History, Science and Technology of Ancient Indian Glass

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Introduction

The Archaeological Sciences Centre (ASC) at the Indian Institute of Technology Gandhinagar (IITGN) has pursued a program of organizing short-term courses cum workshops / conferences that focus upon a selected archaeological artifact class or material. The aim of these events has been to expose a selected group of students with an acute sense of the specific problems and opportunities that are involved in the study of that material. This has taken shape in the motivation to host a conversation between the leading experts of the field, and equally to provide hands on training in the ethnoarchaeological, experimental and scientific prospects of that particular field of archaeological research. With these objectives in mind, at these events, the invited resource persons are required to address pre-assigned themes and topics that combine their research expertise and knowledge towards the planned content for a volume. These volumes themselves are envisaged not as the collection of papers or conference proceedings; they are intended to be valuable and useful resources on the subject. They are aimed at being useful for both students and researchers and thus to be useful for archaeological syllabi in South Asia and also globally.

The first of these 'conference cum workshops' was held between the 10th and 14th of August 2015 and focused on stone beads. The proceedings of that conference have subsequently appeared as a precisely such a volume meant to serve as a resource for both the teaching of stone beads and aid further research into them (Kanungo 2017). The second such conference was held from the 21st to the 25th of January 2019 in IIT Gandhinagar and focused on the History, Science and Technologies of Ancient Indian Glass. A third workshop in this series is planned and shall focus on Ceramics. It too shall similarly aim to provide a foundational course for its participants and endure in the form of a volume for the field.

The Second Conference cum Workshop: Format, Components and Resources

The second conference cum workshop like the previous one in the series, aimed to bring together a wide range of experts. In this case these included archaeologists who

have had extensive experience of south Asian proto-glass, glass, and archaeological chemists with expertise in the elemental analysis of glass. In addition it included established ethnohistorians and ethnoarchaeologists of south Asian glass and vitreous materials, alongside craftspersons who brought their lifelong and inherited skill, expertise and knowledge (Figure 1).

Figure 1: Participants of the Conference cum Workshop

Academic Discussions

Glass in General: Prof. Thilo Rehren's keynote introduced at once the many openings of the scientific analysis of glass: its cultural specificities as a valued artificial material and the networks of raw materials, expertise and experimentation that defined its first origins in Late Bronze Age (LBA) Egypt and Mesopotamia. He stressed, that while glass is a complex material, its additive and not extractive nature allows it to contain all the traces we need to investigate it.

The keynote introduced the chemistry of glass as a matter of three different components: the Sand/Quartz base to which a flux is added alongside the third component — a variety of "spices" to colour, opacify and lend it special qualities. Prof. Rehren's talk provided an overview of the complexity involved in the study of trace element contributions from both the flux and colourants. This technique allows archaeologists to compositionally analyse glass and address questions of changing recipes and the cultural and geological origins of the glass. Through a detailed analysis of LBA glass in Egypt and Mesopotamia, he drew on decades of research to synthesize the story of the production and exchange of coloured glass from various LBA workshops across Egypt and Mesopotamia. He demonstrated how within these

networks, cumulative research had established the movement of finished glass, as well as the movement of the knowledge of glass making and working, and that now arguably the transmission of the idea of glass itself could also be tracked.

Notably, Prof. Rehren's talk stressed the need to be careful in evaluating textual evidence. He summarized archaeometric analyses of the last few decades have made clear that the story of the origin of glass is much more complex than the Mesopotamian origin the texts suggested. Lastly, his talk also stressed the need to locate all archaeometric analysis within a sense of the contemporary glass cultures and elite networks of political economy that sustained them. Only by doing so are we able to better understand the periodic disruption of networks of exchange and knowledge that we encounter repeatedly in the long-term archaeological history of glass.

Dr. Laure Dussubieux's talk "Elemental Compositions and Glass recipes" provided a synoptic overview of the kinds of questions which can be chemically asked of glass artifacts. Dr. Dussubieux very usefully organized these into three kinds of questions. First come questions that can be asked of Glass making: who made glass, where, with what technology, which ingredients, and what was the organization of primary production. Second come questions that we can ask of trade in glass: who traded what, what trade in raw glass existed, how networks sustained varied trade, and finally questions of the use of glass. Her talk went on to stress the necessary use of varied approaches preferably prior to chemical analysis.

She advocated a holistic approach that would include archaeology, ethnography, typology, textual research, and the technical analysis of physical properties of glass and chemistry of elemental compositions. In this way we would be best placed to approach the complexities which analysis of glass compositions sometimes reveals. Only through holistic means can we come to understand complex compositions where the contribution by silica source, flux and colourants can all at times influence trace element counts, and this requires great care to disentangle clear signatures. Further challenges arise from the life of glass objects themselves. Trace signatures are affected every time when glasses are recycled and different glass types are mixed – again as is common in the archaeological record.

After a short history of the history of the chemical analysis of ancient glasses, Dr. Dussubieux presented two case studies: the first of which dealt with unusually early beads from Kish in the Field museum collection that could be re-attributed correctly once they had been analyzed. In addition, she summarized her assessment of the chemical composition of Indian glasses as distinct groups of mineral soda alumina glasses, communicating the identification of a new group as presently known solely from finds from Zanzibar. Her landmark study (Dussubieux et al 2008), which was referred to time and again over the next week, and the addition of a new group of likely Indian glasses, but known presently only from samples which were traded centuries ago outside of south Asia is a salient example of the state of the field and the need for this workshop.

Dr. Thomas Fenn presented a third introductory foundational talk — which covered the prospects and challenges of using isotope systems to understand glass provenance networks. He began by outlining the methodological differences isotope study required, which include: the need for relying on Thermal Ionization Mass Spectrometry (TIMS) over laser ablation, and the need to digest samples in acid for precision owing to the great sensitivity of isotopes to contamination. Dr. Fenn reviewed the major isotope systems that have been used in the efforts to provenance glass - Sr, Nd, and Pb, and highlighted how the field has evolved to a point where a combination of Sr/Nd isotope ratios provides a robust analytic tool.

Dr. Fenn used several examples to show how these tools (alongside Pb 204, 206, 207 ratios) help provide clear tools to distinguish coastal sand, plant ash and limestone bearing sand as well as help establish the different origin of groups of otherwise visually identical artifacts (such as at Basra, or Igbo-ukwu in Nigeria). He also spoke about the recent interest in Boron systems, especially as a tool which in years ahead might be able to especially distinguish Natron glasses as it would bear signals from both the sand and the flux. Dr. Fenn's talk concluded with an account of the need for regional isotopic baselines as an essential first step for any such study. He detailed the present project he is a part of, in collaboration with Drs. Dussubieux, Abraham and Kanungo, that attempts to establish such a database for Indian silica sources, as well the *reh* and *oos* sources which have long been preferred as flux in the Indian subcontinent. The project shall establish the isotopic baselines which are essential for any application of such attempts to attempt to provenance glass and is likely to yield truly transformative results for our knowledge of glass in the next few years.

Three further presentations on the first day built on these foundational lectures. Dr. Bernard Gratuze's talk addressed the issue of the specificities of the transition from Natron glasses to Plant Ash flux glasses and "Forest" glasses in the connected spheres of the Middle East and Western Europe at the end of the first millennium. His talk was a lesson in the kinds of detailed analysis that careful and innovative sample selection from well-dated assemblages that combined with the precision of Laser Ablation Inductively Coupled Plasma Mass Spectometry (LA-ICP-MS) can reveal. Dr. Gratuze presented results from a project that had revisited this transition on the basis of a series of glass weights issued in the first two Islamic centuries by provincial governors. As the artifacts bore precise dates, through their analysis he was able to track the geographical and temporal complexities of the where and when of experimentation with new recipes, the perdurance of old ways of glass-making and even cases of clear admixture between the two.

Dr. Stephen Koob, provided an introduction to the kinds of care which are needed in the handling of glass. He provided a very useful and detailed discussion of the preferred binders (Paraloid B 72) that should be used in the conservation of glass. He provided examples and shared his knowledge about the need to be aware of the environmental factors that aid and complicate their use, endurance and strength. In

addition to this, Dr. Koob also demonstrated a few examples of his own work of conserving glass objects — reconstructing entire vessels from shatter and the process of casting, colouring and retrofitting missing pieces in epoxy towards making truly exceptional display items for glass museums. The last talk of the first day was that of Dr. Joanna Then-Obluska, whose talk was a tour-de-force survey of the issues, challenges and attention to detail which the typological study of ancient glass beads demands. Her talk admirably summarized the different methods by which ancient glass beads were made and provided excellent illustrations of their visible traces on artifacts. In addition to this, Dr. Then-Obluska's talk provided an exemplary summarization of the present state of the field in glass bead studies, stressing the need for recording multivariate standardized attributes of each bead across several sites in a region and providing high quality illustrations of the same.

Proto-glass and Faience: The Conference proceedings in day two were split into two themes: Proto-glass and Faience and the insights of ethnography and historical literature into the study of glass in south Asia. Prof. Mark Kenoyer summarized the results of more than twenty years of the study of Harappan Glazed steatite and faience technologies. This has involved the excavation of faience workshops at Harappa, an evaluation of the range and diversity of faience materials produced by the Harappans and providing the field with a sense of the pyrotechnical virtuosity and playfulness with which they excelled at the manipulation of this material.

Prof. Kenoyer, summarized not only the use of a range of instrumental techniques [ICP-MS, Scanning Electron Microscope (SEM), and others] which he has used to characterize the distinctiveness of Indus Valley faience, but also to the regional diversity and the chronological differences between different eras. He also drew extensively on his continuing replication experiments that have helped re-iterate the technical complexity of the craft, the degree of control that needed to be exerted at various stages (especially in the re-grinding of the frit).

Dr. Kenoyer stressed the portability and the lack of large infrastructure that Harappan craftspersons needed in making faience. On the basis of both excavated finds and his experiments he spoke of the Harappan ability to make faience in small specially made crucibles which on account of being unremarkable had previously been unrecognized as faience production debris. He also pointed to the technical excellence of the Harappans in creating distinctive faience eye-beads that combined on a single artifact, red and white glaze — a feature that is presently proving to be exceptionally difficult to reproduce. This is on account of the Iron (for the red glaze) and the plant ash both acting as fluxes on the silica. At a similar level of archaeological detail and insight, drawing upon decades of research into Harappan glazed steatite, Prof. Kenoyer also provided a short account of the care taken by the Indus Valley craftspersons in sourcing the right kinds of steatite which when fired would glaze. He also communicated the results of recent re-examinations of the glazed steatite "button seals" whose function may need to be re-thought, on account of traces of surviving

glaze which have now been observed and which would make them less usable as seals than perhaps as ornaments of some kind.

Dr. Ivana Angelini provided a second study of faience that involved small samples from both Harappa and Mohen-jo-daro. She described how she and her colleagues have studied these samples using Confocal Stereomicroscopy, X-Ray Powder Diffraction (XRPD) alongside using the latter method with SEM for the study of vitreous slags. Dr. Angelini's close attention to the glaze-body interface confirms the use of efflorescence techniques of glazing on all samples and provided possible insights into when the colouring agents were added, as the percentages of copper varied between the glaze, the body and the core of the sampled artifacts. Dr. Bhuvan Vikrama communicated the interesting finds from the recently excavated site of Sakatpur Mustakil, Dist. Saharanpur, where a series of faience working furnaces and extensive faience artifacts of the Harappan style were found. The nature of the evidence further testified to the regional diversity of Late Harappan faience and raised new questions about the distribution of centres of production, especially in the Upper Ganga valley. In this connection he also discussed the equally remarkable recovery of the Harinagar copper hoard with its distinctive goblet forms.

Glass in South Asia – Part I: Ethnography and Literature: Dr. Alok Kumar Kanungo's talk, summarised several key arguments from his more than two decades of ethnographic, ethnoarchaeological and ethnohistorical research into glass cultures in south Asia. He began by dismantling the unhelpful debates over the origins of glass, glass making and widespread use in south Asia. Dr. Kanungo relativized a series of otherwise difficult to understand textual references (in the Satapatha Brahmana, the Arthasastra and other texts) by pointing to how the metaphorical and allusive use of glass and glass making must presume at least a few centuries of familiarity with the material. He drew on his extensive previous work collating all evidence for glass in south Asia and studying the distribution by period to point to how the density of sites with glass and the relative profusion of the finds amply demonstrate that by the Early Historic period (300 BCE- 400 CE) glass was no more an item restricted to a few elites. Rather, its use was so widespread it even drew partial prohibitions in the Buddhist *vinaya*.

Turning to the evidence for production, Dr. Kanungo, argued that the problem in Indian archaeology persisted on account of our expectations both on account of the forms of evidence and a misunderstanding of the taphonomic processes that are active. He pointed to how at Kopia, unambiguous evidence for a furnace was found. The distinctive form and non-structural clay-only materials of the kiln Dr. Kanungo stressed, were of a kind that have been commonly mistaken for hearths, if not 'altars'. If we could only let go of our expectations of both primary and secondary glass production sites in scale, we might be more alive to the kinds of traces which he has observed in his ethnoarchaeological fieldwork. He emphasised the seasonal exhaustion, destruction and rebuilding of kilns, the repeated abandonment of

workshops and the profusion of the kinds of debris that he has documented and observed at sites likes Purdalpur, Papanaidapet and others. If such finds would be more readily recognized and reported and we could build a denser history of glass working in south Asia and its modes of organization of labour, materials and workshops.

Lastly, Dr. Kanungo cautioned all about what something ostensibly simple, like the profusion of Indo-pacific beads might mean. He reminded all that in his ethnographic fieldwork among the Bondo of Malkangiri he had documented that in one house, where two women lived, their store of three sets of bead-clothes alone would amount to a quintal of beads. He reminded us that if we were to find such a deposit, or indeed some vitreous slag or even a stray early vitreous find from prior to the early historic, we must weigh our own preconceptions and expectations against what the material evidence is actually teaching us. Dr. Kanungo's talk thus provided a series of vital clarifications about the cultural antiquity and status of glass in India.

In the same vein, Dr. V. Selvakumar's talk provided a thorough and thought-provoking review of the evidence for the production, use and status of glass in Tamil Nadu. He pointed to the problem of the lack of glass prior to the Early Historic period in South India, and even then in contexts which exclude megalithic burials, alluding to a complex cultural transition. Dr. Selvakumar added that this was especially problematic, in light of the assertions that have been made for the centrality of sites like Arikamedu as production sites. His talk also provided a very rich account of the historical evidence on glass-makers and especially the caste of bangle traders and makers known from Tamil inscriptions. Tracking the Balukuvaryan and the Valayaikara Chettis from the 12th century onwards, Dr. Selvakumar's talk closed with an assessment of the symbolisms and associations of the glass bangles as markers of prosperity, marital status which specially marked certain festivals and ritual status.

Drs. Jan Kock and Torben Sode presented over two papers a precis of their work over the last several decades on Indian glass crafts - of primary glass production, beading and bead-work and mirror-making. Focusing on the latter they described how over medieval Europe (and elsewhere in the world) convex hot-lead coated mirrors were known from Scandinavian Viking deposits to Italian monuments but the technology of their production had been ill-understood. They communicated their sense of wonder upon first visiting Kapadwanj where they first encountered and documented the process of the manufacture of this distinctive mirror type and the networks through which it is finished into final artifacts and traded. Dr. Kock also spoke about his relationship with the previous generation of craftspersons at Kapadwanj, Muhammad Sisgar, grandfather of Ahmed Basir Sisgar who too was a resource person at the conference. Alongside this they also presented vignettes of their similar ethnoarchaeological documentation of primary glass production at Jalesar, glass crafts at Purdalpur and of the extensive use of such mirrors in traditional costumes in both Europe and India.

Glass in South Asia – Part II: Glass in Different parts of South Asia: The first half of day three involved four papers that related to glass crafts, artifacts and their study in India. Dr. Alok Kumar Kanungo's talk on 'Glass crafts in Northern India' posed difficult but important questions of the ethnoarchaeologists' and archaeologists' responsibility to the marginal and precarious craftspersons whom we study and learn so much from. He summarized key insights from his ethnoarchaeological work at sites like Purdilnagar and Jalesar, as well as at Banaras, to ask Indian archaeologists to be more attentive to the skill, expertise and innovations with which south Asian glass crafts developed and diversified. In doing so, Dr. Kanungo highlighted the need to be attentive to the 'when and why' of changes in Indian glass crafts traditions, especially in the pre-colonial era, a task in which archaeology can contribute but has hitherto has not. Equally, he underlined the need to think concertedly about what measures and what interventions would aid these crafts, which are on the verge of extinction. Dr. Kanungo also poignantly closed his talk with an open question to all: could we think of any cultural interventions that would instill a mass commitment to the use of such crafts products? In a world where archaeology pre-eminently learns from the communities of craftspersons who face ever-increasing economic hardships what measures should we take to ensure that our ethnographic field research and engagements do not remain as one-sided as they presently are?

The next three talks provided regionally and temporally specific accounts of the state of archaeological knowledge of principal kinds of glass ornaments. Dr. Shinu Abraham's talk concentrated on the openings that the analysis of a sample of c. 5000 beads from Pattanam have afforded into the complex which since Peter Francis Jr.'s formulation has been known as the Indo-Pacific beads complex. Dr. Abraham underlined the need for regionally standardized attribute recording systems and databases that would allow a more nuanced analysis of this phenomenon of glass beads that is not only far-flung and extensive, but profuse and long-lived. She pointed to how 75% of the total c. 100,000 glass beads at Pattanam are understood as Indo-Pacific, and are mostly monochrome; but alongside which there are a percentage of other bead types that include the False Beryl, the Gold in glass beads and rare but potentially important types of banded, faceted and biconical beads that might be temporally limited and useful for further analysis.

Dr. Sharmi Chakraborty's talk addressed the important issue of how do we assess the scenario of glass beads and their use in a regional perspective. Most usefully, she addressed the special challenges which regularly face us in south Asian archaeology -- where the data as reported over the last hundred years is far from standardized, and even basic attribute data or photographs of finds are not always available. Despite these limitations, Dr. Chakraborty's talk was a salutary example of using new methods, such as cluster analysis, to reveal key trends in the shifts in colours and shapes across regions such as inland and deltaic / coastal early Historic Bengal. Her analysis was revealing in the degree to which she demonstrated that our extant data does reveal very interesting regional trends, which can serve as the basis for further research and

instrumental analysis in the future. A few examples of these included the preponderance of barrel shapes in Indo-Pacific types, the marked increase in black beads in Kusana period and the widespread use of false agate glass beads in a region where there was no shortage of raw agates or stone beads indexing complex issues of the archaeology of value, preference and choice.

Mudit Trivedi's paper focused on the much neglected category of glass bangles — which while profuse are rarely reported or studied in as much detail as other glass artifacts. Ironically, this is especially true for the medieval period when they are most common. Trivedi reviewed the assumptions of their cultural origins and early studies made of the artifact type that continue to inform their extant typology of monochrome and bichrome in India and compared this to the far more detailed typological systems that attend to pre-Roman La Tene glass bangles and Islamic glass bangles. His talk drew upon the ongoing analysis of an assemblage of 4000 glass bangles from the site of Indor (District Alwar, Rajasthan), where extensive radiocarbon dating of medieval assemblages has allowed for the seriation of the bangles and the isolation of types as they change almost every 50 years over the medieval period. This assemblage includes types that are seemingly produced on the *khalbut* (or cone method as known from Purdalpur) but also other types which could likely have only been produced using a two-mandrel technique. Drawing on ethnographic literature he posed the question of whether archaeological bangle working debris such as at Indor, suggested a model of an itinerant churihar and the specific types of kilns that they are known to have made. If we do not consider such possibilities, we remain, as Dr. Kanungo had argued neglecting the evidence at hand, owing to the expectations we have received of what a bangle-making workshop should look like. Drawing upon the opportunities afforded by the Indor data Trivedi thus sought to revisit the questions of chronological change, typological diversity and cultural significance of the glass bangle as an artifact type.

The next set of papers in these extended panels on the rubric of Glass in different parts of South Asia began by a presentation by Dr. Kurush Dalal and Rhea-Mitra Dalal on the celebrated glass finds at Sanjan. They recounted the unexpected nature and density of vessel glass and the challenges it posed in excavation, recovery and curation— but also even more in identification - as the study of vessel glass in India remains in its infancy. Talking about the cultural specificity of the site of Sanjan, especially in light of its association with the Parsi community, they detailed the range and density of 10th to 12th century glass tableware that they had recovered including bottles, vials, footed plates, distillation apparatus, goblets and other items such as buttons. In addition to this they pointed to other items of the glass assemblage such as distinctive Syrian glass eye-beads and bangles that had been recovered as still intact from the tower of silence. Dr. Dalal concluded by pointing to important questions — the clear lack of any evidence for recycling at Sanjan, in the form of extensive debris. They noted how the relative lack of any glass from the other mounds at Sanjan perhaps suggested that the issues of glass as a material varied widely. To some it was valued, perhaps proscribed in the minds of others. They cautioned as to how in the complex hierarchy of

substances that mark Indian social organization, along lines of purity and pollution amongst others, glass in different periods and contexts will likely leave complex archaeological traces.

Drs. Ivana Angelini and Massimo Vidale provided a detailed account of the development and origin of glassy materials at the site of Barikot, in the Swat valley, Pakistan. They communicated the results of the recent excavations, since 2010, that have yielded a detailed cultural sequence from the Late Bronze age through to a Kusana city abandoned after an earthquake in 266 CE. They provided a very rich account of vitreous materials at the site contrasting their evidence for the use and profusion of faience materials, glass bangles, vessels and beads, noting that in most cases stray finds grow to more common status in Achaemenid times but the peak is notably not Kusana but the preceding Indo-Greek period. Their careful study provided a key example of how close study of the visual traces of the artifacts in well-excavated stratigraphy can yield a range of insights into the arrival and profusion of true glass and the techniques used in the manufacture of bangles, beads and vessels at different periods.

Similarly, Dr. Wijerathne Bohingamuwa presented both a synthetic review of the voluminous evidence of glass production and use in ancient Sri Lanka. He provided first a site-wise and period-wise appraisal of the evidence for glass in Sri Lanka. Subsequently Dr. Bohingamuwa moved to provide an equally valuable evaluation of the present state of evidence for the temporal shifts in glass intensity in Sri Lanka and its place within the Indo-Pacific beads phenomenon. His review pointed to the complex issues that attend the interpretation of the dense evidence from Sri Lanka and the variability within sites as to when the peak intensity of Indo-Pacific beads occurs. Dr. Bohingamuwa also reported new results that add to the corpus of glass production sites known in Sri Lanka. He reviewed the complex and debated issues of what raw materials were used, and the possibility that cullet was imported to supply to vast amounts of production known to have taken place over the first millennium CE. Notably, he demonstrated the profusion of glass has historic peaks, inter-site and temporal variations and laid out an agenda for further research not only in the region but also in south India to adequately compare the two closely linked regions.

Glass in South Asia, Part III: Circulation of South Asian Glass beyond South Asia: In this panel, Dr. Maninder Singh Gill first presented the results of his study investigating early Mughal architectural tile-work. He presented his innovative work as a case study of the interaction of indigenous Indian glass tradition in the context of a cosmopolitan court culture, which drew equally in its political and material cultures on central and south Asian traditions. Dr. Gill described his meticulous fieldwork and preparation for elemental analysis that isolated two groups, distinguished primarily on account of the number of colours they could produce and which parsed in time and geography as well. The earlier Delhi-Agra group which is displayed in the monuments built from 1550-1625 CE differed from the later Punjab-Lahore group on account of the

angularity of quartz grains, and most importantly in being a high alumina, low magnesium glass, i.e., indicative of a mineral soda flux. The Punjab group in contrast displayed a low alumina, high magnesium composition typical of a plant ash composition, indicating that in the first period of Mughal constructions an indigenous recipe had been used to produce the glass for the tiles. Dr. Gill went on to describe his efforts that have isolated the key colourants, including the distinct innovation of Lead Stannate derived orange in the second period. He also described his efforts to understand the source glass production which must have supplied the tile makers and his own fieldwork in the Akrabad-Jalesar area including efforts to replicate the making of reh glass, from firing the sand-mineral efflorescence in a furnace as well as studying other still extant methods of frit-glazing pottery.

Dr. Bernard Gratuze presented the second case study in this panel and communicated new and challenging evidence to the theme of 'the circulation of south Asian glass beyond south Asia'. He spoke about the recent discovery and identification of a range of Indian glass beads in early medieval Europe in two distinct clusters. The first group of finds were from Western Europe and France in the period between 500-800 CE and as recovered from Merovingian era elite burials. The second and more puzzling group was that as recovered from Northern Germany, Denmark and Sweden in the 7th and 8th centuries. Dr. Gratuze provided an object lesson in how archaeometry is more robust when it follows upon detailed and attentive study of the attributes of artifacts.

He described how over the last decade the close morphological study (by Constantine Pion) of up to 5000 small Indo-Pacific beads had isolated different groups based on how they had been finished (heat rounded or cold cut edges). Working independently of Pion, Dr. Gratuze described how he had been analyzing beads and coming to a similar conclusion that there were many different elemental groups — only one of which was distinctively south Asian in origin. His second example, of distinctive red / orange beads, presented an elemental signature outside of all major compositional groups of the time. These glasses which were distinct from mixed soda-potash glasses as well as south Asian high alumina glass, were on very careful study of the Rare Earth Element trace concentrations likely to be local Scandinavian mixtures of South Asian glass with others and matched waste glass found still in crucibles at these sites.

Dr. Thomas Fenn's case study of Indian glass beads in Eastern and Southern Africa added another layer of complexity by addressing the challenges of trying to identify the provenance of glass. He particularly addresses the challenge of attempting to combine the insights of artifact typology, archaeometry and isotope studies. Dr. Fenn spoke of three broad issues: the first that artifact typologies which grouped visually identical beads in Africa had on recent isotopic analysis been found to bear very widely distinct proveniences, outlining the greater need for such studies. Second, that much more work needed to be done to isolate Indian compositional and isotopic signatures for periods when the bead trade from India to Africa was at one of its peaks, especially in the periods between 1000-1250 and 1400-1650 CE.

Ironically this remains a period when Indian glass beads are better known from well-excavated African sites than in the context of medieval Indian assemblages. Lastly, Dr. Fenn spoke about the need to provide greater baselines for Indian glass than the few isotopic signatures for *reh* and for Kopia glass which had resulted from the collaboration between Dr. Kanungo and Dr. Brill (Kanungo and Brill 2009). He emphasized how more work was required to distinguish these from presently isotopically unstudied south-east Asian glasses. Once we had established isotopic baselines, Dr. Fenn added, we could hope to separate regional signatures and begin to understand which regional polities across the Indian ocean rim, at different points in time, exerted the maximum influence over trade networks in such ways that beads of that region travelled the furthest and in greatest numbers.

Dr. Laure Dussubieux' paper drew on her decade long study of the compositional groups of glass in South East Asia (especially sites in Thailand, Vietnam and Myanmar). She demonstrated how influential models such as the Arikamedu centred story advanced by Peter Francis Jr. of technology transfer and / or the movement of craftspersons were in need of re-evaluation in light of the elemental analysis of glass from these sites. Dr. Dussubieux demonstrated a number of clear trends in the compositional data that in South East Asia, a potash glass likely originating from the Laos / Vietnam area was the principal type in the region. When Indian glasses did arrive in that region, in the 2nd to 4th centuries BCE they are of a type known from Eastern India and not from South India.

In addition, Arikamedu in this period itself has a preponderance (45% of all) of a glass type that is not Indian in its composition either, pointing to a need to again revisit our interpretation of the site. Building on her work of identifying and tracking the different groups within mineral soda alumina glass, i.e. the typical south Asian glass, she pointed to how some sub-groups of this glass do travel eastwards in the last few centuries BCE and CE, but they are neither regular nor well extensively distributed in that region. In fact, the clearest evidence for regular and well established contact with eastern India occurs only in the period after 1000 CE when such compositional groups again begin to be found in places such as Cambodia and Sumatra.

The last paper of the conference, by Dr. Joanna Then-Obłuska, similarly presented new evidence to the south Asian audience of Indian beads as traded to northeast Africa in the period between the 1st and 6th centuries CE. Drawing on her recent detailed analysis of glass beads from three different zones — Upper Egypt and the region around Quseir-al-Qadim, Nubia and the tombs associated with the 5th century Makurian polity of Sudan. She pointed out how the distribution of Indian glass beads in this part of Africa can be seen to begin with very exceptional finds only in the Egyptian zone in the Late Ptolemaic /Roman period at Qusier. Subsequent to that, in a time of great trade, up to 50% of the coastal sites and up to 40% of the inland site bead assemblages come to be dominated by Indo-Pacific beads. While in Nubia the fraction of assemblage is smaller the context of the finds in royal tombs and in the form of specially crafted

anklets, with selective and judicious use of colours, especially selecting those for which no stones were available make clear the value and prestige these goods carried.

Together the papers of the last panel brought together the challenges of studying the history, science and technology of ancient Indian glass in vivid detail. Considered together they provided the best possible introduction and training to engage with the complexities of regional diversity in glass traditions, the archaeometric challenges that stand before the field and the prospects of all that we stand to learn from further investigations.

Figure 2: Beading by Miris

Live Workshops with Craftspersons

Throughout the conference a range of other resource persons were present and vital to the learning of all participants without making any paper presentations. These comprised three sets of master craftspersons. The first amongst these were two craftspersons (Nandlalji and Krishan-ji) from Banaras Beads Limited (BBL). The second group was of stone-bead craftspersons from Khambat, Anwar and Pratap-bhai, who had also previously been an invaluable part of the previous History, Science and Technology of stone beads workshop in 2015. The third were a group of women from the Rabari (Meghaben and Ashaben) and Miri (Sakinabe, Madinabed and Zanab) communities, who demonstrated the care, attention and detail that the traditional beading work typical of the Kutch area requires and demands (Figure 2). It is from these resource persons and the generosity and patience with which they answered all questions put to them by the participants that the conference attempted to foster a

considered mode of engagement with the glass crafts and traditions of India. While our studies must remain rooted in rigorous studies of their pasts, this exercise may best advance by standing as close as we can to the present craftspersons, learning from them to build stronger and more attentive accounts of the past of these crafts but also understanding their challenges and predicaments as well.

For many of the participants observing the lamp-wound beads was their first experience of the working of glass at close quarters. At once, interaction with the master craftspersons from BBL covered a range of topics and conversations. These ranged from the specificities of melting canes, combining colours, the clay separators used on the wires beads were wound around, the rates and kinds of failures, to the kinds of innovations in design they are regularly challenged to make. Participants also asked them questions about how they saw their role, of training other craftspersons, making design innovations and as within the multinational presence and reach of their company.

While the academic arm of the conference instilled the relevance of such interactions to all participants, these resource persons, the craftspersons who were as much part of the conference as anyone else, shared their insights and observations on all questions and made the question of the history and future of glass crafts in India not merely an academic one. In a similar vein, the presence of the stone bead chipping (Anwar-bhai) and drilling (Pratap-bhai) master craftspersons provided avenues for many discussions. As none of the students from the first History, Science and Technology workshop (that had focused on stone beads) were also attending this workshop, their presence allowed these students to witness, interact and experiment with these craftspersons and come to grasp the complexities of working with and drilling stones. Engagements with them moved from the basics of stone-identification to the reduction process and its complexities as well as the bow-drill apparatus used for drilling and its body-techniques. Equally, their presence allowed discussions to resituate the focus on glass and the oceanic world of glass beads within the anterior and foundational craft that had first forged such widespread and far-flung networks in India. In the persons of Anwar-bhai and Pratap-bhai, inheritors of those histories of mastery and skill, conference participants were encouraged to think about these networks not solely as networks through which raw materials and finished products moved, nor only in terms of the economies and polities that has thrived on such trade. Rather, in learning from them, all participants learned to think through the excellence and mastery which working these complex materials to scales of pre-industrial mass production requires. In this way, the conference attempted to bring the shadows of the craftspersons who stood behind the workshops at Chaul, at Khambat, or Papanaidupet and those who stitched these beads painstakingly into ornaments and clothes, into stark focus.

Faience Workshops

Profs. Jonathan Mark Kenoyer and Massimo Vidale led a detailed multi-day workshop aimed at the experimental replication of Harappan Faience Technologies (Figure 3).

Their plan involved using a range of source materials (Sabarmati river sand, rock crystal and combinations of both) alongside *sajji khar* (plant ash) to first fire the combination of silica and flux to make a frit. A small kiln was constructed by Prof. Kenoyer, Prof. Vidale and the participants assisting him on the margins of the Academic Complex where on the first evening three crucibles (also made using local materials of clay and straw) were fired. These crucibles were notably of a type known from Harappa and were small flat sided bowls in morphology and attention to their condition and post-firing state was an essential part of the demonstration of how to be attentive to remains of such traces, much modified taphonomically in the archaeological record.

Figure 3: Experimental Replication of Faience

The next day the crucibles were opened, and the partially vitrified frit was ground down to a size as fine as possible in agate mortars. This was then divided and to one-part particles of copper extracted from a heated copper wire were introduced as colourant. Prof. Kenoyer then fashioned a range of artifact forms using the ground frit as bound by acacia resin (*babul ka gond*). These shapes included a range of shapes known from Harappan assemblages including beads, rings, a vessel and the small tablet seals. These were then placed in another crucible (similar to those used previously for the frit but sealed with additional clay) and specially prepared calcined bone was used as separators. These were again fired in the kiln and left to cool. The

crucible was opened to reveal a range of variation in the degree to which glazing had occurred and proceeded, with some artifacts light and frothy in a recognizable blue faience similar to Harappan materials, others which had turned red (understood as on account of inclusions from the sandstone mortar used). Lastly, Prof. Kenoyer also used the special Hazara steatite (which Dr. Randall Law and Prof. Kenoyer have demonstrated to have been the preferred Harappan source) to fashion replicas of the Harappan seals. Prof. Kenoyer then fired these to demonstrate how Harappan pyrotechnological virtuosity had included such knowledge of how to produce excellent white and enhanced hard steatite for their quintessential seals from a material that is sparsely distributed, heterogeneous in composition and only one source produced the aesthetic results they valued.

Figure 4: Display of Lamp Winding Glass Beads

In sum, the faience reproduction workshop was an invaluable component of the conference. It introduced and engaged all participants in the care and systematic outlook and planning which experimental archaeology demands, and especially to the infrastructural, fuel and labour demands which the pyrotechnological products demand. In demonstrating the care and attention needed in both making frit and faience artifacts the workshop made clear how much the glassy phase demands of craftspersons, and a renewed appreciation of the extraordinary excellence of the Harappan artifacts. In addition, the detailed demonstration of all parts of the process, the hands-on experience with all the raw materials and the ability to witness raw materials at various stages, as well as the transformation in them and the crucibles, was simply invaluable.

Figure 5: Lead Mirror Making at Kapadwanj

Figure 6: Participants at an Abandoned Furnace at Kapadwanj

Field Trips

The conference included two field trips. The first of these was to visit the last surviving workshop producing traditional mirrored glass at Kapadwanj. Ahmed Basir Sisgar, proprietor of the workshop, who had also attended the conference, led the group to his workshop. His workshop continues to operate a large tank furnace from which craftspersons produce blown blooms from raw molten glass, which are coloured with lead and then shattered to various sizes for export and local crafts use, especially in textiles.

The field trip to Kapadwanj (Figure 4 – 6) was especially useful as it brought together many of the complexities which presentations had alluded to: the attrition in capacities for traditional crafts to sustain themselves and reproduce and a first hand sense (for the first time for most participants) of the skill, technical excellence and physical endurance which glasswork demands. In addition, discussions on site led by Dr. Kanungo, stressed the need for a more pro-active and responsible approach to ethnoarchaeological engagement with crafts communities and the need on our part to listen and attend to their challenges, difficulties and collaborate in ways where our own institutional capacities may build more bridges than those which only supplement our research questions. In this spirit, the discussions on site ranged not only from the challenges of working with crafts communities who are operating under pressures of slimming economic margins, their challenges in sourcing raw materials from cullet to *ranga* (processed galena source), and in addition attended through the examples of two abandoned furnaces to the vital questions of learning how to recognize and document in detail the special taphonomic processes that attend to the (mis)recognition of much debated primary glass production in the archaeological record. We are deeply thankful to the Sisgar family for their spirit of collaboration and their openness for this essential component of the workshop.

Figure 7: Field Trip to Excavated Site Vadnagar

The second field trip was to the ASI excavations at Vadnagar (Figure 7), where Dr. Abhijit Ambekar and his team from the Excavation Branch guided the conference participants through the extensive and extraordinarily deep soundings made by the ASI, Excavation Branch- V, Baroda. The group visited not only the ASI camp and its

exhibit of selected results, but were allowed to view and examine the extensive evidence of the Solanki shell working bangle industry which the excavations have detailed at the site from that period (900-1200 CE) which provide the cultural context within which glass enters as a substitute alongside Ivory, in a dramatic shift of media in the medieval period. In addition, the group was taken on an extensive tour of the different localities where excavations have been conducted at the metropolitan site, including the Buddhist monastery previously unearthed by the Gujarat State Department of Archaeology.

Remarks

Glass and glass by-products have gained a reputation of being one of the most important markers of ancient technological complexity, especially in South Asia. Their study is crucial in understanding our past contacts, technology and trade, besides comprehending our ancient mastery over material culture and the procurement of diverse raw materials.

This five days of conference cum workshop involved four days of academic presentations and two field trips, together that covered veritably all aspects of the study of glass. These ranged from the origin of glass and faience, to the manufacturing techniques developed at different times in south Asia and the regional distribution of key artifacts both within and as traded far outside the region. Valuably, the talks also included detailed introductions and extended examples of the analytical chemistry of ancient glasses. Finally, the field trips gave exposure to the contemporary traditional glass working and a world-famous archaeological heritage site of India.

The experts and participants at this truly international event were from eleven countries including United States of America, United Kingdom, France, Italy, Denmark, Cyprus, Poland, Malaysia, Thailand, Sri Lanka, and India. It was gratifying to see that participants represented 54 universities, research institutes, laboratories, museums and state departments.

This conference cum workshop had aimed thus to train manpower in how to study and analyse glass, a material whose study poses many different challenges in diverse contexts. Participants were trained in the chemistry, typology and ethnoarchaeology of glass – none of these are topics that are regularly part of the curricula anywhere in India as specialized subjects. This training extended from seminars and class-rooms discussion, to hands-on exposure to the specific challenges of glass related field-work, in laboratories and in working with craftsmen.

This conference cum workshop proved to be a once in a lifetime experience for the participants. They heard, met and discussed their questions with the eminent personalities of the subject from India and abroad, who have excelled in their fields and today are role models to emulate. The participants were exposed to current research trends, the cutting edge of various methods in the scientific analyses of glass,

and also to the ethnoarchaeological challenges of working with traditional craftsmen and their techniques. Participants directly observed the various process of the glass work and bead making as demonstrated by the craftsmen and artisans from Kapadwanj, Banaras Beads Ltd., Rabari and Miri communities and, Khambat. To facilitate learning, this interaction was fostered both during the workshop at IIT-Gandhinagar and also during the fieldtrip to Kapadwanj.

All of this was topped with the experimental production of faience following the method practiced in 3rd millennium BCE in entire northwest province of Indian Subcontinent. Experimental replication of ancient techniques is an invaluable aid to scientific archaeology, but is rarely conducted in India. Participants not only learned about the oldest vitreous technology in India, but also were trained in the methodology to adopt in such experiments. Additionally, all participants were briefed about the ongoing projects at the ASC through poster- exhibitions.

In summary, all participants got a feel of Archaeological Science and the holistic approach for interpreting the past by immersing themselves in its pursuit for 5 full days. They had been selected on the basis of prior interest in glass and/or ancient Indian technologies, and the course-cum-workshop has made them ready to embark on diverse research projects of their own.

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