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Shattered glass of Beirut: collaboration between the Archaeological Museum (American University of Beirut) and international partners following the 2020 port explosion

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The Archaeological Museum at the American University of Beirut (AUB) lies approximately 3 km west of the main port of Beirut, the site of the massive explosion that sent a catastrophic shockwave through the city on 4 August 2020. A display case containing Classical and early Islamic period glass vessels was smashed against the museum's stone floor, shattering 72 vessels into thousands of shards. This paper overviews how the Archaeological Museum (AM) responded to the situation with international partners to document, collect, identify, study, conserve and restore the broken pieces, and how this process of recovery would ultimately imbue the vessels with new historical resonance. In particular, the paper presents a collaborative project with the British Museum (BM) that developed from broader international-AM efforts. The partnership had three objectives: (i) to reconstruct eight of the shattered vessels in conservation laboratories at the BM; (ii) to provide training for a museum professional from the AM as part of the restoration programme in London; and (iii) to conduct scientific analyses of the broken shards before conservation. A fourth objective was realized August–October 2022, when the reconstructed vessels were featured in a single-room exhibition at the BM titled *Shattered Glass of Beirut*, jointly developed by AM and BM curators, in which the vessels helped tell a broader story about the port explosion and its effects on the people of Lebanon.

Keywords Beirut port explosion, glass conservation, museums, American University of Beirut, British Museum, heritage management

At 6.08 pm, on 4 August 2020, Lebanon was rocked by a massive explosion in the Port of Beirut, when a warehouse fire ignited 2750 tonnes of inappropriately stored ammonium nitrate. The explosion is considered to be one of the most powerful non-nuclear explosions in history, and its effects were recorded by the Jordan Seismological Observatory as equivalent to a 4.5-magnitude earthquake (Mady *et al.* 2020: 2; Verma 2020). The resulting shockwave swept across the city as a destructive pulse, blowing out glass from buildings up to 10 km away. At least 230 people were killed, 7000 injured and 300,000 left homeless. The shockwave damaged medical facilities as well as

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educational, cultural and social institutions, affecting not only daily life in Beirut, but deeply impacting everyone in Lebanon and the diaspora. The disaster compounded an already precarious political and economic situation created by the severe Lebanese financial crisis and its stringent capital controls, as well as the ongoing Covid-19 pandemic.

The cultural institutions most badly affected were those in the port-front neighbourhoods of Gemmayzeh and Mar Mikhael, renowned for their historic buildings, art galleries and creative spaces (Fig. 1). According to early assessments by UNESCO and the Ministry of Culture, over 640 historic buildings were damaged, of which 60 were at risk of collapse (Mady *et al.* 2020). The Marfa' Gallery and Galerie Tanit were practically destroyed, and other art galleries sustained extensive damage (including the Opera Gallery, Galerie Alwane, Beirut Art Centre, Ashkal Alwan, Galerie Sfeir-Semler, Saleh Barakat Gallery, Agial Gallery, Galerie Janine Rubeiz and Letitia Gallery). The Sursock Museum, a modern and contemporary art museum housed in an early 20th century villa in Ashrafieh, sustained significant damage to its infrastructure and to collections displayed in its upper floors.

Of Beirut's three main antiquity museums, the National Museum of Beirut and the Museum of Lebanese Prehistory at Saint Joseph University sustained infrastructural damage, particularly to their doors and windows, however, the Archaeological Museum (AM) at the American University of Beirut (AUB) also suffered damage to its collections. A few days after the explosion, when roads had become more accessible, the AM's newly-appointed curator, Nadine Panayot (officially scheduled to commence her position on 1 September), entered the Post Hall building in which the AM is housed with fellow museum staff to assess the damage. Windows were smashed, and the enormous 118-year-old wooden door that opened onto the main exhibition hall had been blown from its hinges. Fortunately, they found the galleries mostly unaffected until they came to the Phoenician Gallery, where a 2-metre-wide case containing 74 Classical and Islamic period glass vessels had been blown forward, smashing the case and its contents on the marble floor (Figs 2 and 3). With the exception of two small flasks subsequently found intact in the debris, the vessels were shattered into thousands of shards of ancient coloured and clear glass, mixed with glass from the display case and from the windows that had blown in around it (Panayot 2022; The MainGate 2020/2021).

The Archaeological Museum at the American University of Beirut

Established in 1868, the AM at the AUB is the third oldest museum in the Near East (after Cairo and Istanbul). Its foundation was a gift of 135 Cypriot artefacts by Luigi Palma di Cesnola, the American

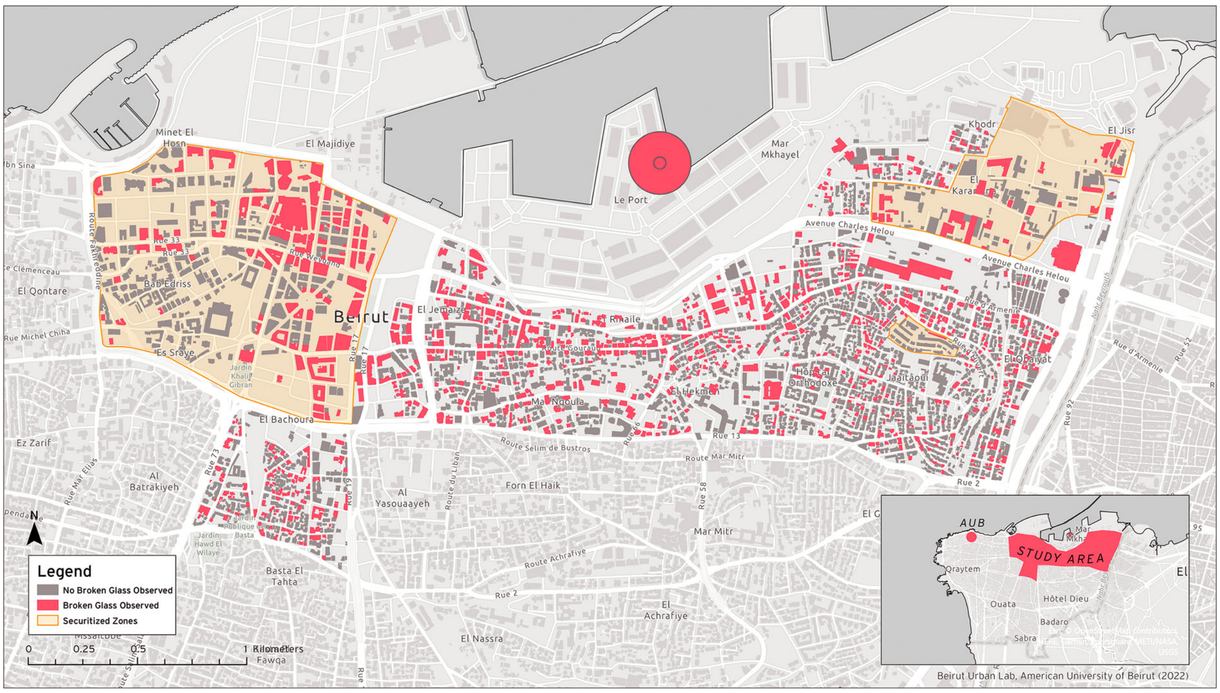


Figure 1 Some of the cultural institutions in Beirut affected by the 4 August 2020 explosion (blast site indicated by red circle).

consul in Cyprus (Mackay 1951: vii–xv; Woolley 1921). The museum expanded through the 19th and early 20th centuries, serving primarily as a teaching collection. During this period it acquired objects as donations or acquired them from the market; most of the 74 glass vessels in the damaged display case were registered at this time. Acquisition processes changed with evolving scientific methodologies, and in the mid-1950s the museum commenced excavations at Tell el-Ghassil in the Beqaa Valley as both a student training dig and as a means of acquiring objects with provenance. As Dimitri Baramki (AM Director 1951–1975) observed: 'the Museum will grow more from artifacts coming from such excavations, rather than from other sources and the scientific value of the collection will thus be greatly enhanced' (Baramki 1967: 13). Baramki also exchanged artefacts with other museums to supplement the AM collection and to fill chronological and regional gaps, for example exchanging Palaeolithic stone tools from Lebanon with Mesopotamian sherds from the Museum of Iraq (Badre 2020: 111). Today the museum comprises approximately 16,000 artefacts from Lebanon, Syria, Cyprus, Egypt, Palestine, Iraq and Iran.

The 2020 port explosion is part of a longer tradition of political violence witnessed by the AUB. During the period commonly referred to as the Lebanese Civil War (1975–1990), the AUB campus was shelled repeatedly, particularly in the 1980s, and the University saw several of its students and members of faculty kidnapped or assassinated. In 1982, AUB President George S. Dodge was kidnapped and released a year later, and in 1984 AUB President Malcolm H. Kerr was assassinated by two gunmen outside his office near the Post Hall steps, metres from the AM. In 1991, a bomb destroyed College Hall, one of the most symbolic buildings on campus, housing administrative offices and teaching facilities. Throughout this troubled period, the AM was the only museum in Beirut to remain open, even in the darkest years of 1982 and 1989 when university teaching was intermittently suspended.

With more stable conditions, Leila Badre (AM Director 1975–2020) undertook a major renovation of the museum that was completed in June 2006, with support from the Society of the Friends of the Museum and the Joukowsky Family Foundation (Badre 2020). Badre updated the displays and expanded the exhibition space, including the addition of a mezzanine. The display of glass vessels was developed as part of this refurbishment.

Chronologies of international co-operation

In August 2020, the world watched with horror the images coming out of Beirut. The city's residents, in spite of their shock, anger and sadness, were quick to start the clean-up, supported by compatriots from other regions. The international community offered considerable assistance, with most support directed to rehousing the homeless, treating the injured, rebuilding infrastructure and equipping hospitals and medical facilities. In contrast, the cultural sector found itself reliant on private and institutional initiatives (Mady *et al.* 2020).

Figure 2 **The centrepiece case of the *Glass through the Ages* display at the AUB Archaeological Museum before the 2020 explosion. Courtesy of the AUB Archaeological Museum.**

Figure 3 The display case following the explosion, August 2020. Courtesy of the AUB Archaeological Museum.

The 72 shattered glass vessels at the AM presented an immediate logistical problem that required careful recovery before more intricate conservation work could occur. With no conservation facilities or trained conservator of its own, the AM looked for international assistance. The various initiatives that developed can be divided into six 'missions' (summarized in Panayot 2022 and The MainGate 2020/2021), of which the AM-BM collaboration is one part.

First mission: recovery

Following the explosion, Panayot immediately sealed the room containing the damaged case and sought advice from the Institut national du patrimoine (INP), with whose director, Charles Personnaz, Panayot had been previously corresponding to establish a joint INP-Lebanese conservation programme. In early September 2020, the INP dispatched specialist glass conservator Claire Cuyaubère to supervise the lifting of the collapsed display case and to start collecting and sorting the fragments, assisted by AM staff and volunteers — part of a rescue team assembled by Panayot to assist museums affected by the explosion (mostly ex-Master's students in Museum Studies and Cultural Heritage Management from the University of Balamand).[1] Like an archaeological excavation, the recovery established a grid system to help identify fragments from the same vessels that had, presumably, shattered in the same place (Fig. 4). The shards were then roughly attributed to each of the 72 vessels and packed in discrete boxes using conservation materials provided by the INP, materials that were unavailable in Lebanon following the blast (Fig. 5). At this preliminary stage, 15 objects were identified as promising candidates for reconstruction, although this number would increase with ongoing work. The initial recovery was documented by the AUB Communications Department, which released a YouTube video on AUB social media channels in late 2020.[2]

Second mission: puzzle-work and restoration

During June–July 2021, Cuyaubère led a second INP mission to commence the conservation of those vessels deemed restorable, assisted by AM staff, AUB student volunteers and INP intern, Cécile Rodier.[3] Restoration first involved intricate puzzle-work, in which the shards of each vessel were laid out and arranged in order to determine the degree to which each vessel could be restored, and to identify shards that had been mis-attributed in the initial recovery (Fig. 6). Twelve vessels were reconstructed: Panayot returned these vessels to the gallery on the first anniversary of the explosion, a moment celebrated in a powerful video created by the AM team and shared on its social media channels.[4] Stephen Koob, Chief Conservator Emeritus at the Corning Museum of

[1]This first collaboration with the INP was supported by ALIPH (the International Alliance for the Protection of Heritage in conflict areas).

[2]'#AUB4Beirut: Museum Recovery Fund', www.youtube.com/watch?v=_HZzNuCVPz4.

[3]This work was further funded by ALIPH.

[4]'AUB Archaeological Museum Restoration', https://www.youtube.com/watch?v=PmSLJ0qez5Q, produced by the AUB and Haroun Studios.

Figure 4 Archaeological Museum staff, volunteers and Claire Cuyaubère (INP) collecting and sorting glass fragments in September 2020. Courtesy of the AUB Archaeological Museum.

Figure 5 Boxes assigned to individual vessels as part of the recovery effort at the Archaeological Museum at AUB, September 2020. Courtesy of Claire Cuyaubère for the AUB Archaeological Museum.

Glass in New York, volunteered to join the AM in Beirut for two weeks in January 2022, and worked together with Cuyaubère to restore a further six glass vessels. His contribution was documented in a short video by the US Embassy in Beirut.[5]

The puzzle-work and restoration treatments presented an opportunity to educate and train. While in Beirut, Cuyaubère and Koob taught an intensive theoretical and hands-on course on glass degradation for archaeologists, and Panayot used the ongoing restoration to develop a new field course in partnership with AUB's Department of History and Archaeology at the Faculty of Arts and Sciences.

[5]'Glass Restoration at AUB Archaeological Museum', www.youtube.com/watch?v=e6130eXVTqk.

Figure 6 Conservator Claire Cuyaubère (Institut national du patrimoine) undertaking initial puzzle-work at the Archaeological Museum, July 2021. Courtesy of the AUB Archaeological Museum.

Third mission: 3D imaging

In mid 2021, a significant accomplishment in the realm of 3D glass reconstruction was achieved through a collaboration with the AUB's Faculty of Engineering and Architecture (MSFEA). This partnership led to the establishment of the Digital Cultural Heritage (DITCH) incubator, which focused on the development of virtual 3D reconstructions of damaged glass vessels (Fig. 7). This groundbreaking approach aims to address the risks associated with manual reassembly by proposing an automatic solution for reconstructing broken glass relics. It offers exciting possibilities to breathe new life into artefacts by creating holograms or replicating the original pieces via 3D printing. The work led to a MA thesis — Automatic Reassembly of Broken Relics Using Machine Learning Algorithms (Kawtharani 2023) — that developed virtual 3D reconstructions for a selection of fragmented glass vessels. The proposed approach involves digitizing the shards and utilizing a geometric method based on projections in the manifold space to provide conservators with an augmented reality (AR) tool that can project the completed object like a solution to a jigsaw puzzle, enabling them to seamlessly restore the fragments. Preliminary results have shown successful matches among the pieces, although cyclic matches were not detected. Nevertheless, this had no significant impact on the algorithm's performance, as demonstrated by the alignment results. To achieve a fully automated and flawless output, further refinement of surface extraction techniques and the determination of final shard positions are still necessary.

Fourth mission: scientific analyses

The analysis of broken shards allows for scientific investigations using sampling methods that would, typically, not be possible for studying complete objects in museum collections. To explore aspects related to manufacturing, origin and usage, the AM collaborated with the AUB's Department of Physics, as well as the Science and Technology in Archaeology and Culture Research Centre (STARC) at the Cyprus Institute. The focus was on employing non-invasive techniques, reserving invasive sampling only for fragments that could not be restored. This project aims to examine the elemental composition of shards derived from shattered glass artefacts, utilizing sampling techniques that are typically not feasible for complete museum objects. The chemical analyses of these shards will contribute valuable insights into the provenance and dating of the original glass, information that is currently unknown or unverified. Despite the historical significance of glass production along the eastern Mediterranean coast during the Roman, Byzantine and Islamic periods, limited chemical analysis of glass objects found in Lebanon has occurred due to ongoing political instability.

Figure 7 **3D model of flask (inventory number 4510) using digital scans of extant fragments. Courtesy of the AUB Archaeological Museum.**

Consequently, this research will enhance our understanding of ancient glass production in the region. The elemental analyses use locally available techniques, such as portable X-Ray Fluorescence (XRF) and Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS) at the Lebanese National Council for Scientific Research (CNRSL) and AUB, respectively. If necessary, ion beam analysis techniques, such as PIXE (proton induced X-ray emission) and PIGE (proton induced gamma ray emission), at the accelerator facility of the Lebanese Atomic Energy Commission (LAEC-CNRSL) can be utilized to control or complement the measurements. Additional analyses were undertaken in the scientific laboratories at the British Museum (see below). There are plans to expand the non-destructive XRF analyses to include glass vessels at the AUB museum. This comprehensive study of glass artefacts from various eras, potentially extending beyond the AUB museum's collection, would be a unique endeavour in the region.

Fifth mission: international workshop

In mid-January 2022, the AM arranged and hosted a two-day international workshop titled *Through Shattered Glass* (Fig. 8). This multi-disciplinary event examined several aspects of the study of glass including typology, conservation, materiality and digital reconstruction. Opening speeches were presented by Panayot (AM), Hartwig Fischer (BM Director), Charles Personnaz (INP Director) and Thilo Rehren (STARC).

Archaeological Museum/British Museum collaboration

The AM-BM collaboration developed alongside the missions outlined above. Immediately after the explosion, Hartwig Fischer (then BM Director) tasked curators James Fraser and Zeina Klink-Hoppe with drafting a report assessing the impact of the blast upon Beirut's heritage sector (Fraser and Klink-Hoppe 2020). This document aimed to identify possible ways the BM could provide assistance, in consultation with colleagues in Lebanon.

A couple of days after the explosion Klink-Hoppe (an AUB alumna) contacted Panayot to discuss possible BM support. Panayot requested conservation materials and expertise. While Covid travel restrictions and the furlough scheme imposed by the UK government prevented the BM Trustees from dispatching an immediate rescue team to Beirut, the BM offered the services of its World Conservation and Exhibition Centre if vessels could be sent to London. During the June–July 2021 mission led by Cuyaubère, the AM identified eight vessels as being potentially restorable and with shards sufficiently robust for travel (Table 1).[6] In July 2021, the BM provided funding and materials to enable Cuyaubère to remain in Beirut for ten days beyond the INP mission, to continue puzzle-work on the eight vessels and to pack the shards for travel. Fragments were individually wrapped and cushioned in padded and lined boxes to prevent further damage in transit (Fig. 9). The transport crates were air freighted to London in early 2022.[7]

By transporting the vessels to London, the AM-BM collaboration sought to achieve four aims:

[6]Principal funding for BM-based conservation was awarded as a grant from the Museum Restoration Fund by The European Fine Art Foundation (TEFAF). Additional funds for the BM-based conservation, training and scientific analyses were awarded by HENI, The Radcliffe Trust, The Charlotte Bonham-Carter Charitable Trust, The Leche Trust, The Thriplow Charitable Trust, The Wakefield Trust and Friends of the Middle East Department at the British Museum.
[7]The materials were transported between Beirut and London courtesy of Middle East Airlines.

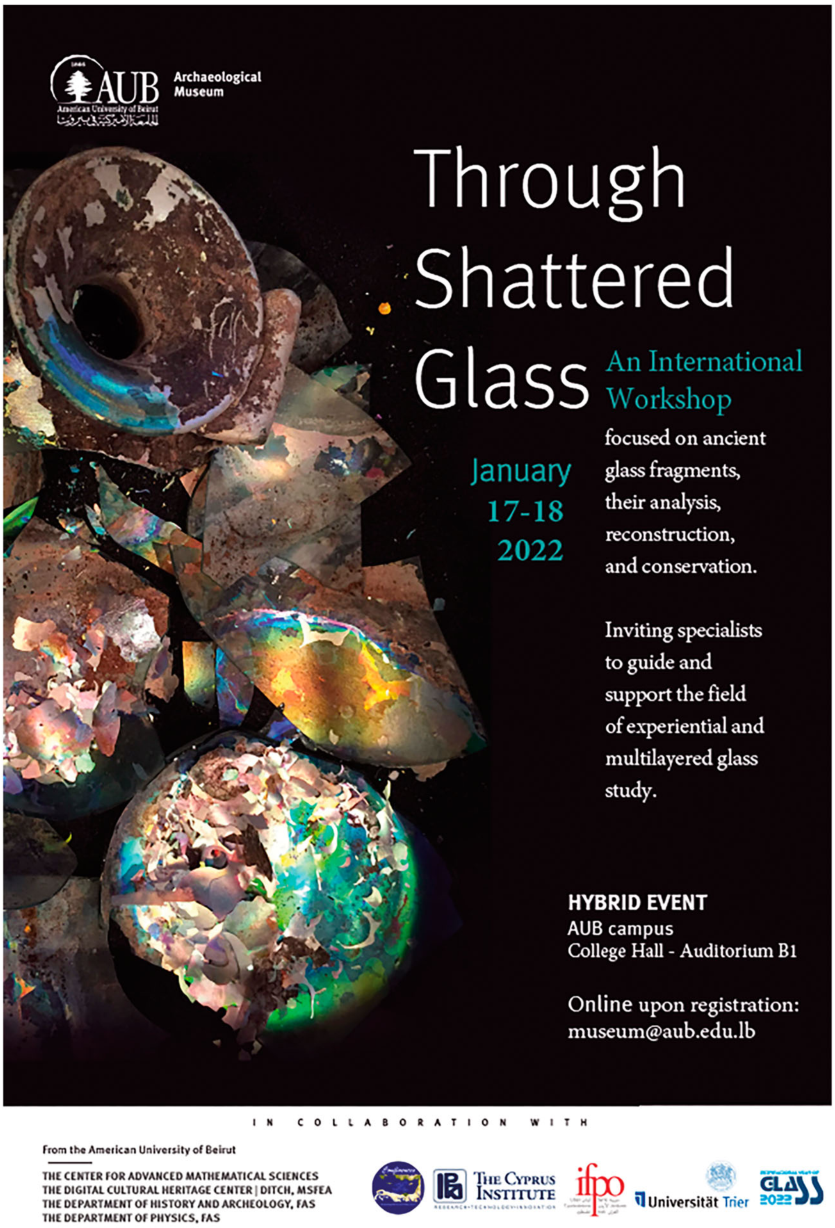


Figure 8 Poster for the conference *Through Shattered Glass*. Courtesy of the AUB Archaeological Museum.

(1) **Conservation:** to restore the eight vessels.
(2) **Training:** to host and train a member of staff from the AM.
(3) **Scientific analysis:** to characterize the chemical composition of the vessels.
(4) **Exhibition:** to display the restored pieces in a jointly curated AM-BM exhibition.

Conservation

With funding secured from The European Fine Art Foundation, the BM hired Cuyaubère, 28 March–8 July 2022, to undertake the conservation of the eight vessels in London, supervised by BM conservator Duygu Çamurcuoğlu and assisted by Aimée Bou Rizk from the AM (see 'Training' below). Following a condition assessment to ensure no damage had occurred in transit, the fragments of each vessel were laid out on tables for close examination. The conservation team sought instruction from Panayot concerning the degree to which the joins should remain distinctive and missing areas in-filled. Following procedures developed during previous conservation missions, a methodology was defined in which new joins were to remain visible as an integral part of the object, and missing areas would only be filled when necessary for the structural integrity of the vessel. The visible joins and negative spaces (losses) of missing shards would, therefore, serve as scars

Table 1 Table of the eight vessels loaned to the British Museum by the Archaeological Museum for restoration. Courtesy of the AUB Archaeological Museum

AUB Inv.#	Period	Date	Object	Provenance	Description	Acquisition Date	H (cm)	W (cm)	Pre-explosion	Post-explosion
3653	Roman	Late imperial, 3rd–4th c. AD	Large Shallow Bowl	Kudus (Palestine)	Very pale-green. Everted thickened shaped rim with two tooling lines just below outer edge; round body, tapering downward then curving in sharply to bottom; ring base with pontil mark at centre. Free blown. Was complete except for chip on rim; thin and matt weathering, few brownish patches on interior and most on underneath of exterior.	Acquired before 1925	6.0	29.2 (rim) 15.25 (base)		
3656	Roman	Late imperial, 3rd–4th c. AD	Shallow Bowl	Dera'a (Syria)	Pale blue-green. Fire rounded, plain vertical rim; convex side to body, tapering downward then curving in sharply to bottom with concentric tooling lines on back side; line folded ring base with slightly convex bottom with pontil mark at centre. Very thin body. Free blown. Was complete; overall healthy glass with some weathering on front side and iridescence on back side, light-brown patched on side and rim.	Acquired before 1925	3.8	21.2 (rim) 10.75 (base)		
3925	Roman	Early imperial, Late 1st c. BC–mid 1st c. AD	Ribbed Bowl	None	Bright blue-green. Vertical rim with edge slightly wavy and uneven; hemispherical body; flat base. Decorated on exterior with fifty-four vertical ribs of fairly same length and width, arranged around bulging middle section of body, ground on interior to top of ribs but not below. Two rotary concentric circles on plain band around top of sides. Cast. Was complete with two small stress cracks; few patches of brown soiling. Exterior well fire polished; small bubbles and one bigger are visible within the glass.	Acquired before 1925	4.5	12.65 (rim) 12.80 (body)		

Continued

Table 1 ***Continued***

AUB Inv.#	Period	Date	Object	Provenance	Description	Acquisition Date	H (cm)	W (cm)	Pre-explosion	Post-explosion
4143	Roman/ Byzantine	Late imperial/ early Byzantine, 4th–5th c. AD	Jug	None	Blue-green, with same colour handle and trails. Trefoil spout made from flat rim with 11/12 trails spiral on underneath; cylindrical neck with single trail around it; cylindrical body blown in a dip mould with slight constriction near base of neck, vertical ribs creating a slanting notched pattern; concave shallow base with pontil mark at centre; rod handle applied to shoulder, drawn up and out, then pinched into fold with loop above, and trailed on to back and underside of rim. Optically blown. Was complete; some powdery, thick, light reddish-brown soil on interior and few silver iridescent patches on surface.	Acquired before 1925	18.5	8.9 (rim) 7.35 (body)		
4150	Roman/ Byzantine	Late imperial/ early Byzantine, 4th–5th c. AD	Flask (amphoriskos)	Nazareth (Palestine)	Green, with same color handles and trail. Everted flaring rim with 1 half trail around it on top; cylindrical wide neck; conical fluted body blown in a dip mould up to just below shoulder, twenty-four almost vertical ribs but going to left near base; flat base nearly solid with pontil mark at centre; two vertical opposite grooved handles from rim to base of neck. Optically blown. One third of the rim was missing down to trail decorating the base of rim; exterior is mostly fire polished; some matt light brown weathering on the surface.	Acquired before 1925	19.6	5.2 (rim) 5.2 (body)		
4218	Roman	Early imperial, 1st c. AD	Beaker	None	Deep yellow. Vertical cracked-off rim; rounded body; slightly concave base; three sets of double line abrasion bands appear below the rim and on body. Blown, wheel cut. Was complete with some stress cracks near rim and on body; iridescent patches mostly on interior, soil line visible on inside from context.	Acquired before 1925	8.9	7.3 (rim) 7.8 (body)		

Continued

Table 1 ***Continued***

AUB Inv.#	Period	Date	Object	Provenance	Description	Acquisition Date	H (cm)	W (cm)	Pre-explosion	Post-explosion
4536	Islamic	Early Islamic, 7th–9th c. AD	Bottle	Described on card catalogue as from Phoenicia	Dull blue-green, yellow stained. Inverted uneven fire thickened rim; long flaring neck; narrow shoulder; domed body; flat base with pontil mark at centre. Free blown and stained (luster-painted, painted with pigments containing silver and/or copper). Was complete but joined in two places at base. Heterogenous thin black deposit (soot?) on exterior and thick, white, blue-green and pink deposit on interior.	Acquired before 1925	18.7	3.55 (rim) 8.5 (body)		
5964	Byzantine	Early Byzantine, 7th c. AD	Small Cup	None	Blue-green, same colour trails. Plain, slightly unturned fire rounded rim; vertical body; slightly concave base with pontil mark at centre. Ten spiral trails starting at rim, lowest two strands pincered together with a separate trail then applied across the centre of the resulting oval, trail above this is slightly wavy. Free blown. Was complete; some light iridescent.	The Ford Collection, donation, 1931	4.9	4.9 (rim) 5.3 (max)		

Figure 9 Fragments from bottle inventory number 4143 individually packed for travel from the Archaeological Museum to the British Museum, July 2021. Courtesy of Claire Cuyaubère for the AUB Archaeological Museum.

signifying the trauma the vessels had suffered and the recovery they had undergone (Fig. 10). Leaving losses unfilled would also help conservators incorporate additional shards in future, possibly unidentified among other fragments awaiting ongoing puzzle-work in Beirut.

The vessels were divided into three categories according to the number of fragments, surface fragility and complexity of treatment. This procedure helped organize the workload and time spent on each vessel, ensuring that the project was completed within the allocated time frame. Category 1 objects had the smallest number of fragments and were the easiest to reconstruct; Categories 2 and 3 were more complex, with surface decoration and degradation, residual deposits or structural losses. Each vessel and its fragments had detailed photography and documentation before, during and after treatment.

Reconstruction of ancient glass is a challenging process, particularly due to a phenomenon known as 'springing': when glass breaks, internal tensions created during manufacture are released, causing the broken shards to become very slightly misaligned. The conservator needs, therefore, to be organized, focussed and experienced in order to achieve the best joins against all the stresses that glass fragments may present. Before each reconstruction, additional puzzle-work was carried out at the BM to ensure that no fragment was missed. This was a painstaking task as it was easy to overlook the smallest fragments, and the conservation team ensured sufficient time was allocated for this crucial step. Additionally, each stage

Figure 10 Vessels after restoration at the British Museum (inventory numbers 3925, 4218, 4143, 5964). Courtesy of the Trustees of the British Museum.

in the conservation process was considered carefully so as not to hinder future conservation and scientific work. For this reason, an initial 'dry reconstruction' (only using tape) helped determine how well the shards joined together and clarified the nature and extent of the missing fragments. However, only three of the eight vessels could sustain dry reconstruction as this technique can only be used on fragments whose surfaces do not contain residual archaeological deposits or iridescence (deteriorated glass) layers.

The final stage of conservation was to reconstruct the vessels with Paraloid® B72 (PB72) conservation adhesive, and, where necessary, to create 'removable' fills to support missing areas. After experimental work and evaluation of results, it was agreed to also use PB72 as a fill material; for consistency in treatment, and for its excellent aging and reversibility in acetone. The adhesive sheets were made in various thicknesses, cut around the shape of the actual gaps and lightly tinted to approach the colour of the vessel; they were then attached into the gaps by gently activating the edges with acetone, creating easily removable fills if required.

Training

The AM and BM recognized the opportunity of building a training scheme into the conservation project. This scheme involved hosting Aimée Bou Rizk (AM Museum Assistant) in London for three months. Commencing on 14 March 2022, Bou Rizk initially joined the BM's established International Training Program (ITP), a skill-sharing programme for museum and heritage professionals from around the world, and particularly countries with museum sectors requesting support and training. Participation promotes shared inter-cultural experiences that offer new perspectives into and understanding of heritage and museology. Bou Rizk also received training from the Conservation and Collections Care teams concerning issues of preventative conservation, skills that she is applying in Beirut. Other opportunities, at Bou Rizk's request, included training in object photography in the Photography Studios, as well as learning BM procedures for exhibition preparation. Training was, however, primarily based in the Conservation labs. Discussions with BM conservators included the logistical considerations of setting up a possible conservation lab at the AM. When conservation work commenced on the eight glass vessels from Beirut, Bou Rizk helped unpack the fragments, undertake the puzzle-work and prepare a condition report for each object; she also assisted in full documentation of the conservation process including taking photos and writing reports. Access to the BM departmental libraries also enabled Bou Rizk to research the vessels, in order to better date and describe them in the AM database (and in Table 1).

Scientific analyses

While the eight objects were at the British Museum undergoing conservation, the AM-BM collaboration conducted a detailed scientific study of the composition, production and surface decoration of the fragments, prior to their restoration, using the research laboratories in the BM's Department of Scientific Research and at University College London (UCL). Joanne Dyer and Andrew Meek (BM) partnered with Ian Freestone (UCL) to use a combination of techniques to capture as much information as possible, including X-ray fluorescence (XRF), scanning electron microscopy (SEM) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), to investigate the composition of the glass, as well as digital microscopy, Raman spectroscopy, Fourier-transform infrared spectroscopy (FTIR) and reflectance transformation imaging (RTI) to study the vessels' production and surface decoration.[8] The full analytical data and a more extensive discussion of the results will be published in collaboration with scientists at the AUB (Tabbal *et al*. in prep.).

The fragmented condition of each vessel meant that their internal surfaces could be examined for possible residues or traces of decoration. It also helped overcome issues of leaching; where some components leach out of the surface as the glass deteriorates over time, meaning that the surface composition of an ancient glass object will not be representative of the original glass. In this case, the broken shards enabled compositional analysis of a 'fresh' glass surface along the break edges, generating results that better represent the original composition.

The compositional data helped characterize the raw materials that were used to make the vessels, such as sand, natron and plant ashes. The techniques listed above were also used to obtain data which we could interrogate to further differentiate between particular sand sources to identify likely primary production locations for the glass which was used to produce the vessels (Tabbal *et al.* in prep.). By integrating these data alongside information gained from the study of vessel form and decoration,[9] a more complete picture of the origins and histories of the vessels emerged.

Of the eight vessels listed in Table 1, only one (4536) is of a plant ash glass composition, produced with a combination of sand and plant ashes consistent with production in the Islamic world. Its major and minor element composition strongly suggest that it was made at a site nearer the eastern Mediterranean coast, rather than in Mesopotamia, the Iranian Plateau or Central Asia. The trace element composition obtained using LA-ICP-MS provides more detailed information suggesting that Syria, and more specifically Raqqa, was the most likely place of production (Henderson *et al.* 2016).

The other seven objects are all natron glass produced using sand and natron. Their glass was produced at sites along the eastern Mediterranean coast. One vessel (5964) shares characteristics with 6th–7th century CE glass from Apollonia (Freestone *et al.* 2008). The other six vessels are typical 1st–4th century CE glass, similar to that produced at Jalame (Brill 1988). This information corresponds well with production dates that were inferred based on the vessel forms.

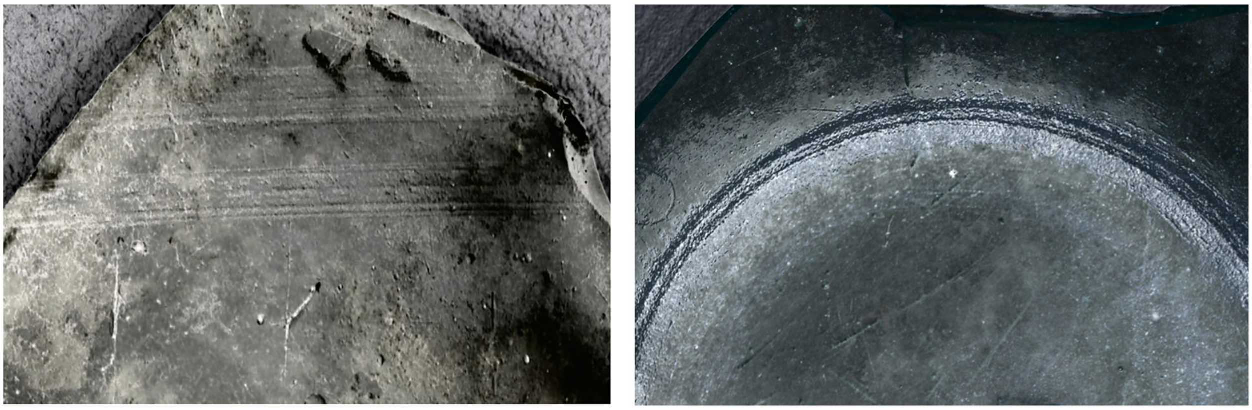
None of the vessels are intentionally coloured; rather, their colouration is produced from impurities in the sands used in their manufacture, particularly iron. Three of the vessels (4536, 5964, 3656) contain very small quantities of elements associated with coloured (e.g. cobalt, copper) or opacified (e.g. lead, antimony) glass. The levels of these elements are too small to produce any colouring or opacifying effect on the glass, however they serve as a marker of recycling. Their presence suggests that coloured or opaque glass, for example a vessel with a cobalt-blue trail, was unintentionally included in the mixture of glasses recycled (Freestone 2015: 30). It is only with detailed trace element analysis of glass that we can reveal such insights into the production of these vessels and the organization of glass production in this period.

Three of the vessels (3925, 4218 and 4536) were subjected to further analysis, to investigate signs of production and decoration remaining on their surfaces and, in the case of 4536, the vessel's contents. Vessels 4218 and 3925 were investigated using RTI (Fig. 11). The images obtained for 4218 highlighted two parallel bands of engraved decoration made up of multiple straight lines. For 3925, signs of cold working around the base ring of this moulded bowl could be clearly seen.

Several techniques were applied to the surface and interior of vessel 4536. Qualitative surface XRF of a fragment of this vessel showed the presence of a small quantity of silver. Digital microscope imaging of a cross section detected a microscopic layer of silver stain or lustre painted decoration (Fig. 12a). Stained or lustre painted glass was produced in Egypt and Syria from the 7th to 9th centuries (Carboni 2001; Carboni and Whitehouse 2002), corresponding with the Syrian provenance for this vessel as suggested by its form and chemical composition.

[8]These analyses were carried out at the British Museum Research Laboratory and the Wolfson Laboratories of the Institute of Archaeology, University College London.

[9]We thank Dr Margaret O'Hea (University of Adelaide) for discussing the form and styles of the glass vessels, which complemented information from the Archaeological Museum database.



(a) (b)

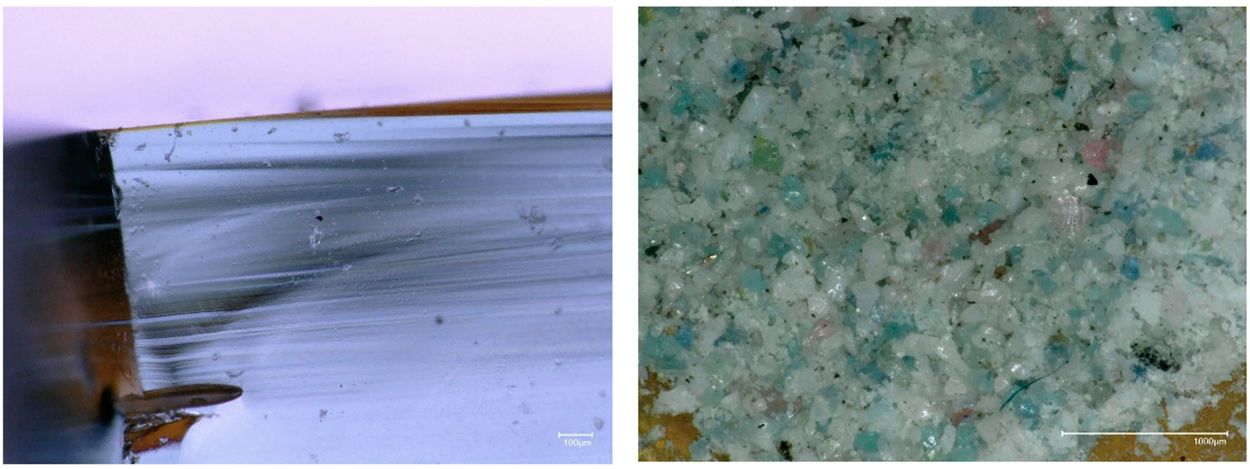
Figure 11 RTI images of exterior fragments of (a) body fragment of vessel 4218; (b) base fragment of vessel 3925.

This vessel also had a coating on its inner surface (Fig. 12b). Initially we believed this coating could be the remains of something stored in the vessel or evidence of a later repair attempt. To the naked eye it appeared light grey-blue and almost plaster-like. However, microscopy showed it to be a crushed angular substance mostly opaque white with some green, blue and pink particles. Using SEM and XRF analysis it was possible to identify the particles within this coating as crushed glass with significant lead and arsenic levels. High arsenic levels in glass suggest production after the 18th century CE, so it seems unlikely that this material is contemporary with the production and use of the vessel. Although it was not possible to establish the purpose of this coating, it was valuable to characterize it as modern. Ultimately, these results complement the scientific study undertaken on other glass vessels from the damaged case by AUB and STARC (see 'Fourth mission' above). With ongoing BM-AUB-STARC collaboration, these institutions can, together, help characterize the unprovenanced glass collections at the AM more precisely than before the explosion.

Exhibition at the BM: *Shattered Glass of Beirut*

From its outset, the AM-BM collaboration planned to feature the restored eight vessels in a temporary exhibition as part of the BM's rotating Asahi Shimbun Displays. These free-entry displays are hosted in a small gallery (Room 3) that flanks the museum's main entrance, and they showcase single or small groups of objects that are usually from the BM's collection. Not only does the intimate exhibition space encourage the visitor to reflect deeply on the displayed object(s), but the temporary Asahi Shimbun Displays are a testing ground for innovations in interpretation and design.

The exhibition *Shattered Glass of Beirut* was co-curated by Fraser, Klink-Hoppe and Panayot, working closely with BM designers, interpretation



(a) (b)

Figure 12 Digital microscope images of the cross section (a) and interior surface (b) of vessel 4536.

officers and the glass conservation team (Fig. 13). The curators sought to introduce the 2020 explosion and its aftermath to UK and international visitors while keeping sensitivity concerns in mind. Significant consideration was given to how the explosion should be visually represented in the exhibition, if at all. Would its inclusion sensationalize the display or serve as a traumatic trigger? Ultimately, slowed-down footage of the explosion was projected onto three banners of voile material that were suspended above the central display case, accompanied by the muffled sounds of the blast and of shattering glass. The partially translucent quality of the voile material softened the film's impact, and slowing the footage from real time helped created a sombre and reflective tone. The film does not, in order to respect the grief and trauma of the surviors, include now-familiar footage of the painful and shocking aftermath of the explosion in Beirut; rather, the extent of the damage was indicated by including footage captured by CCTV around the AUB campus at the moment of the blast.

The exhibition considered how these ancient vessels have a contemporary voice expressing the grief, solidarity and resistance of the people of Lebanon. The vessels were the centrepiece of the display, aligned on a workbench-like case, inspired by the restoration work undertaken in the conservation lab, and up-lit from beneath their base by fibre-optic lighting, effectively accentuating their joins and missing shards. A quote by Panayot was featured across one wall: 'For 2000 years these vessels survived earthquakes, tsunamis and wars until 4 August 2020 when they shattered into thousands of pieces like our hearts and souls'. Two audio-visual installations, in addition to the brief introductory video depicting footage of the explosion, accompanied the display: a 3-minute video, with commentary by Panayot and Bou Rizk, that overviewed the initial recovery at the AM; and a 90-second silent video that documented a time-lapse reconstruction of bowl 3656, at the BM, by Cuyaubère. These in-gallery films were complemented by a 20-minute video released by the BM on its social media channels on the day of the exhibition's opening.[10] The curators hoped that visitors to the exhibition would be moved by a positive story from Lebanon, in contrast to most media stories that define Middle Eastern heritage by what has been lost through looting, conflict and destruction.

Shattered Glass of Beirut opened on 25 August 2022, soon after the second anniversary of the explosion. In its short run to 23 October, the exhibition welcomed over 43,000 visitors (an average of 715 a day), which was one of the highest visitor-counts for any Asahi Shimbun Display. The exhibition was positively received for its reflective tone, balancing the catastrophe of the explosion with uplifting accounts of recovery and restoration as part of the international co-operation. As one reviewer wrote, 'it's a powerful story of a common humanity, a helping hand of assistance, knowledge, funds, support which played out in a myriad of different ways across Beirut in the aftermath of the explosion' (Salterton Arts Review 2022). The exhibition also highlighted conservation work that goes on behind the scenes in museums, and the role of museums as engaged global actors.

Exhibition at the AM: *Shattered and Restored*

The eight glass vessels restored at the BM were returned to Beirut in early 2023, where they joined 18 other vessels restored at the AM in 2021 and 2022 (see Second Mission above). On 24 May 2023, these vessels were unveiled as part of a new permanent display in the same space in which they had been destroyed almost three years earlier. Named *Shattered and Restored*, this exhibit features the 26 reconstructed vessels along with the two small flasks recovered undamaged from the debris. As shown in Fig. 14, the display is structured in two sections.[11] The right-hand panel is titled 'Archaeology of Absence' and explores the poignant absence of the other 46 shattered vessels from the original case that are unrestored. Although these vessels are listed on the case label, they are represented only by broken shards, like funerary stones signifying the presence or memory of the departed. A fragmented glass flask is included along with a photograph of the vessel taken before the explosion. Photographs such as this image played a vital role in the identification and preservation of all fragments during the recovery phase, and print-outs were kept in the same box into which the fragments were sorted. A 3D print of a restored jug is also displayed, indicating the potential of digital technologies as tools for recording and understanding objects threatened or destroyed by crises in heritage management.

[10] 'Conserving Ancient Glass Vessels Destroyed in the 2020 Beirut Explosion', https://www.youtube.com/watch?v=M-MfgeA7EhI.

[11] The right-hand section was curated by Nadine Panayot. The left-hand section was curated by Mohamad Kanaan, a lecturer from AUB's Department of Architecture and Design, who generously volunteered his expertise and time to develop and realize the new display.

Figure 13 The exhibition *Shattered Glass of Beirut* in the Asahi Shimbun Display gallery at the British Museum (15 August–23 October 2022). Courtesy of the Trustees of the British Museum.

The left-hand side of the display features the vessels that were restored in London and Beirut. However, rather than replicating the pre-explosion vitrine, these vessels are recontextualized to allow them to resonate with new significance. A thin adhesive film, carefully attached to the front of the case, reflects mirrors placed on the back, sides and bottom of the case, thereby creating the appearance of infinite glass vessels through multiple reflections (Fig. 14). This effect dramatically and emotionally demonstrates how museum objects are not static and inert, but rather active and dynamic, with the capacity to tell infinite stories in different ways. As they did before the explosion, the restored vessels tell the

Figure 14 The new showcase exhibited in its original space at the Archaeological Museum at the AUB. Left: restored vessels displayed in a design by Mohamad Kanaan, Lecturer, Department of Architecture and Design, AUB; Right: *Archaeology of Absence* exhibit designed by Panayot. Photo by J. Fraser, courtesy of the AUB Archaeological Museum.

story of glass manufacturing in the east Mediterranean, and how locally developed techniques of glass-blowing transformed glass from an elite material into something quotidian. Yet their scarred imperfections also bear witness to the devastating consequences of the corruption and neglect currently inflicted upon the Lebanese people, and these vessels and their myriad reflections will forever recall the tragedy of those people who were killed or injured on 4 August 2020. Moreover, as objects once shattered and now restored, the vessels stand as affirmation of the commitment of the Lebanese people to recognize and protect their cultural heritage, and their resistance to the circumstances inflicted upon them in which they must survive.

Discussion: the presumption of preservation

The recent destruction of cultural heritage in conflict zones, whether by misfortune or design, has cast the long-debated issue of archaeological restoration in new light, particularly the ethical implications of reconstructing monuments destroyed by Daesh or the Taliban. Researchers have spilled considerable ink debating the difference between the 'Disneyfication' of history, in which reconstructions may disrespect the integrity of the original monuments and the cultural landscapes in which they sit (Cunliffe 2016; Janowski 2011; Khunti 2018), and the potential of reconstructions to preserve, or even enhance, the heritage value remaining in damaged sites (Bülow and Thomas 2020; Cooper 2013; Scarbrough 2020). Unlike the Bamiyan Buddhas or the Palmyra Arch, however, the shattered glass vessels of Beirut were not intentionally targeted for destruction, even if those criminally responsible for the explosion have yet to be held to account. Furthermore, unlike proposals for an anastylosis restoration of the Bamiyan Buddhas combining original fragments with modern materials (Petzet 2009 and papers in Nagaoka 2020), or the 3D-printed scale replica of the Palmyra Arch that stood in Trafalgar Square (Korsmeyer 2019: 152–56), the 26 glass vessels are restored from original fragments with minimal fills. In this respect, a better comparison is the restoration of several Gandharan Buddhist statues in the National Museum of Afghanistan that were smashed by Taliban policemen in 2001 (Lerner 2020). It is striking that, unlike the proposed reconstruction of the Bamiyan Buddhas, the restoration of these plaster statues has received little scrutiny in the international press or scholarly attention in theoretical debates. Rather, their status as museum objects seems sufficiently self-evident to warrant restoration without justification or critique. So too the shattered glass vessels, whose restoration in Beirut and London was featured in dozens of international news stories, but for which the very rationale for restoration was assumed.

Heritage disciplines such as archaeology assert fundamental principles for the long-term conservation and protection of the archaeological record. Described by researchers such as Bülow and Thomas (2020: 493) as the 'presumption of preservation', these principles underlie obligations towards heritage articulated in international declarations such as the 1972 statement of the UNESCO World Heritage Convention, in which the 'deterioration or disappearance' of sites of 'exceptional qualities' are described as a 'harmful impoverishment of the heritage of all nations of the world' (UNESCO 1972). Similarly, they shape the 1992 Malta Convention on the Protection of Archaeological Heritage that stipulates preservation for 'historical and scientific study' (Council of Europe 1992: Article 1). Yet, by acknowledging the tensions that can arise between heritage preservation and other priorities (particularly the allocation of resources), heritage practitioners are forced to confront the extent to which the presumption of preservation is reasonable. Indeed, Cooper (2013) goes further, suggesting that archaeologists are reluctant to critically examine these principles because to do so would be to engage with wider debates concerning the extent to which archaeologists 'own' or 'steward' the past: 'to maintain that preservation is not a main priority, or that priorities of preservation different from the archaeologist — those of the tourist industry, say — should prevail, is therefore to challenge the stake in the ownership of the past that archaeologists sometimes profess' (Cooper 2013: 223).

It is, therefore, appropriate to consider the international response to the restoration project, presented by journalists as a natural and fundamental museum priority, in light of the reaction by some members of the local Beirut community who expressed surprise at the allocation of resources in a city suffering the crippling effects of hyperinflation, the Covid pandemic and the 2020 port explosion. Indeed, at face value the case to preserve the vessels is not strong: none constitute rare examples of Roman, Byzantine or early Islamic period glassware, and similar examples are represented elsewhere in the AM collection, in the National Museum of Lebanon, and in museum collections around the world. Moreover, the destruction of the vessels paradoxically increased their potential for scientific study, as broken shards are more easily sampled for scientific analyses. Rather, it is the transformative act of restoration itself that carries the greatest argument for preservation, at least in this case. As examples of ancient glassware, the vessels are neither irreplaceable nor irreplicable, but as antiquities destroyed by the 2020 port explosion they are unique. While the 26 restored vessels refer us to the past, just as they did before the blast, their imperfect restoration refers us simultaneously to the present through the violent scars of their joined shards and by the empty voids of their missing fragments whose absence 'speaks, shames, reminds' (as Roger Cohen (2007) described the bare niches at Bamiyan). A label in the *Shattered Glass of Beirut* exhibition cited a remark made by Panayot to the Financial Times (Shaw 2021) at the one-year anniversary of the explosion: 'honestly, restoring these vessels as they were before the explosion doesn't mean much to me. But restoring them to give them a voice again, to bear witness to what was inflicted upon Lebanon, now that makes a whole lot of sense'.

What, then, does the decision *not* to restore the remaining 46 vessels from the damaged display case tell us about our presumption to preserve and the obligations it implies? Several vessels are broken beyond repair, but most are probably restorable if sufficient time is dedicated to further puzzle-work of the broken shards and resources are found for the conservation required to join them. Unfortunately, these resources are beyond the capacity of the AM and the will of its international partners; evidently, principles of preservation are ideals constrained by practical concerns. However, if the presumption carries with it an ethical obligation to preserve *where possible*, then it follows that if resources were to be found, then these vessels should also be restored; indeed, it could even be argued that failure to do so would be to act disrespectfully to the objects by denying them their historical value as artefacts (see Bülow and Thomas 2020: 494). Yet, as argued above, none are especially remarkable examples of ancient glassware, and the 26 restored vessels certainly represent a sufficient corpus to witness the effects of the explosion. Surely there comes a point when, even on theoretical grounds, it becomes difficult to justify the allocation of resources to the preservation of damaged cultural remains. Conversely, we also recognize that the shattered vessels as shards have narrative values that resonate with people in ways that the restored vessels do not. By championing a priority for preservation, heritage professionals can sometimes dismiss the fascination by non-professionals for decaying sites, monuments or objects as superficial '*Ruinenlust*' (as German Romanticists termed the pleasure in and sensitivity to ruined remains (López Galviz *et al.* 2017)). Yet Cooper (2013: 228) is right to caution that the aesthetics of ruins are deeply felt, and that this connection should not necessarily be dismissed compared to scientific arguments to preserve. In this respect, both sections of the AM *Shattered and Restored* display are equally important, as they feature broken and restored materials that speak about the effects of the explosion in different ways, and which resonate on different intellectual and emotional levels.

Conclusion

The shattered and restored vessels newly displayed at the AM ultimately assumed a healing mission, in which the scientific and academic value of the vessels as objects was eclipsed by their symbolic value to represent humanity's capacity to rise above conflict and destruction through solidarity and respect. The collaborative initiatives that the AM developed with international partners are effective instances of cultural institutions coming together in times of crisis. Museums need not be defined by their collections or by the walls in which they sit, but by the connections that exist between collections across the world. In this regard, the AM-BM collaboration exemplifies how both museums serve as global citizens in an international heritage community, and how the purpose and reach of each is strengthened by their association with the other. It is this solidarity that was ultimately celebrated in the exhibition at the BM, and which informs the permanent redisplay at the AM.

Beirut is a city that has suffered decades of political violence, and the effects of this are written indelibly throughout its urban landscape (Sandes 2013). For example, bullet holes scar the National Museum from its time on the infamous sniper alley at the front lines of the Civil War (Sabri *et al.* 2023). The broken shards and restored vessels, redisplayed in the AM in the same place they were destroyed, are part of this landscape that embodies the effects of political violence and the capacity of people to resist. As Panayot described in a film that accompanies the exhibition online:[12] 'These objects used to tell stories of banquets during the Roman period, faith during the Byzantine period, and of light during the Islamic period … They survived earthquakes, tsunamis, and wars for over 2000 years, recounting our roots and origins, until August 4, 2020, when they were all gone. Shattered into thousands of pieces, like our

[12]See link in footnote 4.

hearts and souls. But three years later, we bring them back to life again. Breathless, exhausted, and crippled, they stand tall again, heads held high to tell new stories … They will bear witness to the deceased, the injured, the orphans, the homeless … They will testify to the guilt of the culprits of this atrocity, and they will keep telling that story for another 2000 years if necessary … '

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