass from Shihsanhang (十三行, 150-1450 AD) (Tsang and Liu 2001), Kiwulan (淇武蘭, 650-1150 AD in the lower cultural layer) (Cheng 2007) and Siliao (西寮, 550-1400 AD) (Chen and Cheng 2011). It can be seen that soda plant ash glass has higher MgO and K_2O, while m-Na-Al glass has more Al_2O_3. Further investigation reveals that, within the m-Na-Al group, samples from Kiwulan have higher concentrations of Al_2O_3 and lower Na_2O when compared to those from Shihsanhang and Siliao. On the other hand, in the soda plant ash group, Kiwulan and Shihsanhang samples generally cluster together, and higher concentrations of Al_2O_3 can be observed in Siliao samples. These results probably suggest the presence of sub-groups in m-Na-Al glass and plant ash glass in Taiwan. The sub-groups could potentially be at-tributed either to the use of different recipes, the importation of raw materials from different workshops/regions, and because of the large time span of the material under study, to changes in procurement and use of raw materials over time. It is also possible that the analysis of the material in different laboratories, using different instrumentation may contribute to some of these compositional differences. These differences, however, may shed light on trade/exchange activities in after the 4th century AD (Lankton and Dussubieux different periods and geographic regions in prehistoric Taiwan.

Table 1 indicates that glasses with distinct concentrations of lead oxide and potash seem to be rather uncommon, and are only found in Shihsanhang. The provenance of potash glass is controversial in Southeast Asia and southern China, but it is noteworthy that this Shihsanhang sample contains high CaO (7.8%) and low Al_2O_3 (1.6%); both concentrations are slightly higher than the typical m-K-Ca glass in Southeast Asia. However, glass containing lead in this period, as these samples do, is usually associated with a Chinese origin. To support a Chinese origin, Shihsanhang is thought to participate in the trade/exchange activities with southeastern China on the basis of artefacts showing Chinese typology, and there is no evidence of glass production at this site (Tsang and Liu 2001). The presence of high lead glass could potentially support such a hypothesis, but the small numbers of items representing this composition probably suggests that China may not be the major source of glass beads at Shihsanhang. This can be supported by the dominance of m-Na-Al glass at Shihsanhang. However, the styles of the majority of soda plant ash glass beads in Shihsanhang are uncommon in contemporary Southeast Asia (Dussubieux, pers. comm., 2014), which suggests investigating the provenance of the Shihsanhang beads may be quite complex. It should be noted that many of the sites discussed in this paper have a long duration of occupation. Therefore at this point in time examining changes in bead use and composition, through the sequence is not possible because of the lack of detailed contextual information. Therefore, through on-going research, it may be possible to establish a rough temporal and regional pattern of glass composition in Iron Age Taiwan in the near future, and to elucidate patterns of trade and exchange in the region.

SUMMARY

The increasing number of scientific studies of glass from around Taiwan, Southeast Asia and southern China in recent decades provides further evidence to investigate the compositional types produced in each area and to examine the interaction between different regions based on the production, consumption and trade/exchange of glass beads. Glass artefacts in Southeast Asia and southern China generally show regional features in terms of chemical composition and typology, and by using these together, different groups can be determined. Taiwan has been little studied within this geographical area, and this review examines how the compositions seen in beads from Taiwan fit within this broad geographical area, and what interactions may have taken place.

Within Southeast Asia and China, several different compositions have been identified; some of these com positions appear to be specific to particular locations

Table 1: a summary of the chemical composition of glass artefacts in prehistoric Taiwan to 2014.

Site	Artefact (N)[1, 2]	Reduced base composition	Remarks	Analytical technique	Reference
Shihsanhang, northern Taiwan 150-1450AD	Bead (21): opaque red, orange, yellow, greyish green or light blue.	Mineral soda alumina: SiO_2 60-70%, Al_2O_3 7-14%, Na_2O 12-20%, K_2O<3%, MgO<1.5%, CaO < 4% and FeO<3%.	1. Different degrees of copper oxide: 1.5-12.1%. 2. A few samples contain ~1.5% PbO.	Electron microprobe	Tsang and Liu 2001
	Bead (26): (a) opaque red, orange, yellow or blue, (b) translucent greyish green, (c) translucent or transparent greenish blue. Bracelet (3): translucent green, blue and yellow Earring (6): translucent green, yellow, blue or white.	Soda plant ash: SiO_2 65-70%, Na_2O 15-18%, K_2O~3%, MgO>3%, Al_2O_3 <3%, CaO 4-7% and FeO<1.5%.	1. The content of copper oxide is less than 0.5% on average. 2. Some orange and yellow beads contain more than 10% of PbO.		
	Bead (1): translucent or transparent greyish blue	Mineral soda lime silica: SiO_2 71.4%, Na_2O 15.4%, CaO 8.2%, MgO 0.6%, FeO 1.8% and Al_2O_3 2.1%.	1. CuO 0.2%.		
	Bead (1): transparent greenish blue	Potash: SiO_2 67.1%, K_2O 18.8%, Na_2O 2.7%, Al_2O_3 1.6%, MgO 1.1%, CaO 8.0% and FeO 0.8%.	1. CuO 0.8%. 2. Low total (~90%) in raw data.		
	Bead (1): unknown	Lead silicate: SiO_2 44.8%, PbO 34.3%, Na_2O 9.2%, CaO 4.0%, K_2O 1.9%, MgO 2.7, Al_2O_3 2.1% and FeO 1.0%.	1. According to the excavation report, this bead has a blue body and orange surface. It does not mention the exact area analysed. 2. CuO 1.3%		
	Bracelet (2): translucent green, blue or yellow	Potassium-lead-silicate: SiO_2 37-42%, K_2O 9-14%, PbO~45%, Na_2O ~0.5%, MgO~0.15%, CaO~1%, Al_2O_3<1% and FeO~0.6%.	1. CuO 1.0-1.5%		
Kiwulan, north-eastern Taiwan 650-1150AD[3]	Bead (5): opaque orange	Mineral soda alumina: SiO_2 63-70%, Al_2O_3 11-15%, Na_2O 10-16%, K_2O~2%, MgO<1%, CaO 3.5-4% and FeO<1.5%.	1. One sample contains 3.3% FeO.	SEM-EDS	Cheng 2007
	Bead (8): (a) opaque red or yellow, (b) translucent blue or yellow	Soda plant ash: SiO_2 67-70%, Na_2O 12-17%, K_2O 2-3%, MgO 3-5%, Al_2O_3< 3%, CaO 6-9% and FeO ~1%.	1. PbO of 10-18% in yellow beads.		
Siliao, southwestern Taiwan 550-1400AD	Bead (2): translucent greenish blue	Mineral soda alumina: SiO_2 67-70%, Na_2O 13-15%, Al_2O_3 ~9%, K_2O~2%, CaO ~4%, FeO~1.5% and MgO below detection limit.		XRF (non-destructive surface analysis)	Chen and Cheng 2011
	Bead (10): translucent blue Bracelet (1): translucent greenish blue	Soda plant ash: SiO_2 67-70%, Na_2O 12-15%, K_2O 2-4%, MgO 4-6%, Al_2O_3<3%, CaO 4-7% and FeO<1.5%.	1. One sample has 4.5% of Al_2O_3	SEM-EDS	

1: N refers to the number of artefact analysed in the reference. All of the artefacts are monochrome.
2: For Shihsanhang artefacts, the colour and diaphaneity of specific sample are not shown in the original data. The descriptions of these attributes here are obtained from the bead classification section in the reference, and therefore the colour and the chemical composition may not be one-to-one relationship in this table.
3: This table only uses the data from the Lower Cultural Layer (the Iron Age layer) in Kiwulan.

and these compositions in particular help to determine the putative provenance and hence movement of these glasses. Soda and potash glasses, made with mineral deposits, have been found in Southeast Asia.

Mineral soda alumina glass is associated with Southeast Asia and South Asia. Further identification of five sub-groups within this m-Na-Al glass shows that only some types are found in Southeast Asia at specific periods (although recent research seems to suggest a potential relationship to northern India), whilst others appear to originate from India or Sri Lanka. Similarly three chemical groups of potash glass have been found which may be associated with different production regions. While secured production locations have yet to be determined, they have characteristic geographical distributions. A soda plant ash glass is also found in the region, which may have been produced in the Near or Middle East and traded to Southeast Asia.

In China other compositional groups are present. Whilst potash compositions are common, many glasses are barium-lead-silicate, and in later periods lead silicate glasses and potassium-lead-silicate glasses are present. They may be products of China. The potash glasses in China use a mineral alkali and some are very similar to those found in northern mainland Southeast

Asia, but others appear to be specific to China and are believed to have been manufactured in southern China.

Although further research will enhance and enrich the picture of production, consumption and exchange networks in these regions, the different compositional groups in Southeast Asia, China and beyond allow the beads from Taiwan to be placed within the larger context of production and distribution networks in the area. Research on the beads found in the 1st millennium AD in Taiwan shows that there appear to be more similarities with the compositions seen, and potentially originating, in contemporary Southeast Asia than those of China. This is evidenced by the predominance of m-Na-Al and soda plant ash glass, both of which are more abundant in Southeast Asia. There is the possibility of multiple sources of importation of glass beads to Taiwan. However at present, there is a lack of comparable chemical data and detailed contextual information for glass in eastern Taiwan, south-eastern China and island Southeast Asia to securely reconstruct the consumption and production of glass beads in Taiwan, mapping any changing prehistoric exchange patterns between these regions and the island, and within Taiwan itself. With this in mind, research is in progress on glass beads from geographically distinct sites in Taiwan; these analyses should help elucidate any regional and chronological differentiations and allow this material culture to be placed within the wider trading network.

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