From sand to sea: tracing the production and trade of glass beads from the 10th-century CE Cirebon shipwreck in the Java Sea

Abstract: Around the year 970 CE, a merchant ship carrying an assortment of goods from East Africa, Persia, India, Sri Lanka, Southeast Asia, and China foundered and sank to the bottom of the Java Sea. Thousands of beads made if many different materials—ceramic, jet, coral, banded stone, lapis lazuli, rock crystal, sapphire, ruby, garnet, pearl, gold, and glass—attest to the long-distance movement and trade of these small and often precious objects throughout the Indian Ocean world. The beads made of glass are of particular interest, as closely-dated examples are very rare and there is some debate as to where glass beads were being made and traded during this period of time. This paper examines 18 glass beads from the Cirebon shipwreck that are now in the collection of Qatar Museums, using a comparative typological and chemical perspective within the context of the 10th-century glass production. Although it remains uncertain where some of the beads were made, the composition of the glass beads points to two major production origins for the glass itself: West Asia and South Asia.

Keywords: glass beads, chemical analysis, Indian Ocean trade, Cirebon shipwreck

Carolyn Swan

UCL Qatar

Polish Archaeology in the Mediterranean 29/1
Swan 2020: 355–380
https://doi.org/10.31338/uw.2083-537X.pam29.1.17

Acknowledgments
I would like to thank Qatar Museums for its kind permission to study and sample the Cirebon glass, and Meghan Magee and Nemanja Cavlovic for arranging the necessary permissions to access and sample the collection. I am grateful to Mark Horton for sharing his knowledge of the history and character of the Indian Ocean trade networks, and to Horst Liebner, Michael Flecker, and Luc Heymans for their insight into the Cirebon and Intan shipwrecks. My thanks also to Laure Dussubieux and James B. Lankton for sharing their thoughts about glass beads and the glass chemistry of South and Southeast Asia. Many thanks to Bernard Gratuze for conducting the chemical analyses, and to Thilo Rehren for reading and commenting on drafts of this paper. This publication was made possible by NPRP grant 7-776-6-024 from the Qatar National Research Fund (a member of the Qatar Foundation). The statements made herein are solely the responsibility of the author.

THE CIREBON SHIPWRECK

In 2003, the Cirebon shipwreck, also known as the Nanhan shipwreck, was discovered by local fishermen in the Java Sea of Indonesia [*Fig. 1*]. The wreck was not archaeologically excavated: Indonesia has not signed the 2001 UNESCO Convention on the Protection of Underwater Cultural Heritage and, in current legal practice, Indonesian authorities issue permits to private commercial salvage companies for the recovery of shipwrecks and their associated finds (for more on the complex political, economic, and ethical issues related to the maritime heritage of Southeast Asia, and to shipwrecks in particular, see Flecker 2002b; Maarleveld 2011; Tjoa-Bonatz 2016). Such a permit for the salvage of the Cirebon shipwreck was issued in 2005 to Cosmix Underwater Research and Recovery Ltd. The wreck and its cargo were recovered and studied systematically, this work forming the basis for a doctoral degree granted by the University of Leeds (Liebner 2014).

Approximately one half of the Cirebon shipwreck's cargo remains in Indonesia, while the other half was legally purchased by Qatar Museums in 2013. The original cargo is estimated to have weighed some 300 tons and included nearly 500,000 objects. The vast bulk of the cargo (approximately 75%) is made up of ceramic vessels, and other goods onboard include finished products as well as raw materials: metals, gemstones, rock crystal, gold, ivory, aromatics, nuts, glass, beads, and much more. The sources for these goods appear to include Madagascar, Mesopotamia and

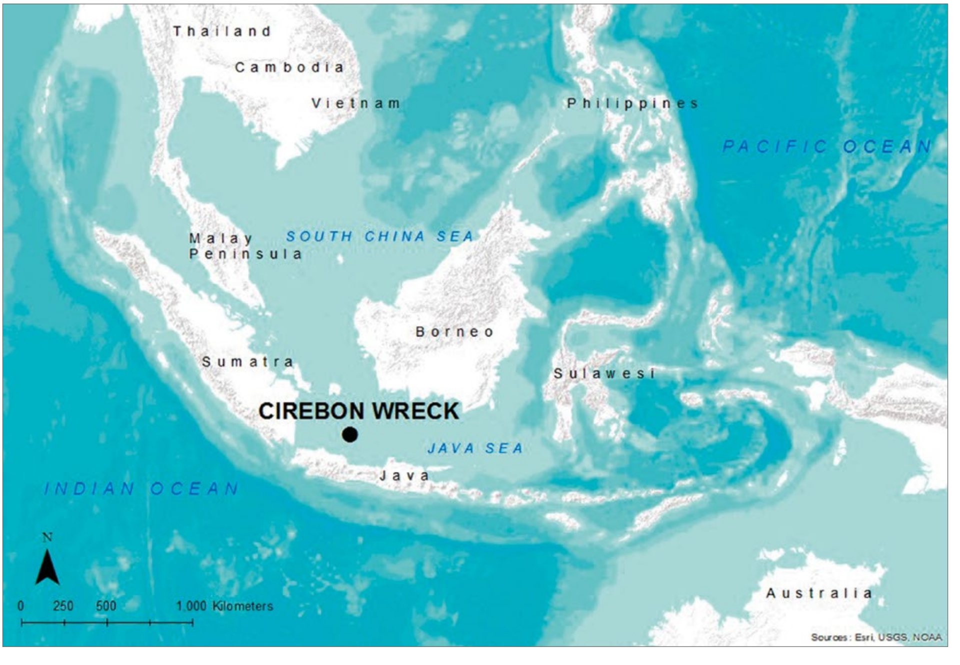

Fig. 1. Map of Southeast Asia showing the location of the Cirebon shipwreck (map C. Swan)

Persia, Afghanistan, South and Southeast Asia, and China; the final cargo was likely assembled together at a port somewhere along the Straits of Melaka. The ship is of Malayo-Indonesian construction, and it is believed to have been sailing from southern Sumatra to northeastern Java at the time of sinking. The event itself can be closely dated to about 970 CE, thanks to the evidence of ceramics and coins in particular.

A variety of beads made of different materials make up a small part of the ship's cargo [*Fig. 2*]. At the time of writing, Qa-

Fig. 2. Examples of the non-glass beads from the Cirebon shipwreck. From top to bottom, left to right: banded stone (round), banded stone (cylinder), jet, garnet (rough), garnet (polished), rock crystal, pearl, lazurite (bicone), lazurite (melon), and ceramic (Photos C. Swan)

tar Museums had registered 26,726 beads made of glass, 2541 beads made of stone (including banded stone, lapis lazuli, and carnelian), 1815 beads made of gemstones (including ruby, garnet, sapphire, garnet, and turquoise), 9748 beads made of pearl, 624 beads registered as wood but actually made of jet (incised with the Arabic words *al malik* in Kufic script), 33 beads made of rock crystal, and 22 ceramic beads (M. Magee, personal communication, June 2017).

In this paper, the typology and chemistry of the glass beads from the Cirebon shipwreck in the collection of Qatar Museums are discussed. Glass beads from closely-dated contexts are rare, so the objects recovered from the Cirebon shipwreck present welcome evidence for the range of beads in circulation within the wider Indian Ocean world about 970 CE as well as their production origins and patterns of movement.

Fig. 3. The glass bead types examined in this paper. From top to bottom, left to right: purple tabular; emerald octagonal tube; dark blue octagonal cone; light blue irregular polygon; red, black, and light blue Indo-Pacific; polychrome oblate with eyes (powdery); polychrome oblate with stratified eyes; and polychrome oblate mosaic (Photos C. Swan)

TYPOLOGY OF THE GLASS BEADS

All of the glass beads and other glass objects (finished vessels and raw glass chunks) from the cargo of the Cirebon shipwreck in the Qatar Museums collection are now believed to have been registered (M. Magee, personal communication, June 2017). 18 glass beads representing different types and decorative variations present within the cargo were selected for examination [*Fig. 3*]. Typological descriptions largely follow the guidelines described by bead expert Peter Francis Jr (2002: 13–15).

◂ **Purple, round tabular** (count: 12): Circular in shape, this type of bead is thin and flat. On both surfaces the circumference is faceted, forming an edge that is beveled nearly to a point. The count of 12 fragments appears to represent nine or ten complete beads of this type. There is some variability in size, with a range of 1.4–2.3 cm in diameter and 0.2–0.3 cm in thickness, although most of the beads are relatively standard in size with a 2 cm diameter and 0.3 cm thickness. The deep purple color of the glass looks opaque until the bead is held up to let the light pass through, revealing its translucency. This bead type was analyzed as *SAMPLE 52*.

◂ **Emerald-green, octagonal tube** (count: 16): This bead type is tubular with eight faceted surfaces along the length that form an octagonal shape when the bead is viewed from the short ends. 12 complete examples and four fragments indicate the presence of at least 15 or 16 complete beads of this type. All of the beads are made of a translucent glass with a distinctive, brilliant emerald-green color; they are mostly of the same size, approximately 1.8 cm in length and 0.7 cm in diameter. This bead type was analyzed as *SAMPLE 53*.

◂ **Dark blue, octagonal cone** (count: 1): A single example of a faceted, cone-shaped bead of translucent dark blue glass. The bead has eight faceted surfaces along its length that give the cone a flared, octagonal appearance. The bead is broken at its narrower end, while the wider end has eight facets cut at a slightly downward angle to form a more rounded terminus; it measures approximately 1.2 cm by 0.6 cm. This bead type was analyzed as *SAMPLE 54*.

◂ **Light blue, irregular polygon** (count: 1): One translucent light blue glass bead has an irregular shape: almost rectangular in section, with an off-center perforation, the shape is rather polygonal with uneven undulating surfaces, measuring ~1.2 cm by 0.5–0.6 cm. No other bead in this combination of size, shape, and color has been registered by Qatar Museums. This bead was analyzed as *SAMPLE 55*.

◂ **Indo-Pacific, red, black or light blue** (count: 24,589): A shortened form of the designation "Indo-Pacific Monochrome Drawn Glass Beads" (Francis 1990: 2), Indo-Pacific beads dominate the Cirebon bead count with 24,589 examples registered by Qatar Museums. On the order of 3–4 mm in diameter, the bulk of these beads is made of opaque red (*SAMPLE 56*) and opaque black (*SAMPLE 57*) glass, but at least seven opaque light blue (*SAMPLE 58*) Indo-Pacific glass beads were also identified in the collection. The inclusions,

Fig. 4. The polychrome oblate eye beads, at high magnification, showing the stratified layering of glass blobs. From top to bottom, left to right: samples 68, 69, 70, and 71 (scale 5 mm); detail of stratified eyes for samples 68, 69 (scale 1 mm) and 70 (scale 5 mm) (photos C. Swan)

pitting, color, opacity, and matt surface of the red and black beads give them an appearance akin more to ceramic than to glass. They are rounded at the edges (R3 according to Francis 1990: 19). Beads of this type were mass produced with the *lada* technique, drawing a hollow tube and cutting small sections (Francis 1990; Abraham 2016: 4), packed in ash and stirred to reheat and give the beads globular or cylindrical bodies with rounded ends (Wood 2016b: 68).

◄ **Polychrome oblate, eye beads** (count: 2040): After the tiny Indo-Pacific beads, this type is the second(?) most numerous amongst the glass beads. The spherical body is faintly flattened at the perforated ends and is classified as oblate in shape; the surface is decorated with applied, multicolored "eyes." There are two variations of glass eye beads [*Figs 4,5*].

The first variation includes a vast majority of the polychrome beads. The body is 1.0–1.3 cm in diameter and is made of translucent opaque red, translucent purple, or (most commonly) translucent dark blue glass. The state of glass preservation makes it difficult to determine with certainty how the beads were manufactured, but it is most likely that they were furnace-wound (i.e., hot glass twisted around a metal rod or mandril). The eyes are "stratified," meaning they were created by adding multiple layers of glass to the surface of a bead that had already been formed and perforated; the individual glass blobs could have been applied directly to the bead while it was held on a rod, but given the number of eyes and their multiple layers it is also possible that the eyes were assembled first and then applied to a bead. To form the eyes, blobs of warm glass were layered in alternating colors of decreasing size (starting from the body, moving outwards): first white glass, then red or purple or blue glass, then white again, and finally blue. Weathered surfaces of the beads have made this stratified layering much more pronounced [*Fig. 4*]. The eyes are applied in two or sometimes three rows, and they may originally have been marvered flush with the body, as seems to be the case for the better-preserved dark blue beads with two-layer eyes from the cargo of Intan, another

Fig. 5. The second variation of eye beads, with a powdery weathered surface, at high magnification. From left to right: samples 61 and 62 (scale 5 mm) (photos C. Swan)

10th-century shipwreck in the Java Sea (M. Flecker, personal communication, June 2017).

Four eye beads of the first variation were selected for analysis based on their differing color combinations. ***Sample 68*** has a translucent dark blue body with 10 eyes total in two rows, each eye composed of four layers (white-red-white-blue). ***Sample 69*** has a translucent dark blue body with 12 eyes total, arranged in three haphazard rows, and each eye has two layers (white-blue). ***Sample 70*** has a translucent purple body decorated with 10 to 13 eyes total, and each eye has four layers (white-purple-white-blue); most of the eyes have fallen off the bead, leaving craters that indicate their original position but make the total count uncertain. ***Sample 71*** has an opaque red body with 10 eyes in two rows, and each eye has four layers (white-blue-white-blue).

The second variation of the eye beads stands out in appearance from the first. These beads, too, have eyes applied in two rows, but the eyes look notably different: the pupil of the eye is vertically oblong, surrounded by an almost rectangular patch of contrasting color, with thin rectangular borders. These beads have weathered in a manner different from the first variation, suggesting they have a different composition. They have a powdery surface that has discolored to pale pastel hues: ***sample 61*** has a yellow body and eyes seem to consist of light turquoise-green, white, and perhaps blue glass [*Fig. 5*]. The eyes remain flush with the body of the bead. These beads are oblate in shape and consist of two different sizes: the smaller examples are 1–1.3 cm in diameter and the larger ones are 1.2–1.7 cm in diameter. In number, there are far fewer beads of this type within the cargo, with some 30 fragments in the collection of Qatar Museums. This bead type was analyzed as ***sample 61*** (larger size) and ***sample 62*** (smaller size).

◄ **Polychrome oblate, mosaic** (count: 63): This type of polychrome oblate glass bead is comparatively large in size (1.5–2.0 cm in diameter), and consists of many colors and complex decorative schemes. The patterns are not applied to the surface, but are made using a mosaic technique. To produce beads of this type, bundled rods or threads of various glass colors had first to be fused together to form a pattern (stripes, dots, eyes, etc.); once cooled, these rods were then cut into slices, and several slices were likely melded together by joining around a mandril after reheating (Francis 2002: 11) as there is no visible seam that would suggest a mosaic plaque being folded. In this way, the colored pattern extends all the way through the bead, rather than resting on the surface like the stratified eyes of the smaller polychrome oblate beads.

Five beads with four decorative patterns and color schemes were selected for analysis [*Fig. 6*]. The greenish glass of ***Sample 64*** is strewn with bundled white and purple "eyes" that are surrounded by a field of orange; bundles of white and red threads, and bundles of yellow and green threads, create patches of color with dotted or striped effects. ***Samples 65*** and ***66*** are very similar in appearance to sample 64; they are distinctive because they do not have red and white bundles, and very little orange glass is visible. ***Sample 67*** also appears to be quite similar: the striped ef-

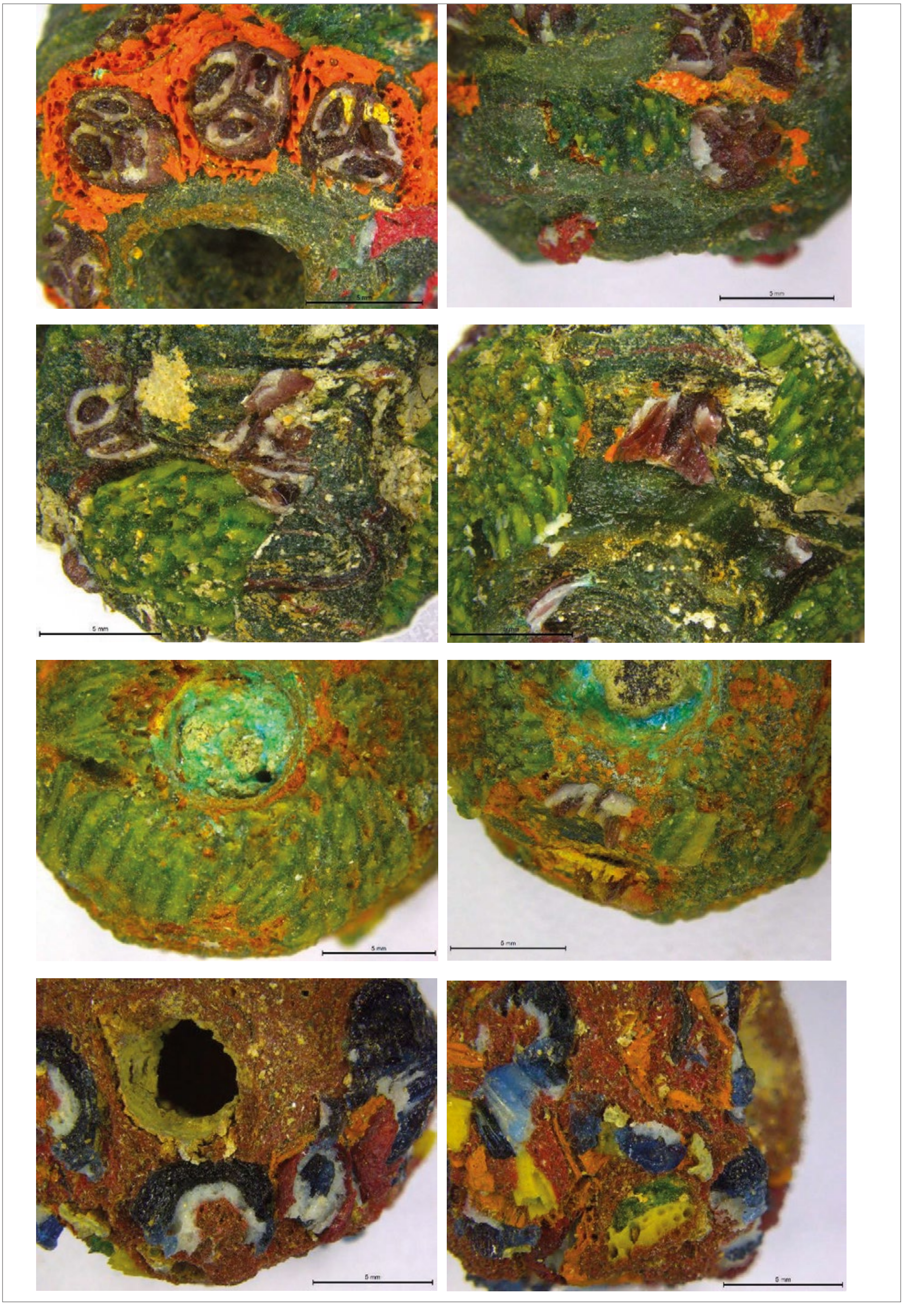

Fig. 6. The polychrome oblate mosaic beads, at high magnification, showing their color combinations and patterns. From top to bottom, with two photos each (scale 5 mm): sample 64, 66, 67, and 63 (photos C. Swan)

fect of yellow and green is best preserved here and dominates the decoration, but there is a hint of the same purple-and-white eyes in the field of an orange motif. ***Sample 63*** is the most distinctive mosaic bead, consisting of an opaque red body strewn with patches of color that include all the hues previously noted except for purple: clusters of yellow, green, and orange as well as blue-and-white eyes.

CHEMISTRY OF THE GLASS BEADS

A chemical analysis was conducted using the technique of Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA-ICPMS), following the methods and instrumental parameters outlined elsewhere (Gratuze 2013; 2016; Swan et al. 2017: 104–105). This technique is virtually non-destructive, as no sample preparation is necessary for analysis and no visible damage occurs to the object of study. The chemical analysis of the beads was sometimes highly challenging, due to the weathering of the objects that includes cratering and pitting of the surface as well as glass layers delaminated and lost; for the mosaic beads (***samples 63–66***), in some cases it was also difficult to isolate a particular color during analysis, while for the powdery eye beads (***samples 61–62***) it was particularly difficult to find an area of non-corroded glass to analyze. Because the beads have variable added colorants and opacifiers, usually in high amounts, the reduced chemical composition of the glasses is given alongside average compositional data [*Table 1*] in order that the base glass compositions be more easily comparable to other published analytical data (Brill 1999: 9). The results show that most of the Cirebon samples are the soda-lime-silica glasses characteristic of West Asian (Middle Eastern) glass production; glasses containing high lead were also identified, and are likely also of West Asian origin, while glasses containing high alumina are of South Asian origin.

Glass beads with a West Asian chemical composition include the purple, round tabular beads (***sample 52***); the dark blue, octagonal cone bead (***sample 54***); the polychrome oblate, eye beads (***samples 68–71***); and the polychrome, oblate mosaic beads (***samples 63–67***). The average composition for this group as a whole, and for the different glass colors, is given [see *Table 1*]. These glasses are soda-lime-silica glasses, with an average composition of 12.4 wt% Na_2O, 5.8 wt% CaO, and 62.5 wt% SiO_2; the average magnesia and potash content (3.8 wt% MgO and 3 wt% K_2O) indicates the glasses were made using a vegetal source of soda, and the soda and manganese are both in keeping with glasses produced in the Middle East (2.9 wt% Al_2O_3 and 1.3 wt% MnO). Whether the glasses were produced in Egypt, Syria-Palestine, Mesopotamia, or Iran is not definitively certain, but a comparison of the samples' trace element composition with that of other Middle Eastern glasses supports the notion that the glasses were made in the eastern rather than western part of that region, i.e., Mesopotamia or Iran (compare with data in Henderson et al. 2016 and Freestone et al. 2017).

Below, the coloring chemistry of the West Asian glasses is highlighted. For the West Asian glasses, a similar basic glass was used across the different bead types and glass colors; the compositions of the different bead types display similar characteristics and compare favorably to the glass vessels and raw chunks that were also carried onboard the ship, further underscoring a common general geographic origin of the glass materials as a whole.

The translucent purple glass used to make the round, tabular beads (*SAMPLE 52*); the body of the polychrome, oblate eye beads (*SAMPLE 70*); and the decoration in the polychrome, oblate mosaic beads (*SAMPLES 64–67*) is quite close compositionally. The glass contains relatively low iron (0.6–0.7 wt% FeO) and a moderate addition of manganese as a colorant (1.6–2.5 wt% MnO). The corcular, tabular beads are perhaps the least similar to the purple glasses, having slightly lower potash, iron, phosphate, titanium, nickel, copper, zinc, and arsenic, as well as slightly higher magnesia than the other purple glasses—patterns that match more closely two glass vessels with purple decoration from the Cirebon shipwreck's cargo.

The same translucent dark blue glass is used for the body and eye decoration of the blue polychrome, oblate eye beads (*SAMPLES 68–69*); for the eyes of the purple and red polychrome, oblate eye beads (*SAMPLES 70–71*); and for the decoration of one variation of the polychrome, oblate mosaic bead (*SAMPLE 63*). These glasses contain relatively high iron (1.4–1.8 wt% FeO), as well as added cobalt (730–1500 ppm Co) and copper

Table 1. Chemical composition of the glass bead samples by glass color, including averages and reduced compositions (after Brill 1999: 9); major and minor oxides in wt%, and trace elements in ppm

Glass color, opacity	Type	Production	*SiO_2	*Na_2O	*K_2O	*MgO	*Al_2O_3	*CaO	*FeO
Purple, translucent	v-Na-Ca	West Asia	68.9	13.7	3.87	3.34	3.27	6.22	0.70
Dark blue, translucent	v-Na-Ca	West Asia	67.6	14.0	3.22	4.24	3.17	6.26	1.51
Greenish, translucent	v-Na-Ca	West Asia	68.4	13.6	3.27	4.04	3.39	6.43	0.89
Orange, opaque	v-Na-Ca	West Asia	67.8	13.9	3.55	4.20	3.38	6.38	0.80
Red, opaque	v-Na-Ca	West Asia	65.7	13.5	3.09	4.29	2.92	6.17	4.32
White, opaque	v-Na-Ca	West Asia	69.2	13.8	2.98	4.72	2.76	5.98	0.51
Yellow, opaque	v-Na-Ca	West Asia	69.1	13.0	3.60	3.47	3.60	6.30	0.86
All glasses average	v-Na-Ca	West Asia	68.3	13.6	3.29	4.13	3.21	6.33	1.13
Red, opaque	Pb-Na	West Asia	65.3	10.5	2.47	5.85	3.41	9.01	3.48
Emerald-green, translucent	Pb-Na	West Asia	68.4	10.0	2.68	4.09	4.38	9.04	1.41
Red, opaque	m-Na-Al	West Asia	63.8	19.4	1.66	0.60	7.70	3.67	3.17
Black, opaque	m-Na-Al	South Asia	63.5	15.6	2.07	0.63	13.04	3.76	1.39
Light blue, opaque	m-Na-Al	South Asia	67.4	15.9	2.93	0.54	9.41	2.25	1.56
Light blue, translucent	m-Na-Al	South Asia	75.3	14.0	1.06	0.27	4.21	4.64	0.50

(1380–2070 ppm Cu) working as colorants. The composition of the octagonal cone bead (*SAMPLE 54*) is slightly different from the other dark blue glasses, having the lowest iron, manganese, cobalt, and copper (0.9 wt% FeO, 0.08 wt% MnO, 360 ppm Co, 670 ppm Cu). Overall, the composition of the dark blue glass beads matches well with the translucent dark blue glass vessels and raw chunks that were also carried in the ship's cargo.

Four slightly different glasses of green color are used to decorate the polychrome, oblate mosaic beads. A grayish-green glass is used to make the body of four of these beads: in *SAMPLES 65–67*, this grayish-green color is due to the addition of copper (2.6–3.7 wt% CuO), and the glass also contains a small amount of tin and lead (0.2–0.4 wt% SnO and 0.7–0.8 wt% PbO); the body of *SAMPLE 64* is visually the same color as these other three beads, but the glass has comparatively much less copper (0.16 wt% CuO) and no tin or lead. In *SAMPLES 65–67*, the greenish glass that appears with the yellow threads, forming patches of yellow-and-green stripes or dots, has higher copper and lead (3.8–4.3 wt% CuO and 1.1–1.2 wt% PbO) as well as notable zinc (0.6–0.9 wt% ZnO) that could indicate the use of scrap brass as a colorant. In *SAMPLE 63*, the green glass that decorates the opaque red bead body is also colored by the addition of copper (2.7 wt% CuO) but the glass differs from the other green glasses in its lower silica and manganese as well as higher lead (55 wt% SiO_2, 0.8 wt% MnO, and 12.3 wt% PbO).

Opaque yellow glass is used in all of

Table 1. (continued)

SiO_2	Na_2O	K_2O	MgO	Al_2O_3	CaO	FeO	TiO_2	MnO	P_2O_5	Cl	CoO	CuO	ZnO	SnO_2	PbO
66.7	13.3	3.74	3.23	3.17	6.02	0.67	0.12	2.01	0.22	0.62	0.00	0.00	0.01	0.00	0.00
65.6	13.5	3.13	4.11	3.08	6.07	1.46	0.13	1.21	0.20	0.66	0.12	0.20	0.04	0.01	0.07
63.3	12.6	3.02	3.74	3.14	5.95	0.82	0.12	1.66	0.21	0.75	0.00	3.11	0.34	0.15	0.80
53.9	11.0	2.82	3.34	2.68	5.07	0.64	0.09	1.10	0.16	0.57	0.00	12.62	1.19	0.78	3.70
60.2	12.4	2.84	3.94	2.68	5.66	3.96	0.11	1.13	0.18	0.64	0.06	1.67	0.42	1.30	2.18
62.9	12.6	2.70	4.29	2.51	5.43	0.46	0.09	0.87	0.13	0.69	0.00	0.02	0.01	4.11	3.06
60.6	11.4	3.15	3.04	3.16	5.52	0.75	0.12	1.67	0.21	0.62	0.00	0.05	0.01	1.34	8.12
62.5	12.4	3.01	3.78	2.93	5.78	1.03	0.11	1.32	0.18	0.66	0.03	1.43	0.18	1.18	3.19
48.7	7.8	1.84	4.36	2.54	6.71	2.59	0.12	0.79	0.18	0.52	0.01	2.20	0.63	0.53	19.97
52.2	7.6	2.05	3.12	3.34	6.89	1.08	0.12	0.05	0.17	0.73	0.00	1.39	0.24	0.05	20.60
62.2	18.9	1.62	0.59	7.50	3.57	3.09	0.60	0.05	0.06	0.69	0.00	0.55	0.00	0.00	0.00
62.4	15.4	2.03	0.62	12.82	3.70	1.37	0.28	0.04	0.04	0.91	0.00	0.01	0.00	0.00	0.00
65.7	15.5	2.86	0.52	9.18	2.19	1.52	0.32	0.04	0.05	0.51	0.00	1.00	0.00	0.08	0.14
74.2	13.8	1.05	0.27	4.15	4.58	0.49	0.14	0.09	0.12	0.84	0.01	0.00	0.00	0.00	0.00

the polychrome, oblate mosaic beads (although it was not analyzed for *SAMPLE 64*); yellow is of course part of the yellow-and-green striped or dotted decoration in *SAMPLES 64–66*, and it also appears as irregular patches in *SAMPLE 63*. The yellow glasses appear to be compositionally the same; high tin and lead (0.6–1.9 wt% SnO and 5–9.6 wt% PbO) suggest the use of lead stannate as the colorant-opacifier.

Opaque white glass was used in all of the polychrome, oblate eye and mosaic beads. The white glasses are compositionally similar, containing high tin and lead. The white glass of the stratified eyes, however, notably contains more than twice the amount of tin and lead (5–6.8 wt% SnO and 2.7–6.5 wt% PbO) than the white glass used as to decorate the mosaic beads (2–3.6 wt% SnO and 1.5–2.4 wt% PbO). The opaque white glasses as a group contain slightly lower iron and manganese and higher magnesia (0.4–0.5 wt% FeO, 0.6–1.5 wt% MnO, and 3.6–5 wt% MgO) than the opaque yellow glasses (which contain 0.7–0.8 wt% FeO, 1.6–1.8 wt% MnO, and 2.8–3.5 wt% MgO). The white glasses contain the highest tin of any of the other opacified glass colors.

Opaque orange glass is visible in two of the polychrome, oblate mosaic glass beads: *SAMPLES 63* and *64*. The composition for these two orange glasses is the same, with the color produced by adding large amounts of copper (12.4–12.8 wt% CuO) and the opacity due to tin and lead (0.7–0.8 wt% SnO and 3.6–3.8 wt% PbO), although the tin content is much lower than that of the opaque yellow and white glasses. The orange glass has the lowest silica.

Opaque red glass is used to form the bodies of a polychrome, oblate eye bead (*SAMPLE 71*) and the larger polychrome, oblate mosaic bead (*SAMPLE 63*); red is also used to make the four-layer stratified eyes for a bead with a dark blue body (*SAMPLE 68*). All of these red opaque glasses contain added copper as a direct colorant, with iron and lead serving as a colorant facilitator and tin as an opacifier. For all the three samples, copper is 1.4–2.2 wt% CuO and tin is 0.5–1.6 wt% SnO, whereas the amount of iron and lead varies much more. The eye of *SAMPLE 68* contains 3 wt% FeO and 1.7 wt% PbO, while the body of the small eye bead contains 5 wt% FeO and 2.7 wt% PbO. The body of the large mosaic bead contains 2.6 wt% FeO and 20 wt% PbO; as lead makes up such a significant portion of the glass composition, the opaque red glass of *SAMPLE 63* is identified as a lead-soda-silica glass rather than a soda-lime-silica glass; its low silica and soda (48 wt% SiO_2 and 7.8 wt% Na_2O) confirm this identification.

The opaque red of *SAMPLE 63* is not the only glass with high lead in the cargo of the Cirebon shipwreck. The octagonal, tubular beads made of emerald-green glass (*SAMPLE 53*) are also lead-soda-silica glasses rather than soda-lime-silica glasses. Lead was an effective glassmaking flux that served to lower the melting temperature of the glass; lead made the glass softer, and therefore easier to cut or carve, while also enhancing the brilliance of the color. *SAMPLE 53* contains 21 wt% PbO, and the glass is colored green by the addition of 1.4 wt% CuO. Of nine emerald-green glass vessels from the cargo that were chemically analyzed, six have a closely-comparable composition (14–20 wt% PbO) to the emerald-green beads, while three emerald-green vessels have lower lead (8–11 wt% PbO). Many of the emerald-green vessels have wheel-cut decoration or faceting, thus the facet-cut beads might conceivably be from the same workshop; the emerald-green glass vessels of the cargo include shapes and decorative techniques that are linked to Iran (Swan Needell 2018). The Cirebon shipwreck's emerald-green glasses contain lower lead than most other types of high-lead glass: lead-silicates contain ~35–75% PbO, barium-lead-silicates contain >20 wt% PbO, and potassium-lead-silicates contain 35–50 wt% PbO (Wang and Jackson 2014: 54); for example, the analysis of an emerald-green faceted biconical glass bead from the site of Nishapur in Iran resulted in 70 wt% PbO (Wypyski 2015: 125, 129, Table 1, sample 6, MMA48.101.86a; for other examples, see Krueger 2014). For the Cirebon emerald-green glasses, it is possible that a lead-silica glass was mixed with the more common West Asian soda-lime-silica glass to produce the compositional patterns observed here.

While the bulk of the sampled glasses is West Asian (Middle Eastern) in the compositional characteristics, four of the analyzed samples are of the South Asian origin. The three Indo-Pacific beads of opaque red, black, and turquoise glass (*samples 56–58*, respectively) as well as the translucent light blue bead with an irregular polygon shape (*sample 55*) all contain high amounts of soda and alumina [see *Table 1*], making them soda-alumina glasses rather than soda-lime-silica glasses. The low magnesia and phosphorus of these glasses indicate that a mineral form of soda was used as a fluxing agent.

The three Indo-Pacific beads contain the highest soda and alumina (15.3–18.9 wt% Na_2O and 7.5–12.8 wt% Al_2O_3) of any of the glasses analyzed; the glasses also contain very low magnesia, lime, manganese, and phosphate as well as a very different trace element pattern compared to West Asian glasses. These characteristics indicate that *samples 56–58* correspond to a mineral soda-alumina glass that was likely produced in South or Southeast Asia, and the red and black beads display characteristics of the subtype m-Na-Al 1, including high barium and strontium and comparatively lower uranium (Dussubieux, Robertshaw, and Glascock 2009; Dussubieux, Gratuze, and Blet-Lemarquand 2010). The light blue Indo-Pacific bead displays some differences in trace elements, for instance, lower zirconium and barium, but the compositional differences between the three beads appear to relate largely to their coloring chemistry: the red bead is colored by iron (3 wt% FeO) with copper (0.6 wt% CuO), and the light blue bead is colored by copper (1 wt% CuO) that has associated traces of tin and lead; the black bead has no obviously-added colorant, and was likely produced by iron (1.4 wt% FeO) in combination with sulfur (although this particular element was not measured). The translucent light blue bead with an irregular polygon shape (*sample 55*) represents a second subtype of mineral soda-alumina glass, with lower alumina (4.2 wt% Al_2O_3) than the three Indo-Pacific beads; it, too, has a trace element pattern that is distinctive from West Asian glasses, the most notable being its comparatively higher uranium (22 ppm U). Bead *samples 55 and 58* are both light blue in color; the former has lower iron compared to the latter, as well as no added copper as a colorant.

Chemical analysis was most difficult for *samples 61–62*, and the interpretation of the data is therefore limited here. These two polychrome, oblate eye beads have weathered in a very different manner from the other glasses: instead of pitting or delamination, the surface has become powdery and the visible color scheme is a discoloration of the original glass resulting from chemical alteration. Two analyses were conducted for *sample 61* and three analyses for *sample 62*; one set of data was thrown out for each bead, as the glass proved to be too altered from its original composition (evidenced by a significant decrease in soda, magnesia, and lime as well as a significant increase in alumina). The spot tests indicate that in one case, the turquoise green color is a weathering effect of copper in what was originally red glass; the red glass seems to be chemically similar to the red glass used for some of the other polychrome oblate beads (3.1 wt% FeO, 2.2 wt% CuO, 0.6 wt% ZnO, 1.6 wt% SnO, and 1.8 wt% PbO). Two other spots suggest the tested glass was originally blue, colored by iron and small amounts of cobalt and copper, sometimes with associated lead (1.8–4.6 wt% FeO, 0.2–0.5 wt% CoO, 0.3–0.6 wt% CuO, and 0.4–3.7 wt% PbO).

Fig. 7. Comparison of quantity versus relative volume or bulk: a container of 1,824 black Indo-Pacific beads, a container of 931 black and red Indo-Pacific beads, and 47 polychrome oblate beads (Photo C. Swan)

CONTEXTUAL DISCUSSION

BEADS AS CARGO: ORIGINS AND RELATIVE QUANTITIES

It is the chemical data that provide the clearest evidence for the production origins of the glass used to make glass beads. Most of the sampled glasses are soda-lime-silica glasses, typical of contemporaneous West Asian (Middle Eastern) raw materials and glassmaking recipes, and likely originating in the eastern territories of that broad region—Mesopotamia or Iran. Two glasses (opaque red and translucent emerald-green) were found to be lead-soda-silica glasses, but these are also linked to the Middle East based on a comparison of their compositional characteristics with other high-lead glasses; moreover, the use of different West Asian glass types in one bead (e.g., *SAMPLE 63*) and the particular typology of vessels that were made using the same glass as another bead (e.g., *SAMPLE 53*) further underscore the close link of these objects with West Asia. Four of the sampled glasses are soda-alumina glasses typical of South Asian glass production, likely Sri Lanka or southern India. While the bulk of the sampled glasses thus proves to be West Asian in origin, samples were selected to represent the variety of bead types and color combinations present in the cargo of the Cirebon ship: as the West Asian glasses are quite diverse, they therefore comprise the majority of the samples discussed here, whereas the South Asian beads are largely lim-

Fig. 8. From the collection of Qatar Museums: all the Indo-Pacific beads at the left and all the polychrome oblate beads, including both the eye and the mosaic types, at the right (Photo C. Swan)

ited to just two monochrome colors. For the sake of clarity, most of the analyzed glass samples are of West Asian origin, but the bulk of the beads themselves is South Asian in origin.

In terms of sheer quantity, the Indo-Pacific beads of South Asian origin outnumber the beads of West Asian origin. However, in the context of a ship cargo, it is perhaps more useful to compare the size and relative bulk or volume of beads, as counts alone can be misleading in terms of significance and assemblage interpretation [*Fig. 7*]. If we reasonably envision that beads of the same type were acquired and carried together, for example in a leather or cloth bag, the 24,589 tiny Indo-Pacific beads are quite comparable to the physical "amount" of larger polychrome oblate beads [*Fig. 8*]. Similarly, while in the total quantity the glass beads outnumber the beads made from other materials, the polychrome oblate glass beads are similar in size to or larger than the stone beads and have a roughly similar count; therefore, based on the Qatar Museums collection, we might imagine three more-or-less equal size bags full of beads in the cargo hold: one bag of stone beads, one of polychrome oblate glass beads, and one of the tiny Indo-Pacific glass beads. Such hypothetical "eyeballing" is far from precise, but it makes some sense given the context of cargo and how beads would likely have been handled, contained, and moved.

Finally, as previously noted, the collection of Qatar Museums essentially represents half of the original cargo. Taking this into consideration, we might expect to double the number of registered beads to better indicate the original cargo of beads on the ship. Doubling the registered counts given above comes out to the following: 24 purple, round tabular beads; 31 emerald-green, octagonal tube beads; two dark blue, octagonal cone beads; two light blue, irregular polygon beads; 49,178 black and red (perhaps a dozen light blue) Indo-Pacific beads; 4080 polychrome, oblate eye beads; and 126 polychrome, mosaic beads for a total estimated count of 53,443 glass beads. Again, it should be emphasized that this is a mental exercise only, as it assumes an equally-divided collection and does not account for single examples or odd numbers of items, which would be more realistic.

FINDING PARALLELS: PRODUCTION AND MOVEMENT OF GLASS BEADS

The search for parallels for the Cirebon glass beads in archaeological site and museum collections presents some challenges. Early Islamic beads are poorly identified and discussed in the literature, and in the past they were often assumed to be Greek or Roman (Francis 2002: 87–95); there is no firm typology for Islamic glass beads, and there is a general lack of dating and cultural context for these beads because so many examples come from the market (Liu 2012: 59). Many publications and museum online collection records do not include color photographs of beads, and/or show only one view of the bead. Direct, clear parallels with the published beads are thus often difficult to find for the Cirebon examples.

Tiny Indo-Pacific beads are the most recognizable and widespread type of trade bead of all times (Francis 2002: 19–50), and are familiar finds at sites in South and Southeast Asia, China, South Korea, East Africa, South Africa, and as far away as Europe (Francis 1990; Pion and Gratuze 2016). Indo-Pacific beads have a long production history, from the 1st to the 12th centuries CE, probably made first on the southeast coast of India and then spreading to northern India, Sri Lanka, and Southeast Asia (Francis 2002: 31). This type is not typically found on Middle Eastern sites during the Islamic era and is uncommon in the Arabian/Persian Gulf (Francis 1990: 1). However, Indo-Pacific beads were recovered in large numbers at the Iranian port of Siraf, in fact, the bulk of the glass beads at Siraf (39.7%) was found to be of the Indo-Pacific type (Francis 1988: 4); this fact gives good evidence for the role of Siraf and the Gulf in linking the Western and Eastern Indian Ocean trade networks in general, and for the westward route these beads took from South and Southeast Asia to consumption points in Africa and Europe in particular. The Indo-Pacific beads were produced in a wider variety of colors than represented by the Cirebon cargo (including opaque orange, yellow, white, and green, as well as translucent green, purple, and amber; see Francis 1990: 1 and Abraham 2016: 6, Fig. 2). As certain production sites made beads of some colors and not others (Francis 1990: 19), it is possible that the Cirebon beads derived from just one or two sources; m-Na-Al 1 glasses are thought to have been produced in Sri Lanka (Wood 2016a: 177). It would be interesting to know whether the Indo-Pacific beads onboard the Cirebon ship were carried already strung or loose as "pound beads" (Francis 1990: 15–16); to answer this question, a closer examination of the collection in the future could reveal whether there are many collapsed beads, beads with knots, broken beads, or related debris.

The round tabular beads of purple glass do not appear to be a common type, and no published parallels have yet been noted; the dark blue octagonal cone bead and light blue irregular polygon bead face similar challenges in the search for parallels. The octagonal cone is, however, similar in shape to a faceted carnelian bead from Nishapur, which is described as a drop "*Imam*" bead of the type used for Muslim prayer strands (Francis 1989b: 33, Fig. 2 h) or *misbaḥah*; this identification might explain the rarity of this particular bead type in the cargo, as well as help to characterize the nature of the jet beads within the cargo: *al malik* is one of the 99 names of Allah, thus the jet beads are likely to have served as prayer strands (see Jenkins and Keene 1982: 30–32, items 40.170.696 from Nishapur; jet beads made up to 40.8% of the total bead assemblage at Nishapur, and many had incised Arabic inscriptions, see Francis 1987: 3; 1989b: 23 and 35).

Emerald-green glass is not a common color, so beads made of this color are sometimes more obvious in the published literature. Three facet-cut tubular beads of emerald-green glass were recovered during excavations of the 9th-to-10th-century site of Nishapur (Kröger 1995: 196–197, Nos. 269–271); these beads are similar in size and appearance to the Cirebon emerald-green beads, although they are biconical in shape and have a different chemical composition, as noted above. Green beads with a hexagonal tube shape were recovered from the ports of Quseir on the Red Sea, but these larger beads also have a different chemical composition and date to the Roman era (Then-Obłuska and Dussubieux 2016: 93, 97, Fig. 13).

Large mosaic glass beads of the early Islamic period are rather unusual in Southeast Asia (J.W. Lankton, personal communication, February 2017), but various mosaic bead types are indeed found in the region, especially at sites connected to Srivijaya (Francis 2002: 94); round mosaic beads with "complex mosaic eyes" have been reported from Takua Pa, Laem Pho Chaiya, and Sungai Mas (Francis 2002: 93). Although not extremely common, mosaic glass objects (bowls and dishes, cosmetic tubes or tool handles, plaques for architecture or furniture, beads) were produced in the Middle East starting in the 9th century CE (Whitehouse 2014: 13–22). It has been assumed that the source of mosaic glass beads was the core of the Abbasid world in Iraq, near Bagdad and Samarra, although there may be some evidence for their production in Egypt at Fustat (J.W. Lankton, personal communication, February 2017). The pitted surface of the polychrome oblate mosaic beads from the Cirebon wreck makes it extremely difficult to determine how exactly the beads were made (melding, folding, or piercing mosaic plaques) and to compare decorative patterning with better-preserved objects.

One specific variation of the wound polychrome, oblate eye beads holds a particular significance for discussions of production and trade: the dark blue beads with two-layer, stratified eyes of white-and-blue glass. In the literature, these beads are often referred to as "Takua Pa eye beads," a name coined by Francis (1989a: 16) because this type was first identified at an 8th-to-11th-century archaeological site of this name on the west coast of peninsular Thailand (Lamb 1961: 52; note that the proper name for Takua Pa is now recognized as Thung Tuk). Such beads have been excavated at sites in South and Southeast Asia (Francis 1989a: 16; 2002: 97; Guillot 2003: 273; Francis and Hannibal-Deraniyagala 2013: 357) as well as on the coast of East Africa (Wood et al. 2017); all but one of the 245 beads found in the cargo of the Intan shipwreck were eye beads, and more than half of these were dark blue beads with two-layer eyes of white-and-blue glass (Flecker 2002a: 78–79; note that the other beads with two-layer eyes are described as opaque gray, green, and brownish, although it is thought the colors may be an effect of deterioration).

Chemical analyses of a "Takua Pa eye bead" recovered from Unguja Ukuu on Zanzibar (Wood 2016b: Fig. 5 upper right, UU12: UU225) and three examples from Thung Tuk (Wood 2016b: Fig. 6) indicate the glasses are similar in composition: a soda-lime-silica glass made with a vegetal source of soda (v-Na-Ca subtype A in Wood et al. 2017: 886–888 and online supplemental data). That the composition of the glass used to produce the "Takua Pa"-type beads is West Asian is agreed, but the question about where such beads were actually produced remains open.

Because the production of glass objects involves a two-stage process (the primary production of raw glass from its raw materials and secondary production of glass vessels, beads, and other items), it cannot always be assumed that an object was made in the same place as the glass material itself. Francis suggested that the "Takua Pa"-type beads were produced at Thung Tuk because of the abundance of this type at that site (Francis 2002: 97), and another proposed production location is the nearby site of Sungai Mas (Adhyatman and Arifin 1996: 64). Other scholars have agreed that Middle Eastern glasses could have been imported as scrap glass (cullet), raw chunks, or pre-formed tubes to South and Southeast Asia to be used there in the local production of beads, but they also acknowledge that the beads could have been produced in the Middle East and transported as finished products (e.g. Wood et al. 2017: 897).

The Cirebon shipwreck material presents new evidence for a debate on where glass beads were produced and traded, particularly the "Takua Pa"-type eye beads, but the implications are not entirely clear. The Cirebon ship cargo demonstrates that raw chunks of glass were indeed being transported from the West Asian glasshouses to locations in Southeast Asia, in this case as far as eastern Java. Most of the Cirebon glass chunks are notably translucent dark blue in color, but at least one large chunk of translucent light yellow glass was also included in the cargo (Swan Needell 2018). Local production of glass beads using this imported raw material might be assumed, given the history of bead production in the region (Lankton, Dussubieux, and Rehren 2008) and the lack of evidence for secondary production of vessels (Perret 2014: 13). Although no opaque white glass chunks were found in the Cirebon ship cargo, white glass for the eyes of "Takua Pa"-type beads could conceivably have been colored locally at bead production sites in Southeast Asia by the addition of tin oxide to a glass (perhaps a translucent light yellow chunk?), as has been shown for earlier 4th-to-9th-century Bird Star beads (Lankton, Dussubieux, and Rehren 2008: 347–349). As previously noted, the white glass of the Cirebon eye beads has notably different amounts of tin than the white glass of the Cirebon mosaic beads, which are thought to be Middle Eastern products. Tin ingots were recovered from the Cirebon wreck (Liebner 2014: 202–203) and tin was one of the main cargo items of the Intan wreck; SEM analysis of tin ingots from the Intan observed traces of zinc and lead, and a possible origin for the material is the so-called Tin Belt of the Malay Peninsula (Flecker 2002a: 81–83).

The presence of raw chunks of glass in the Cirebon ship cargo supports the conclusion that imported West Asian glass was used in Southeast Asia for the local production of beads, and the translucent dark blue and light yellow colors of this raw glass seem to fit well with the proposed production narrative of the "Takua Pa"-type beads. If we assume that the "Takua Pa"-type beads were indeed produced near Thung Tuk or Sungai Mas, then the finished beads of this type on a ship heading towards eastern Java would seem reasonable: these items could have been taken onboard at a port somewhere near the Straits of Melaka, along with Indo-Pacific beads originating from Sri Lanka and the glass beads, vessels, and chunks originating from the Middle East.

There are, however, a few follow-up questions that may complicate this picture. How do we explain the other varieties of polychrome oblate beads with stratified eyes? These beads are the same size as the "Takua-Pa"-types, and the blue-and-white eyes have the same glass composition. Why do these translucent dark blue, purple, and opaque red beads have four-layer rather than two-layer eyes like the "Takua Pa" beads? Were they made in the Middle East, whereas the "Takua Pa"-type beads were made in Southeast Asia? If all varieties of eye beads were produced locally in Southeast Asia, why are only the "Takua Pa"-type beads reported at Thung Tuk and other sites? Further issues arise when considering the very close chemical composition of all the soda-lime-silica glass vessels, chunks, and beads in the Cirebon ship cargo; even if the eye beads were produced in Southeast Asia from glass imported from the same West Asian glasshouses that produced the rest of the glass cargo, what is the likelihood that the compositions would be such a close match? Could all of the eye beads have been made in the Middle East, including the "Takua-Pa"-types? Many of the patterns of the Cirebon polychrome beads clearly require more careful consideration before conclusive interpretations are made, and no doubt more questions will arise during the process.

Considering the Cirebon shipwreck's cargo of glass beads as a whole assemblage, the variety of types is notably limited: red and black Indo-Pacific beads, polychrome eye or mosaic beads, and just a handful of other types. Some of the best-known contemporaneous types of Middle Eastern glass beads are not present in the Cirebon cargo, for example eye beads with wave-form trailing or drawn and segmented foil beads (Francis 2002; Liu 2012), although these types certainly took part in long-distance trade. Segmented beads in particular "were a key product of the Middle Eastern glass bead industry and are common throughout the region" (Francis 2002: 90–91), for example, at Siraf and Nishapur. Such observations could suggest that the Cirebon cargo represents a limited supply chain or that the merchants and buyers involved in the glass bead trade in Southeast Asia were highly selective in the types of beads they acquired.

CONCLUSIONS

Chemical analysis of 18 glass beads recovered from the cargo of the Cirebon shipwreck indicates two production origins for the glass used to make the beads: West Asia and South Asia. The West Asian glass beads are of particular interest; some of these were likely produced in West Asia and traded to the East via the Persian Gulf, but others, such as the polychrome oblate beads with stratified eyes, are more difficult to interpret—the glass most certainly was produced in West Asia but whether the beads were also produced there or, instead, were made locally in Southeast Asia with imported glass, is not entirely easy to conclude. The chunks of dark blue and light yellow raw glass that were also onboard the ship, which were produced in the Middle East, seem to support the notion that at least the dark blue "Takua Pa"-type beads with a two-layer stratified eye could have been produced locally in Southeast Asia of imported West Asian glass; however, the typological and chemical relationship of this bead variety with the other stratified eye beads bears closer examination. While the Cirebon cargo suggests that a great deal of glass was being imported from West Asia to Southeast Asia in the 10th-century—including various types of beads, raw chunks, and finished vessels—glass beads were also notably being imported to the region from South Asia: numerous, tiny Indo-Pacific monochrome drawn glass beads.

It is unquestionably unfortunate that the Cirebon shipwreck was not archaeologically excavated, as valuable information has no doubt been lost and underwater cultural heritage in Indonesia continues to be at risk. A silver lining of this particular case is that studying the wreck remains can still contribute to our knowledge of material culture. Despite the circumstances, the Cirebon shipwreck does provide a closed context that can be very closely dated by means of ceramics and coins to the year 970 CE. Beads are notoriously difficult to date on their own: some styles and manufacturing traditions are long-lasting and often very difficult to differentiate, while other beads "were essentially unchanged for 1500 years and are worthless for dating purposes" (Francis 2002: 88). To be able to date the glass beads found in the Cirebon cargo to within a few years of 970 CE is a rarity indeed, and it provides an unparalleled opportunity for a close examination of far-flung and widely-dispersed objects like beads; combined with the discriminatory power of chemical analysis, the Cirebon glass beads provide important data that will benefit the broader study of glass beads in West Asia and the Indian Ocean world. Moreover, the context of a ship's cargo and the location of the wreck itself enables us to see the particular movement of a variety of finished beads, as well as raw glass and glass vessels, and to examine how all these objects may have been linked.

Dr Carolyn Swan
UCL Qatar, Research Fellow
c.swan@ucl.ac.uk

How to cite this article: Swan, C. (2020). From sand to sea: tracing the production and trade of glass beads from the 10th-century CE Cirebon shipwreck in the Java Sea. In I. Zych, M. Gawlikowski, and J. Oller Guzmán (eds), *Red Sea trade in resources and other studies. Proceedings of the Red Sea VIII conference in Warsaw, 4–9 July 2017* (=*Polish Archaeology in the Mediterranean* 29/1) (pp. 355–380). Warsaw–London: University of Warsaw Press; Archaeopress. https://doi.org/10.31338/uw.2083-537X.pam29.1.17

References

Abraham, S.A. (2016). Glass beads and glass production in early South India: Contextualizing Indo-Pacific bead manufacture. *Archaeological Research in Asia*, 6, 4–15

Adhyatman, S. and Arifin, R. (1996). *Manik-manik di Indonesia / Beads in Indonesia* (2nd ed.). Jakarta: Djambatan

Brill, R.H. (1999). *Chemical analyses of early glasses* II. *Tables of analyses*. Corning, NY: Corning Museum of Glass

Dussubieux, L., Gratuze, B., and Blet-Lemarquand, M. (2010). Mineral soda alumina glass: occurence and meaning. *Journal of Archaeological Science*, 37(7), 1646–1655

Dussubieux, L., Robertshaw, P., and Glascock, M.D. (2009). LA-ICP-MS analysis of African glass beads: laboratory inter-comparison with an emphasis on the impact of corrosion on data interpretation. *International Journal of Mass Spectrometry*, 284, 152–161

Flecker, M. (2002a). *The archaeological excavation of the 10th century Intan shipwreck* (=*BAR IS* 1047). Oxford: Archaeopress

Flecker, M. (2002b). The ethics, politics, and realities of maritime archaeology in Southeast Asia. *International Journal of Nautical Archaeology*, 31(1), 12–24

Francis Jr., P. (1987). *Report on the beads from Nishapur, Iran in the Metropolitan Museum of Art* (=*Contributions of the Center for Bead Research* 2). Lake Placid, NY: Center for Bead Research

Francis Jr., P. (1988). *Preliminary report on the beads from Siraf, Iran in the Department of Oriental Antiquities, British Museum* (=*Contributions of the Center for Bead Research* 3). Lake Placid, NY: Center for Bead Research

Francis Jr., P. (1989a). *Beads and the bead trade in Southeast Asia* (=*Contributions of the Center for Bead Research* 4). Lake Placid, NY: Center for Bead Research

Francis Jr., P. (1989b). Beads of the Early Islamic period. *BEADS. The Journal of the Society of Bead Researchers*, 1(1), 21–39

Francis Jr., P. (1990). Glass beads in Asia, part two. Indo-Pacific beads. *Asian Perspectives*, 29(1), 1–23

Francis Jr., P. (2002). *Asia's maritime bead trade: 300 B.C. to the present*. Honolulu: University of Hawai'i Press

Francis Jr., P. and Hannibal-Deraniyagala, A. (2013). Beads. In J. Carswell, S.U. Deranigayagala, and A. Graham, *Mantai: City by the sea* (pp. 349–373). Aichwald: Linden Soft

Freestone, I.C., Phelps, M., Simpson, S.J., and Gratuze, B. (2017). *Analytical investigation of Early Islamic glass from Sir Bani Yas (United Arab Emirates)*. Paper presented at the 51st Seminar for Arabian Studies, London, 4–6 August 2017

Gratuze, B. (2013). Glass characterisation using laser ablation inductively coupled plasma mass spectrometry methods. In K. Janssens (ed.), *Modern methods for analysing archaeological and historical glass* I (pp. 201–234). Chichester: John Wiley & Sons Ltd

Gratuze, B. (2016). Analysis of vitreous archaeological materials by LA-ICP-MS. In L. Dussubieux, M. Golitko, and B. Gratuze (eds), *Recent advances in laser ablation ICP-MS for archaeology* (pp. 137–139). Berlin: Springer

Guillot, C. (ed.). (2003). *Histoire de Barus, Sumatra: le site de Lobu Tua* II. *Étude archéologique et documents*. Paris: Association Archipel

Henderson, J., Chenery, S., Faber, E., and Kröger, J. (2016). The use of electron probe microanalysis and laser ablation-inductively coupled plasma-mass spectrometry for the investigation of 8th–14th century plant ash glasses from the Middle East. *Microchemical Journal*, 128, 134–152

Jenkins, M. and Keene, M. (1982). *Islamic jewelry in the Metropolitan Museum of Art*. New York: Metropolitan Museum of Art

Kröger, J. (1995). *Nishapur: Glass of the early Islamic period*. New York: Metropolitan Museum of Art

Krueger, I. (2014). Islamisches Bleiglas und *mīnā*. *Journal of Glass Studies*, 56, 61–84

Lamb, A. (1961). Some glass beads from Kakao Island, Takuapa, South Thailand. *Federation Museums Journal*, 6, 48–55

Lankton, J.W., Dussubieux, L., and Rehren, T. (2008). A study of mid-first millennium CE Southeast Asian specialized glass beadmaking traditions. In E.A. Bacus, I. Glover, and P.D. Sharrock (eds), *Interpreting Southeast Asia's past: Monument, image and text. Selected papers from the 10th International Conference of the European Association of Southeast Asian Archaeologists* II (pp. 355–356). Singapore: NUS Press

Liebner, H.H. (2014). *The Siren of Cirebon: A tenth-century trading vessel lost in the Java Sea* (unpubl. Ph.D. diss.). University of Leeds

Liu, R.K. (2012). Islamic glass beads: the well-traveled ornament. *Ornament*, 36(1), 58–63

Maarleveld, T J. (2011). Ethics, underwater cultural heritage, and international law. In A. Catsambis, B. Ford, and D.L. Hamilton (eds), *The Oxford handbook of maritime archaeology* (pp. 917–941). Oxford–New York: Oxford University Press

Perret, D. (2014). Ancient glass vessels in Southeast Asia: a review of the evidence. In D. Perret and Z. Jaafar (eds), *Ancient glassware in Malaysia: The Pengkalan Bujang collection* (pp. 13–35). Kuala Lumpur: Jabatan Muzium Malaysia

Pion, C. and Gratuze, B. (2016). Indo-Pacific glass beads from the Indian subcontinent in Early Merovingian graves (5th–6th century AD). *Archaeological Research in Asia*, 6, 51–64

Swan, C.M., Rehren, T., Lankton, J., Gratuze, B., and Brill, R.H. (2017). Compositional observations for Islamic Glass from Sīrāf, Iran, in the Corning Museum of Glass collection. *Journal of Archaeological Science: Reports*, 16, 102–116

Swan Needell, C. (2018). *Cirebon*: Islamic glass from a 10th-century shipwreck in the Java Sea. *Journal of Glass Studies*, 60, 69–113

Then-Obłuska, J. and Dussubieux, L. (2016). Glass bead trade in the Early Roman and Mamluk Quseir ports—A view from the Oriental Institute Museum assemblage. *Archaeological Research in Asia*, 6, 81–103

Tjoa-Bonatz, M.L. (2016). Struggles over historic shipwrecks in Indonesia: economic versus preservation interests. In B. Hauser-Schäublin and L.V. Prott (eds), *Cultural property and contested ownership: The trafficking of artefacts and the quest for restitution* (pp. 85–107). London: Routledge

Wang, K.-W. and Jackson, C. (2014). 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. *Journal of Indo-Pacific Archaeology*, 34, 51–60

Whitehouse, D. (2014). *Islamic glass in the Corning Museum of Glass* II. *Mosaic glass, blown vessels without decoration; vessels with mold-brown or pincered decoration; objects with applied decoration; gold glasses; bracelets; miscellaneous objects; and molds*. Corning, NY: Corning Museum of Glass

Wood, M. (2016a). Eastern Africa and the Indian Ocean world in the first millennium CE: the glass bead evidence. In G. Campbell (ed.), *Early exchange between Africa and the wider Indian Ocean world* (pp. 173–193). Cham: Springer International Publishing

Wood, M. (2016b). Glass beads from pre-European contact sub-Saharan Africa: Peter Francis's work revisited and updated. *Archaeological Research in Asia*, 6, 65–80

Wood, M., Panighello, S., Orsega, E.F., Robertshaw, P., Elteren, J.T. van, Crowther, A., Horton, M., and Boivin, N. (2017). Zanzibar and Indian Ocean trade in the first millennium CE: The glass bead evidence. *Archaeological and Anthropological Sciences*, 9(5), 879–901

Wypyski, M.T. (2015). Chemical analysis of early Islamic glass from Nishapur. *Journal of Glass Studies*, 57, 121–136