SHINY EXCEPTIONS? GLASS IN MIMOTIEN CONTEXT

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ABSTRACT

Circular earthworks with an outer wall and inner ditch are characteristic of the Mimotien culture of the red soil area of eastern Cambodia and southern Viet Nam. The lack of metal finds has urged most researchers to classify this cultural complex as Neolithic, as a reliable series of radiocarbon dates is still lacking. The discovery of five fragmentary glass bracelets in the upper part of the occupational layer of circular earthwork Krek 52/62 gives new evidence. The lack of metal artefacts can be explained by the very acidic conditions of the soils, with a pH under 4. The excellent macroscopic state of preservation of the glass bangles is due to their very high alumina content, which protects the glass from weathering, although one fragment shows significant chemical alteration phenomena on the outer surface. Their composition points to an origin of the glass masses in India or southern Viet Nam. Similar translucent glass bracelets with triangular cross-sections are known from Sa Huynh related contexts in Viet Nam, Thailand and the Philippines. At Giong Ca Vo, near Ho Chi Minh City, parallel finds for the Krek glass bangles were found next to a probable Sa Huynh glass production area. Two Indo-Pacific beads from Krek Village No. 18 differ from the bangles clearly in their composition, as do natural tektite glasses.

The first glass objects appeared in Southeast Asia at about 500 BC and are linked to Iron Age or later contexts. Widely known are the small Indo-Pacific glass beads, which were distributed all over the Indo-Pacific mainland and archipelago. One early production site for these has been located at Arikamedu in southeast India. In the early centuries AD, manufacture of these spread to urban centers such as Mantai in Sri Lanka, Khlong Thom in South Thailand and Oc Eo in South Viet Nam, probably with the movement of Tamil bead makers (Francis 1990). Since 1998, glass bangles have also been reported from Mimotien circular earthworks (Malleret 1959; Groslier 1966). These help to link the Mimotien complex to other Southeast Asian cultures (Haidle 2002).

MIMOTIEN CIRCULAR EARTHWORKS

The distribution of this very homogeneous site group appears to be restricted to the red soil area of eastern Cambodia and southern Viet Nam. The circular earthen structures with their outer wall, inner ditch and central plateau generally have a diameter of 250 to 300 m, but diameters range overall from 110 to 440 m. They are situated on slight slopes and possess one entrance, or two opposite ones (Albrecht *et al.* 2001; Dega 1999; 2002; Thuy 2002).

The artefact assemblages of these sites are predominantly composed of ceramic and stone artefacts (Chhor et al 1999; Heang 1999; Heng and Som 1999; Heng and Mao 1999; Sok and Vin 1999; Thuy 1999). At Krek 52/62, where 100 m^2 have been excavated between 1997 and 2004, the pottery is tempered with organic as well as mineral additives, formed by the paddle and anvil technique and fired at rather low temperatures in open fires. Decorative elements consist primarily of incised, indented and impressed motifs and some vessels are slipped and/or burnished. The ceramic inventory is completed by spindle whorls, an anvil for pottery production and clay balls.

Lithic flakes, blades, borers, chisels, thin-butted and shouldered adzes were produced at the site from several hornfels-type raw materials (Neumann 1999). The same materials were also used to make bracelets with rectangular and triangular cross sections. Chert was sometimes used for blade production (Neumann and Haidle 2002), quartzite pebbles were occasionally used to burnish pottery, and two bifacial tools were made from coarse limonitic sandstone. Polishers and whetstones were mainly made from sandstone.

Additionally, a garnet bead of mixed pyrope-almandine type with a biconically drilled hole and a spherical carnelian bead were discovered within the occupational layers of Krek 52/62.

Metal artefacts and moulds were not found and the lack of bones, charcoal and metal can be explained by the very acidic pH value of the red tropical soil. Dating the circular earthwork sites is rather difficult: the typology of the Mimotien pottery and stone adzes is not very helpful and metal is lacking. Organic residues within potsherds were used for radiocarbon analyses (Albrecht et al 2001; Dega 2002), but yielded results considered unreliable by the C14 laboratory at Zurich. Therefore, dating has mainly been based on artefact typology, restricted to pottery and stone tools. The dates proposed by several authors range from 3500 BC to AD 800, but are concentrated in the Neolithic period. New chronological evidence now comes from the glass bracelets found in Mimotien contexts at Krek 52/62 (Haidle 2002).

GLASS FINDS FROM KREK 52/62

Five fragments of five different glass bangles were discovered *in situ* in the uppermost zone of the occupational layer in Krek 52/62. Neither the colour nor texture of the soil at the findplaces give any hint of modern disturbance and the glass fragments were found together with the known artefact range of circular earthworks. All the fragments are made of light to dark green or blue-green translucent glass and have triangular (one example) to pentagonal (four examples) cross sections (Figure 1). Dimensions vary slightly (Table 1): widths from 11.3 to 13.5 mm, heights from 5.0 to 6.8 mm. Width/height ratios lie between 1.95 and 2.26. Preservation is very good and few signs of weathering can be observed.

According to Glover and Henderson (1995), the production of true glass (not faience) started in India between 1000 and 800 BC. In Southeast Asia, glass is only found in contexts dated younger than 500 BC and seems to accompany the first use of iron (Basa *et al.* 1991:366). The earliest finds of glass in Southeast Asia, beads as well as bangles, are reported from Thailand and from the Sa Huynh culture of central and southern Viet Nam.

Glass bangles comparable to those from Krek are known from Viet Nam, Thailand and the Philippines. Find spots of possibly similar bracelets have been reported from Indonesia, the Moluccas, Micronesia and New Guinea. Several glass bangles with triangular cross sections in dark green, black and violet have been reported from Giong Ca Vo, near Ho Chi Minh City. This late Sa Huynh jar burial site is dated to about 100 BC and fritty waste glass in dark green and black gives evidence for local glass production. This assumption is backed by three pits, each about 80 cm in diameter, containing white sand which could have been used as a raw material in glass making (Francis 1995; Nguyen 1995). Additionally, glass bracelets with different cross sections have also been found at the site (Andreas Reinecke, pers. comm. 2001).

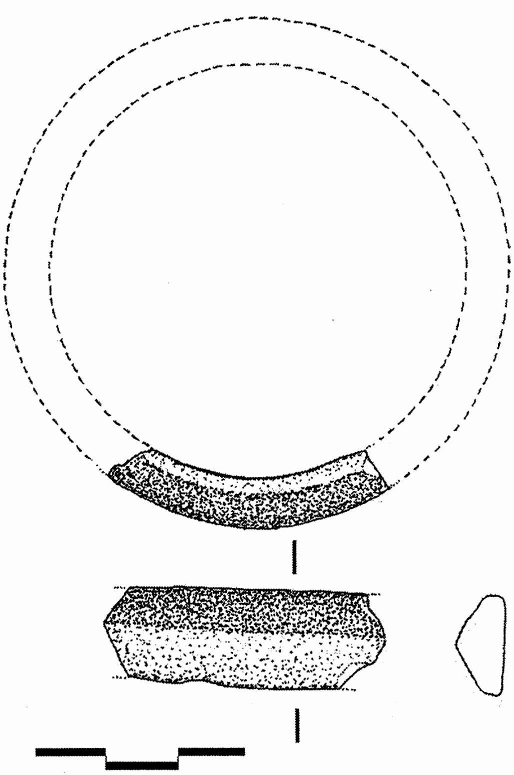

Figure 1: Glass bangle M9/13 from Krek 52/62. See Table 1 for measurements.

From Go Ma Voi, another Sa Huynh jar burial site in Quang Nam Province, one fragment of a dark green translucent bangle with a triangular cross section has been reported (Reinecke *et al.* 2002:77, Figure 59:9). Around two dozen Vietnamese Metal Age sites of the second half of the first millennium BC have yielded glass bangles with triangular and semi-circular cross sections. The majority are of green, blue and green to blue translucent glass and originate from Dong Son graves (e.g. Xuan Lap, Lang Vac, Dong Mom) and Sa Huynh jar burials (e.g. Giong Phet, Ban Tram, Suoi Chon, Phu Hoa, Dan Giay, Tam My) (Fontaine 1972:437; Andreas Reinecke pers. comm. 2001). Another similar find is reported from Ban Don Ta Phet, an early Iron Age burial ground in Kanchanaburi province, western Thailand, which also yielded several other glass bangles. This translucent pale green glass bangle is dated to the first half of the 4th century BC. Remarkable is the cross section, which again resembles a pentagonal house shape. With a height of 32.6 mm and width of 15.2 mm this specimen is

Table 1: Fragments of glass bangles from Krek 52/62, Unit II: square, measurements, colour and flaw frequency.

square /#	width in mm	height in mm	width/height ratio	facette in mm	colour	flaw frequency
M9/13	13.0	6.5	2.0	1.0	dark green	few
L8/12	13.5	6.8	1.99	1.3	light green	numerous
K13/1	12.6	6.4	1.97	1.0-1.4	light green	few
J11/5	11.7	6.0	1.95	1.0	light green	few
M12/3	11.3	5.0	2.26	-	light blue-green	few

markedly larger than the Krek fragments, but the height/width ratio of the Ban Don Ta Phet bracelet is 2.14 - well within the range of the Mimotien pieces (Glover 1990:170). Basa *et al.* (1991:371) regard this bracelet as evidence for non-Indian, possibly local glass ornament production.

In Chamber B of Manunggul Cave, one of the Tabon sites on Palawan, Philippines, bangles with triangular cross sections made from translucent green glass were discovered in Sa Huynh related jar burial contexts (Fox 1970:118). A jar burial site at Makabog on Masbate Island yielded fragments of glass bangles dated to the Iron Age (Henson 1992:213).

From India, bangles with triangular cross sections are reported. A green one with yellow decoration originates from Atranjikhera IV and is dated between 600 and 50 BC. A light brown one was found at Hastinapura II, dated to 1100-800 BC (Lal 1987:44). The examples from India, however, differ from the Krek 52/62 specimens and the common Sa Huynh-related type in colour and decoration.

From ethnographic contexts, translucent blue and green bangles with triangular cross sections are known from Micronesia and New Guinea. Complete bracelets were believed to be objects with magic power, animated by a spirit. They were highly valued and could not be traded (de Beauclair 1961; 1977). However, fragments of this type of bracelet, the origins of which may well lie in prehistory, were used as native money on several islands in Micronesia (de Beauclair 1962). Inez de Beauclair also reports several other finds of translucent blue and green glass bangles from Taiwan, the Philippines, Moluccas, Borneo and Seram. It is not clear whether all of these belong to the Sa Huynh type with triangular cross-section, but it is evident that this type of artefact was still in use in exchange systems in recent times. The distribution of these finds cannot therefore be related directly to Sa Huynh influence, but may belong to a later chronological span.

ANALYSIS OF THE KREK 52/62 FRAGMENTS

The five bangle fragments from Krek 52/62 are not only very similar in shape, but also in chemical composition. They were analyzed using an electron microprobe at the Geochemical Institute of the University of Göttingen (specimen M9/13) and at the Mineralogical Institute of the University of Tübingen (specimens L8/12, K13/1, J11/5, M12/3).

The light blue-green specimen M 12/3 was formerly thought to be exceptional in its very low amounts of flux and a potash-soda ratio of 3.2 (Haidle 2002). However, a second set of analyses on a freshly broken fragment show that these strange values were due to leaching. Although the state of preservation of the green glass is good and no signs of weathering can be observed by macroscopic or microscopic methods, the microprobe analysis indicated a strong chemical alteration of the outer part. In the back-scattered electron image, a thin outer zone of alteration can easily be recognized (Figure 2, light area). This zone is 10-20 µm thick and has a sharp contact with the unweathered core. The outer surface is irregular and in places exhibits cracks.

The analyses (Table 2, beam diameter 5 µm) show a strong depletion of Na_2O from 16.3-16.6% of sample weight to less than 1% in the altered surface and of K_2O from around 1.7 to 0.3-0.7% of sample weight. Parallel to this loss of alkaline elements, an enrichment of water in the altered surface by about 13-14% of sample weight can be observed. This is indicated by the decreasing subtotals of the measured solid elements in analyses M12(15)-M12(18), to which water content must be added to reach 100% of the weight.

In general, even significant leaching of alumina-rich glass does not result in macroscopic weathering phenomena like irisation – giving the surface an opaque, but sparkling appearance – or decay, because alumina is a strong network modifying and forming element. Therefore, chemical analyses of excavated glass fragments can only be reliable if the analyzed sample was cut and polished perpendicular to the weathered surface and if unaltered areas were measured. Similar leaching phenomena have been observed in two Indo-Pacific glass beads from Krek Village No. 18 (Figure 3).

The Krek bangles can be compared to natural glasses from mainland Southeast Asia and to the two glass beads from Krek Village No. 18. In Table 3, the first tektite value shows the mean of 112 tektites given by Schnetzler (1992; cited in Heinen 1997:100). The second tektite value (M13) refers to a micro-probe analysis of a small tektite fragment from Krek 52/62. The translucent blue-green and violet glass beads were found in association with garnet beads of mixed pyrope-almandine type, similar to the one found at Krek 52/62. A preliminary date for Krek Village No. 18 is given by a Dong Son drum fragment as 300-100 BC (Heng 2004: 13). The values given in Table 3 and Figs. 4 and 5 represent the mean percentage weight values of several independent

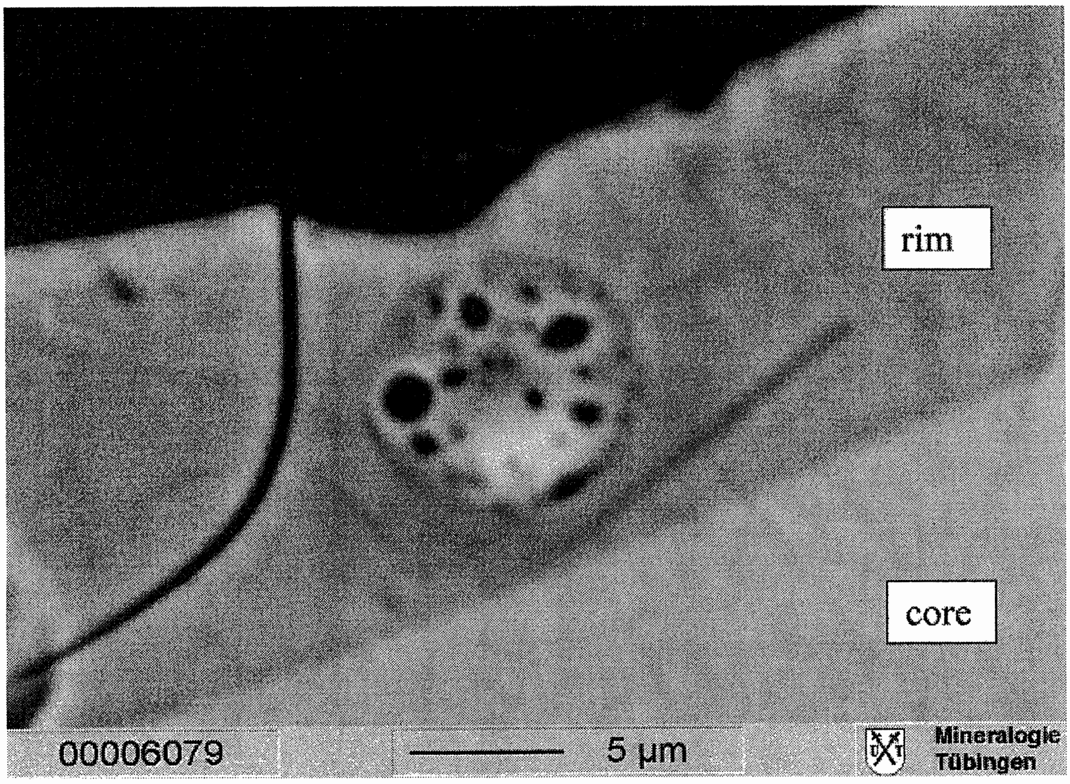

Figure 2: Back-scattered electron image of cut and polished piece of bracelet M12/3. Note the darker rim zone of the glass fragment. The round porous structure in the middle of the rim area is the product of the damage from the microprobe beam due to the high water content of the glass in this area (beam diameter 10 µ, 15 kV).

Table 2: Microprobe analyses of glass bracelet M12/3. Analyses number M12/3.9– M12/3.14 refer to the core area of bracelet, M12/3.15 –M12/3.18 to the rim area. Note the strong depletion of sodium and (to a lesser degree) of potassium in the 10 – 20µ thick outer rim of the bracelet

	M12/3.9 core	M12/3.10 core	M12/3.11 core	M12/3.12 core	M12/3.13 core	M12/3.14 core	M12/3.15 rim	M12/3.16 rim	M12/3.17 rim	M12/3.18 rim
SiO_2	67.94	67.95	68.49	68.42	68.85	69.01	71.85	73.28	73.08	73.02
TiO_2	0.36	0.38	0.33	0.34	0.36	0.39	0.33	0.31	0.33	0.32
Al_2O_3	6.64	6.61	6.75	6.66	6.65	6.71	6.41	6.56	6.56	6.48
CaO	2.13	2.11	2.09	2.04	1.85	1.90	1.80	1.86	1.81	1.76
BaO	0.00	0.01	0.01	0.02	0.04	0.04	0.03	0.04	0.00	0.01
FeO	2.08	2.03	2.03	2.04	2.09	2.17	1.94	1.87	1.94	1.91
MgO	1.20	1.28	1.26	1.30	1.18	1.24	1.31	1.10	1.16	1.15
MnO	0.09	0.13	0.12	0.07	0.11	0.13	0.08	0.09	0.06	0.06
Na_2O	16.40	16.53	16.44	16.63	16.30	16.29	0.85	0.74	0.34	0.48
K_2O	1.70	1.69	1.65	1.63	1.72	1.75	1.33	0.72	0.32	0.45
Cl	0.29	0.31	0.28	0.34	0.38	0.33	0.33	0.32	0.35	0.36
P_2O_5	0.40	0.56	0.46	0.40	0.39	0.39	0.42	0.40	0.46	0.45
Total	99.23	99.59	99.91	99.89	99.92	100.35	86.48	87.29	86.41	86.45

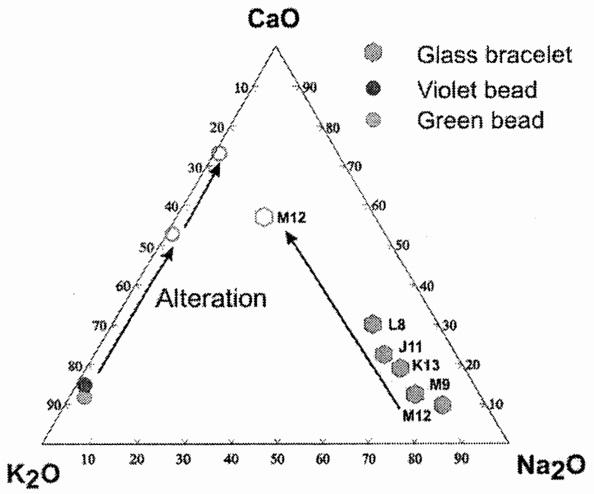

Fig. 3. Composition of glass samples from Krek in the CaO-K_2O-Na_2O-diagram. Note the remarkble alteration trends of glass bracelet M12 (loss of sodium) and of two beads (loss of potassium) due to surface leaching.

microprobe (EMPA) measurements, standardized to 100% for easier comparison.

The main character of the Krek glasses is the very high alumina content of between 7 and 8% (Table 3, Figure 4). Like the main glass component, silica, alumina (Al_2O_3) is an element that is able to build up the basic network in the glass mass – a network forming component. But it works also as a modifier of the glass mass and enhances durability (Richter *et al* 1988:74). Due to the very high values for alumina, the bangles show no signs of weathering despite the acidic soil conditions at Krek. Alumina contents are also very high in the tektites. Different to the bracelets and to the natural glasses, the beads from Krek Village No. 18 have only a low alumina values. Titanium oxide (TiO_2) is a common companion of alumina in natural deposits and the alumina–titanium oxide ratios of the tektites and four bangles range between 19.4 and 15. One bangle has a markedly higher ratio of 33. The ratios of the two Indo-Pacific beads are 20.2 and 12.2.

All the glass bangle fragments from Krek 52/62 have soda (Na_2O) as the main flux, with a minor proportion of potash (K_2O) (Table 3, Figure 4). Potash-soda ratios range from 0.18 to 0.27, very low for mixed-alkali glasses. The two Indo-Pacific beads from Krek Village No. 18 can be clearly distinguished from all other glasses owing to their high potash content and their significant potash-soda ratios, of 26 and 147 respectively.

Table 3: Microprobe analysis (EMPA) of glass bangles from Krek 52/62 (M9/13, L8/12, K13/1, J11/5, M12/3) compared with glass beads from Krek Village No. 18 (No. 18 green and violet) and Southeast Asian tektites (M13 from Krek 52/62). All analyses in % of weight normalized to 100% total. Analyses of tektites (n = 112 pieces) by C. C. Schnetzler (1992; cited in Heinen 1997, 100), analyses of M9/13 by Geochemical Institute of the University of Göttingen, Germany, Prof. Dr. Hans Wedepohl. All other analyses by Institute for Geosciences of the University of Tübingen, Dr. Thomas Wenzel.

Sample	tektites	tektite M13	M9/13	L8/12	K13/1	J11/5	M12/3 surface	M12/3 core	No. 18 green surface	No. 18 green core	No. 18 violet surface	No. 18 violet core
analyses n	(112 p.)	3	14	5	5	5	4	6	2	5	2	5
SiO_2	73.20	80.45	66.28	76.68	73.39	75.20	84.01	68.57	95.15	86.55	90.09	81.16
Na_2O	1.32	1.55	15.82	6.06	10.24	7.71	0.70	16.46	0.03	0.36	0.02	0.07
K_2O	2.39	1.81	2.88	1.61	2.26	1.95	0.81	1.69	1.12	9.35	0.74	10.26
$K_2O:Na_2O$	1.81	1.17	0.18	0.27	0.22	0.25	1.16	0.10	37.30	26.00	37.0	146.60
Al_2O_3	12.84	8.99	7.75	7.69	7.09	7.77	7.50	6.69	1.24	1.21	0.61	0.61
TiO_2	0.75	0.61	0.42	0.23	0.36	0.40	0.38	0.36	0.01	0.06	0.04	0.05
$Al_2O_3:TiO_2$	17.12	14.74	18.45	33.43	19.69	19.42	19.74	18.58	124.00	20.17	15.25	12.20
BaO	—	0.01	0.06	0.03	0.05	0.02	0.02	0.02	0.00	0.01	1.03	0.98
CaO	2.15	1.04	2.11	3.22	2.64	2.87	2.09	2.02	1.26	1.30	2.29	1.98
MgO	2.23	1.45	1.14	1.61	1.33	1.29	1.31	1.24	0.36	0.34	0.28	0.18
CaO:MgO	0.96	0.71	1.85	2.00	1.98	2.22	1.60	1.63	3.50	3.82	8.18	11.00
FeO	4.73	3.87	1.86	2.15	2.11	2.20	2.21	2.08	0.38	0.38	0.23	0.19
MnO	—	0.10	0.08	0.09	0.12	0.10	0.09	0.11	0.04	0.04	3.80	3.73
P_2O_5	—	0.10	0.49	0.42	0.42	0.40	0.50	0.43	0.19	0.18	0.67	0.58
Cl	—	0.03	0.28	0.25	0.09	0.10	0.39	0.32	0.22	0.18	0.19	0.20

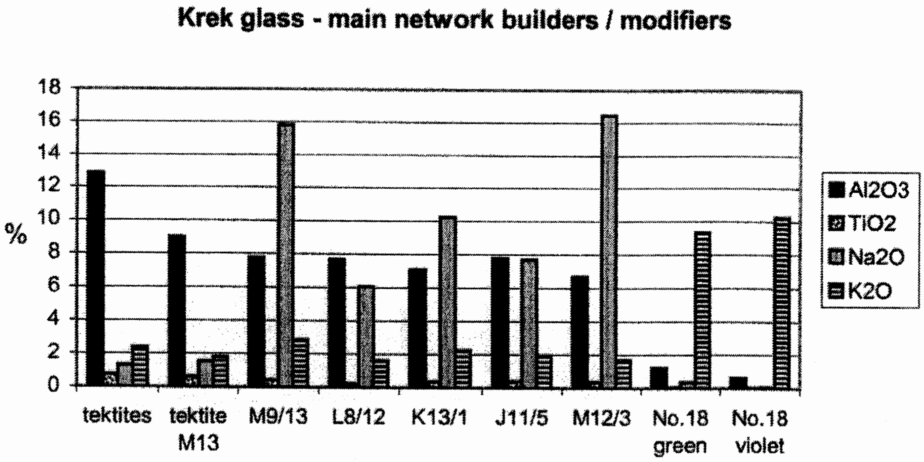

Figure 4: Selected main network builders and modifiers.

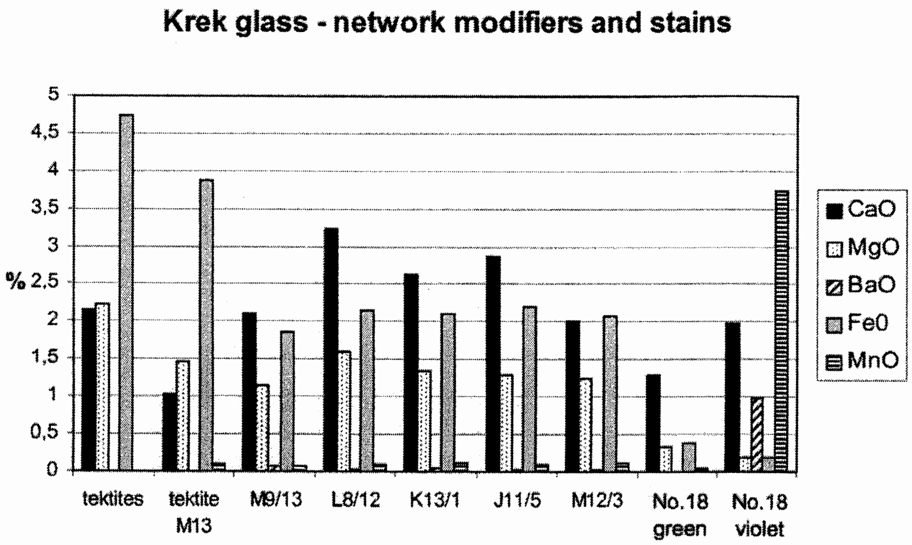

Figure 5: Selected network modifiers and stains

Iron oxide and manganese oxide are staining components. They often occur as natural impurities in glass raw material, but manganese is sometimes added deliberately for colouring purposes (Richter *et al* 1988:82). The Krek glasses are very homogeneous, having medium iron oxide contents between 1.8 and 2.4 and only traces of manganese (Table 3, Figure 5). The tektites are characterized by high iron oxide values of 3.9 to 4.7 and almost no manganese. The Indo-Pacific glass beads, however, possess only low iron oxide values of 0.4 and 0.2. The violet bead reveals high manganese (3.7) used as a staining component.

In sum, the fragments of glass bracelets from Krek are characterized by a high alumina content, around 7%. Sodium is the main alkali, with low amounts of potassium (less than 3%). The potash-soda ratio is generally below 0.3. Lime (between 2-3%) and magnesia (between 1-2%) values are low and the lime-magnesia ratio ranges around 2. The iron-oxide value lies between 1.8 and 2.4%. The Indo-Pacific glass beads from Krek Village No.18 can be clearly distinguished from the bangles from the circular earthwork site by their low alumina values of 1.2 or lower and high potash values of around 10%. Their potash-soda ratio is very high, the lime-magnesia ratio is markedly increased and the iron oxide amounts are very low.

Lime and magnesia are important network modifiers that stabilize the glass mass and prevent devitrification (Richter *et al* 1988:70). As they often occur together in natural deposits, the lime-magnesia ratio can point to differences in raw materials. All the Krek glasses show low contents of lime (CaO: 1.9-3.2%) and a lime-magnesia ratio of 1.8 to 2.3 (Table 3, Figure 5). The tektites are characterized by higher magnesia than lime values, so the ratio lies below 1, whereas the Indo-Pacific beads show markedly higher ratios of 3.8 and 11. Barium is another component which serves as a network modifier and significant amounts of this element (BaO) are observed in the violet bead from Krek Village No. 18. But all other samples show only traces of barium (Table 3, Figure 5).

ORIGIN OF THE GLASS FROM KREK

Analyses of chemical composition give no hint where the bangles were produced, but they may help to trace the provenience of the raw materials, or the areas of production of glass cullets. Accor-ding to Glover and Henderson (1995), three regions have to be considered as early production centers for Southeast Asian glass, these being India, China and the Mediterranean. Brill (1987) describes Indian glasses with soda as the main alkali (14-17%) and low values for potash (0.5-3%). Typically, the content of alumina is high

($Al_2O_3 > 3.5$-4%) and the value for lime lies below 4.5-5%. Glover and Henderson (1995:153) state that most of the glass from Arikamedu contains even more aluminum and less calcium than Brill's typical Indian glasses. For the Indo-Pacific beads from Arikamedu, Peter Francis Jr. (1998:11) determines two different glass compounds which can be distinguished by their main flux. Soda is the specific flux for red beads, potash the characteristic network modifier for all other colors.

In comparison, Roman glasses show lower alumina contents ($Al_2O_3 < 3.5$-4%), higher values of lime ($CaO > 4.5$-5%) and less titanium oxide than Indian glasses (Brill 1987:153). Mixed-alkali glasses are rare, soda-lime glasses are predominant (Brill 1987:141, 153). Typically, early Chinese glasses are rich in barium and lead, although in Southern China some potassium glass is found which may have been produced locally (Brill 1987:159).

Analysis of Vietnamese Iron Age glass by Nguyen Truong Ki (1983; cited in Glover and Henderson 1995:153) showed two different groups of glass masses – probably locally-produced potassium glasses with low natrium, lead and alumina values from Dong Son contexts, and soda glasses with high alumina values (more than 5%) from Sa Huynh contexts. The results of recent Vietnamese research allow the postulation of at least four early Southeast Asian production centers of glass in the last centuries BC and shortly after. These include India, with mainly mixed-alkali glasses, low lime and high alumina contents; China, with barium-lead glasses; the Mediterranean, with mainly soda-lime glasses with high values of lime and a smaller amount of alumina; and, finally, southern China and northern Viet Nam, with potassium glasses showing only low values for soda, lead and alumina. It is probable that southern Viet Nam served as a fifth center for soda glasses with very high alumina contents, and that Giong Ca Vo was one of the production sites.

The chemical compositions of the glass bangle fragments from Krek 52/62 resemble the values for the Indian mixed-alkali-glasses, but do not match completely. The alumina contents are higher than would be expected and sodium is the main alkali. These are similar values to two translucent green bracelets with triangular cross sections from Giong Ca Vo (Salisbury and Glover 1997:12). Therefore, we would like to identify the Krek glasses as soda glasses, with high alumina amounts, and argue for a southern Vietnamese origin.

The bangles show no similarities to the known Mediterranean soda-lime, Chinese lead-barium or southern Chinese-northern Vietnamese potassium glasses. The Indo-Pacific beads from Krek Village No. 18, however, clearly do not belong to the same glass group as the Krek bracelets, but can be identified as potassium glasses with low soda and alumina. This combination is typical for opaque green and violet Indo-Pacific glass beads from Arikamedu, or from Dong Son contexts in northern Viet Nam or southern China. The composition of all ornamental glasses studied here differ clearly from natural tektite glasses.

CONCLUSIONS

Typological analysis of the Krek glass bangles suggests links between the Mimotien complex and Iron Age Sa Huynh. Therefore, the date for later occupation in Krek 52/62 should be second half of the first millennium BC. The chemistry of the Krek glasses points to a glass production center in southern Viet Nam. A different source can be suggested for the Indo-Pacific glass beads from nearby Krek Village No. 18, either Arikamedu as suggested by chemistry, or via northern Viet Nam in terms of the associated finds of Dong Son drum fragments. The future may yield exciting insight into the coexistence of Indian, Dong Son and Sa Huynh influences in Iron Age eastern Cambodia.

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