CHAPTER-IX

GLASS

The knowledge of making glass was known to ancient Indians as early as the 1st millenium B.C. It was considered to be precious object and hence its occurrence is sporadic.

The review of ancient Indian literature reveals the mention of the word 'Kāça' to denote glass, as found in the Sanskrit and Pali literature. It was mainly used for making glass beads, ornaments, and for the decoration of horses. A study of ancient Buddhist Sanskrit literature reveals the use of glass ornamented shoes and glass bowls as prohibited for Buddhist Bhiksus. Rāmāyana even mentions the word 'Kachakāra' for glass makers. Mahābhārata also refers to Kāça (glass) produced by the action of fire on a special variety of earth. The setting of glass fragments (kṣepana) in gold ornaments has been mentioned in Arthasastra. All these references clearly point out the existence of glass as a material for making various kinds of objects.

The glass technology made a significant progress during the early cent. of Christian era. It was developed as an industry prominently during A.D. 100-300. Glass became a commodity of common use. Now it could be manipulated in different ways from the experience only acquired through past centuries and it is during this period, i.e. A.D. 100-300, the glass craft could take the shape of full-fledged developed industry as is evident from the contemporary literature and archaeological evidences. Many references to glass, and its types, uses and objects are found in contemporary literature. It appears that the working in glass was very popular during this period. Medical treatise 'Caraka' and 'Suśruta Saṁhitā' prescribe the use of glass vessels for preserving medicines, serving food to a cough patient in the vessels of glass, crystal and of cats eye, use of glass salts as an ingredient in a recipe called Muktadya āurna prescribed against cough. Glass has also been suggested in the same text serving as a substitute for better surgical instruments.

The word 'Kāça' and its comparison with jewels is found in Divyāvadāna 'Kāhamāṇyo raṭna sadrish'. Other contemporary texts also refer to the same comparison. Milindapañho refers to 'śisakāra' (man working on glass). The Ācāraṅg Sūtra, a Jain canonical Text, also mentions glass as a prohibited article for the Bhiksus. Silappadikarna even refers to looking glasses.
Glass was a commodity for trade and commerce also. Periplus\textsuperscript{11} gives us very valuable information regarding the trading activity of the glass on the western coast of India, the Persian Gulf and in the adjoining areas. It states that in the B\=arbaricum, located somewhere near the mouth of the Indus, the imports included many vessels of the glass. Pliny's\textsuperscript{12} account regarding the origin of glass and the vitreous substance formed on Nitre blocks used for cooking\textsuperscript{13}, is worth noting. He relates to the fine quality of glass produced in his time in India which was superior to all others, because it was made of pounded crystal. Though this observation was doubted by the scholars but subsequent discoveries have proved beyond doubt that the glass of this period was very rich in its silica content supporting the validity of Pliny's statement. Pliny has also alluded to the use of obsidian glass in India\textsuperscript{14}.

The specimens of glass approximately dated to the contemporary period, have been recovered from about forty different sites all over India. Important sites include - Ahichchatra\textsuperscript{15}, Arikamedu\textsuperscript{16}, Bhit\textsuperscript{17}, Brahmagiri & Chandravalli\textsuperscript{18}, Brahmanabad\textsuperscript{19}, Brahmapuri\textsuperscript{20}, Broach\textsuperscript{21}, Chandraketugarh\textsuperscript{22}, Dharnikot\textsuperscript{23}, Eran, Kausambi\textsuperscript{24}, Kaundinayapur\textsuperscript{25}, Hastinapur\textsuperscript{26}, Maski\textsuperscript{27}, Kumr\textsuperscript{28}, Maheshwar\textsuperscript{29}, Navd\textsuperscript{30}, N\textsuperscript{a}gar\textsuperscript{31}, N\textsuperscript{a}sik & Jorwe\textsuperscript{32}, Ne\textsuperscript{v}\textsuperscript{a}sa\textsuperscript{33}, Prak\textsuperscript{a}sh\textsuperscript{34}, Rairh\textsuperscript{35}, R\=agh\textsuperscript{a}th\textsuperscript{36}, Salue\textsuperscript{37}, Ter\textsuperscript{38}, Tripuri\textsuperscript{39}, Ujjain\textsuperscript{40}, Vai\textsuperscript{a}li\textsuperscript{41}, Paijampalli\textsuperscript{42}, Patn\textsuperscript{a}\textsuperscript{43}, Ra\=ngmahal\textsuperscript{44}, Sopara\textsuperscript{45}, Kopia\textsuperscript{46} and Taxila\textsuperscript{47}.

**OBJECTS**

Various glass objects and their specimens related to the contemporary period, have come to light in the course of archaeological excavations. Following are the important shapes, colours and types of the objects-

(I) Beads

Various types of beads belonging to this period, that reveal differences and similarities pertaining to their shapes, colours and techniques, have been found. (See table 3 pp. 249-250 of this thesis)
A) Types

Wire wounded\(^{48}\), multiple wound beads of opaque glass\(^{49}\), drawn beads\(^{50}\), twisted beads\(^{51}\), cane glass beads\(^{52}\), folded beads\(^{53}\), double strip method beads\(^{54}\), pressed beads\(^{55}\), bead made of spoke, eye beads\(^{56}\), gold foiled beads\(^{57}\), red beads with dark brown core\(^{58}\), millefiori beads\(^{59}\), and composite beads\(^{60}\).

B) Shapes

Many varieties in shapes of glass beads were found from the contemporary period, i.e., square, barrel, square barrel, bicone, globular, hexagonal, cylindrical, lenticular, oval, ellipsoid or oblate, annular, spherical, circular blurred edged beads, long convex, collard, drum-shape, prismatic square, elephant impression, flat disc shaped, cornerless, cubical and eye shaped. (See Pl.XXIII, Fig.1-28)

An analysis\(^{61}\) of these beads brings to notice the fact that the most popular shapes were cylindrical, circular, square with its variations as these shapes have been found from various sites both in North and South. But the most important recovery, assigned to the period c.1st cent. A.D. to c.2nd cent. A.D., is of two different types of beads - One is of ‘Millefiori’ patterned, small blurred lenticular collar shape beads & the other is eye-shaped beads’ from Ahichchatra and Taxila. ‘Eye shaped beads’ were also recovered from Rājghāt and Śrāvasti.

Recovery of lenticular shape beads from Kōhlāpur assigned to c.2nd cent. B.C. to 2nd cent. A.D., in abundance show that there must have flourished a factory of lenticular shaped beads during the Sātvāhana’s at Kōlhāpur\(^{62}\). Oblate shaped beads and hexagonal beads were also popular at Kōlhāpur\(^{63}\), Taxila\(^{64}\) and Ahichchatra\(^{65}\).

C) Colours

Glass beads of this time in India were of different colours i.e. blue and its various shades (sky blue, deep blue, pale blue, greenish blue & turquoise blue, etc.), green and its shades (green amber, light green, deep green, sea green or bluish green), yellow and its all shades, red and its shades (orangish red, copper red, red with dark brown, shellac red, reddish white), opaque, black, white, violet and gold foiled.
Colour and site wise study shows that the widest range of beads of blue and its all shades were recovered only from Taxila. Copper red coloured beads were found from Kausāmbi along with almost all colours beads. Ahichchhatra beads were of a peculiar red and white colour (solely found from here, though all other coloured beads were also found). Gold foiled beads were surprisingly found from almost all sites in India during the contemporary period. In Ujjain, only black and gold foiled beads were recovered. Violet coloured beads were found from Tripuri and Kauśambi only.

The site wise popularity of a particular colour was perhaps due to the differences in the percentage of chemical compositions as verified by their chemical study.

(II) Bangles

Fragments of bangles, both monochrome and polychrome type, plain and designed, have been unearthed from different archaeological contemporary sites in India. It is found that monochrome bangles are more abundant than the polychrome bangles.

The thickness of the bangles was normally about 2.5mm though a few were found with a thickness varying from 3 mm to 6mm.

(A) Monochrome Bangles

The glass used for monochrome bangles was generally translucent and in some cases opaque or brittle with limited range of colours. Only limited decoration was done on these bangles. Specimens from Maheshwar and Navadātoli are mostly yellow and black coloured. The specimens from Raṅgmahal are black and blue in colour. The black specimens also show fine streaks of red glass within them, which might have been fused with black glass in the form of a thin red plastic glass thread. They can be called as bichromes, which have been found from Prakāsh and Ujjain too. The shapes of the specimens are monotonous in character. (See Pl.XXIII, Fig.29).
(B) Polychrome Bangles

These are complicated types of bangles with multicoloured designs and decorations and were unearthed from different excavation sites (See Pl.XXIII, Fig.30). Southern specimens of bangles from Maheśwar and Navadätoli show a varied range of combination of colour designs. In the case of a bangle from Brahmapuri, it was found that possibly two or three thin wires of different coloured glass were first placed on a thick white band of colourless glass, and then polished off to give a smooth surface, so that it gives look of a painting over a white background.

Some bangles of Nevasa show a skillful combination of wires of different coloured glass arranged one above the other and then fused together. In some other specimen, different coloured glass were fixed and fused to the body of a broad bangle surface so as to present an ornamental design. Specimens found from Prakš were also of Polychrome type.

Whether upper surface of bangles was glazed during the period under study is not certain.

(III) Flasks, Bottles and Bowls

Some glass vessels were discovered at Taxila, Ter & Arikamedu, mostly in broken state. Taxila has yielded three complete flasks (See Pl.XXIV, Fig.31) and the upper portion of a glass bottle (See Pl.XXIV, Fig.32). They belong to Śaka-Parthian levels in Sirkāp, possibly of foreign origin. These vessels are sea green and jade green colours and have a gourd shape tapering body with a flattish base. Their rims are fashioned by tooling. Their tall cylindrical neck has a small groove at the base. The bases have pontil marks, perhaps the initial of the owner or maker of the vessel. Besides these flasks, a fragmentary glass bottle from Taxila is noteworthy on account of its Mediterranean parallels.

Marshall has grouped a number of foreign glass objects from Taxila and denotes at least six types of glass -- lac glass, ribbed glass ware, swirled glass ware, blue and white cameo glass ware, mosaic glass and millefiori glass. Two pieces of first type recovered from Sirkāp are the rings of a bowl (dated 1st cent. B.C. & 1st cent. A.D. respectively). The earlier dated specimen (1st cent. B.C.) seems to have been prepared by taking threads of a white and colourless glass
into a spiral. The later\textsuperscript{86} (dt. 1st cent. A.D.) is prepared from canes of blue and white glass altered with cables of black & white. The examples of ribbed ware have been recovered from the \textsuperscript{Śaka-Parthian level at Taxilā.}

Ter\textsuperscript{87} has yielded a flask of agate glass (c.150 - c.200 A.D.). It is conical in shape with a slight omphalos at the base, with a high cylindrical neck and a slightly projecting rim which is damaged. It is about 7 cms. in height and about 5 cm. wide at the base. The neck is about 2.5cm high. The walls are about 3mm. thick all over, somewhat thicker at the base.

Arikāmedu\textsuperscript{88} has supplied the evidences of two fragmentary glass bowls (dt. 1st cent. B.C. - c.2nd cent. A.D.). First specimen (pillar moulded bowl) is of whitish iridescent glass (See Pl.XXIV, Fig.33) and the second ribbed - horizontal bluish green glass, full of bubbles, characteristic of Roman type Glass (See Pl.XXIV, Fig.34).

(IV) Tiles

A floor of glass tiles, recovered from Dharamrājika stūpa at Taxilā\textsuperscript{89} (dt. 4th cent. B.C. to 1st cent. A.D.), possibly made during the reign of Kaniṣṭha, was found to consist of bright azure, black, white and yellow tiles. These tiles are transparent and measure 10-1/4" square and 1/8" in thickness.

(V) Other Glass Objects

Quite a wide range of glass of local manufacture can be seen in Taxilā\textsuperscript{90}. These articles comprise of seals, finger-rings, intaglios, lenses, glass disks and other objects. Minor glass fragments from Sirkāp include the base of an unguentarium\textsuperscript{91}. Most of these have been recovered from \textsuperscript{Śaka-Parthian Strata. Besides these two, plano convex objects of blue glass described as lenses has been recovered from Strata II at Sirkāp. Marshall\textsuperscript{92} thought these to be ornaments for encrustation, though it is difficult to decide the actual use of these objects (See Pl.XXIV, Fig.35).

It is worthwhile to mention here that all the glass specimens discovered from Taxilā were not essentially of foreign make. Glass objects, made locally, were also noticed here. The
discovery of as many as 392 flans of gray coloured glass for making beads from a jewellers shop at Sirkāp⁹³ suggest the local working in glass. A. Ghosh's excavation here also brought to light some beads and bangles made of glass⁹⁴.

Besides, a glass factory site at Kopia near Maidavāl in the Basti district of Uttar Pradesh was noticed. The site belongs to c.300 B.C. - A.D. 300, and has yielded a large number of glass fragments and lumps of unworked glass, fused lumps and sintered glass. Moreover, molten glass on earth platters and crude glass in various stages of manufacture were also found here in great quantity. The site belongs to Kuśāna's time and notably to the period of Kaniśka⁹⁵. All this as well as specimens from Raṅgmahal, Sāmbhar, Ahar, Tripūrī, Maheśwar, Eran and Ter⁹⁶ suggest the existence of highly developed glass industry. Moreover, the fine colour of these glass objects and their low specific gravity suggest that the Indians had good knowledge of the chemical aspects of glass technology⁹⁷.

**MATERIAL & TECHNIQUES**

The literary evidences do not mention any specific material for making glass. However, the chemical analysis of different objects⁹⁸ found from various sites reveals that various raw material like - Silica (SiO₂), Alkalies (Na₂O & K₂O), Calcium and Magnesium oxides (CaO, MgO), Aluminium (Al₂O and SiO₂) Sodium Compounds (NaCl, Na₂SO₄ and Na₂CO₃), Lime, Magnesia etc. were used.

Higher percentage of SiO₂ was noted in general in all Indian specimens which was due to the use of good quality sand, sand stone or quarts, widely distributed throughout India. Higher percentage of alkali was noticed in the specimens found from all Northern sites with addition of K₂O to improve the quality of glass. Higher proportion of Potash, Sodium carbonate and bicarbonate was found in all Indian glass specimens found from Ter, Rājghat, Nāsik, Arikāmedu and Kausāmbī. Aluminium was universal component of all ancient glass specimens, obviously passed into the glass batch from clay and other materials present in sand. A much higher percentage of Aluminium than its limits was noticed from the specimens found from Rājghat, Ter and Nāsik.
Colouring Agents

Based on the analysis of samples found from various sites in India, Caley could classify these four groups of Indian coloured glasses -

1. Glass Coloured with Iron (Fe₂O) and Mangnese (MnO) - In Indian samples in general higher percentage of Fe₂O and lower one of MnO is noticed.

2. Glasses coloured with Iron Fe₂O, Copper and Manganese (MnO) - The colours were also developed by the combined action of Iron and copper oxide and sometimes with manganese as noticed in some specimens of this time.

3. Cobalt in Blue Glasses - Along with Fe₂O, MnO and CuO, cobalt is also seen in some Indian glass objects of Satavahana's time.

4. Lead (PbO) Antimony, Barium and Tin with other oxidase - Lead has been noticed in Indian specimens found from Ter, Arikāmedu and Trīpurī. In Ter, 2.05% PbO is associated with pale green bead and 3.12% PbO with a dark green bead. Arikāmedu specimens contain 0.07% PbO in deep violet and bluish violet glass. Trīpurī specimens contains 3% to 12% PbO to show bluish opaque.

   Presence of Antimony in white opaque and turquoise blue in Taxilan specimens is quite significant and made Lal to comment that the addition of the antimony in appreciable amounts in special glasses was a recent development during 1st cent. A.D. Barium has been detected in the specimens from Trīpurī, Ter and Arikāmedu.

Thus, the main colouring agents appear to be iron, copper, manganese, but cobalt is seen frequently in Sātvāhana beads. Also, nearly colourless and clear Indian glass specimens have rarely come to notice in analysis. No elements like Nickle, Vanadium, Zirconium, Silver, Stronium and chromium has been detected in contemporary specimens, which are commonly found in Modern specimens.
Furnace

Regarding the glass furnace in ancient India, our information is meagre. Glass making kiln\(^{101}\) have been excavated at Nevasa (dt. 3rd-4th cent. A.D.) (See Pl.XXV, Fig.36) and Lothal (See Pl.XXV, Fig.37). The klin at Nevasa, is a circular oven of 2'6" in diameter with 1'7" in depth and is made of burnt clay. Around it was found an abundance of bichrome glasses, stag lime and cow dung etc. C.S. Fox\(^{102}\) remarked that most of the glass furnaces in India were open and fired type using solid fuels.

Glass Pots (Crucibles)

Lumps of glass separately or sticking to clay pieces were found from Kopia\(^{103}\). They were recognised as the parts of a clay crucibles, which might have been used for the heating and melting process. The clay pieces are reddish brown in colour and hard as stone-lime to touch. Perhaps latritic clay was used for making them\(^{104}\).

Tools

The contemporary literary evidences does not speaks much about the tools employed in making these glass objects. On the basis of informations gathered from present day workers of glass industries of different parts of India employing the same techniques, these tools can be enumerated as below. These tools though have different names in different parts of India but essentially their purpose appears to be the same.

1. **Ånkri, Ådhkar, Unkri or upri** - used for stirring the molten glass and taking it out of the crucible.
2. **Åaraṅg, Sallukh or Suja** - Long pointed spit of iron of uniform thickness used for making beads.
3. **Māle, Bālā, Thāpe or Pathia** - A spoon like tool used for moulding and pressing.
4. **Bardhana, Barauna, Bidarka or Unar** - Inserted between the inchoate bangles to prevent its sticking to them.
5. **Chaitarna** - Used for twisting the molten glass for certain kinds of bangles.

6. **Kalchul** - Used to transfer the molten glass from one crucible to another.

7. **Kalbul, Sundar, Sartari** - Used for shaping bangles. It is called in Punjab as Sarbāndī, Sarkaṇḍī these days.

**Tools used for Blowing** (See Pl.XXV, fig.38)

1. **Nāl, Phuṅka or Dhokli** (an iron blow pipe).

2. **Κuṇḍ, Sarhendi** (a solid iron bar which is attached to the bottom of the bubble of glass when blown).

3. **Mālā** (pressing instrument).

4. **Maṣa or Masha** (used for making the rough edge of an article to separate and shape it from the blow pipe).

5. **Chimlā or Amber** (used for placing broken pieces of glass in position in the furnace).

6. **Sikh** (used for stirring the melting glass).

7. **Sil** (slab of stone to put the article).

**TECHNIQUES**

(I) **Beads Making Process**

**Fabrication** - In an container a mixture of powdered quarts or very pure sand with alkali (soda, potash and Nitre) and some lime in quantities is heated to fusion to form a uniform molten mass. Generally before heating colouring agents were added. When all these were thoroughly mixed and melted into a thick syrupy mass, a workman stir it with a iron bar and gathers a viscous mass of red hot glass at the end of bar. Then he fixed another bar in the mass and gives it to second workman, who runs it with full speed, pulling the glass mass out into a rod which is 25 to 35 yards long, half an inch thick near the base and thinning out to perhaps 1/20 of an inch in the middle.
This long rod is then cut down to handy legends of two or three feet. These glass rods or sticks are the raw materials for making the various kinds of beads evolving different techniques, presented below -

(a) *Wire Wounded and Multiple Wire Wounded beads Technique:* To prepare these beads the workmen melts the already prepared glass rods at one end and then fold the soften rod into ring round a copper or iron wire, which they hold in the other hand. When the glass ring is closed round the wire, the rest is cut-off and the wire with the glass ring turned and heated till it is nicely round or oval. When three or five rings have been turned round the wire it is laid aside to cool. In cooling, the metal contracts more than the glass and the beads can be stripped off, especially as the wire has first been turned round in ashes and fine sand. According to the diameter of the wire, a wide or narrow perforation can thus be made in the bead. When the wire tapers, the perforation will also be tapering, which was often the case in the olden days too. The heat was often not strong enough to melt a thick rod of glass and beads were made by binding a rod of 1 to 2mm diameter several times round the tapering wire or other core, a process called multiple winding (See Pl.XXV, Fig.39).

(b) *Drawn Beads Technique*\(^{105}\): These beads were prepared from tubes of 2 to 5mm in length drawn out from molten glass containing an air-filled cavity. The tubes turned out cylindrical beads while still hot and soft and were rounded at their edges to give them ellipsoid or oblate shapes (See Pl.XXV, Fig.40).

(c) *Twisted Beads Technique*\(^ {106}\): A small lump of molten glass is taken on a thin wire and is rotated briskly till it acquired the desired shape.

(d) *Cane Glass Bead Technique*\(^ {107}\): For making these beads, long threads were pulled out and bundled together in a requisite shape. At the time of finishing, these beads were subjected to a heat treatment so as to produce a uniformly even surface. At Prakash, the distinctive technique of perforation by a poker in these beads is evident.
(e) *Folded Beads Technique*[^108]: These beads were made from flattened rods of glass, folded round a wire in the same way as wire wounded beads.

(f) *Double strip method*[^109]: Two pieces of molten glass are pressed against each other with a small rod in between them and cut-off to the required shape of the bead.

(g) *Pressed Beads Technique*[^110]: Using half molten glass under pressure, beads of all shapes with flattened end can easily be prepared.

(h) *Beads made on spoke*: On a comparatively thick spoke, small masses of semi-molten glass are dropped on an earthen platter and then pierced with a pointed spoke, lifting the whole mass from the platter, which shows a blurred edge.

(i) *Eye Beads Technique*[^111]: In making such beads, layer of different colour glasses were overlaid on a matrix resembling the shape of an eye, which is surrounded by marginal rings in white.

(j) *Gold foil Beads*[^112]: A layer of gold foil is pressed on a glass matrix when hot and is laid over again with another coating of transparent glass. The most prolific period for the use of this technique was c.100 A.D. - c.300 A.D.[^113]

(k) *Red beads with dark brown core*: These were made by turning a white tabular matrix of white opaque glass found round wire and by applying a thick coating of translucent ruby glass over this matrix.

(l) *Millefiori Beads Technique*[^114]: Composite canes of coloured glass rods were cut across for revealing a design (Mosaic Glass). Pieces of such canes could be arranged side by side to produce repetitive patterns.

(m) *Composite Beads Technique*: It was a difficult process where two glasses required the same co-efficient of expansion and thus marks a definite advancement in making of glass beads.
(II) Bangles Making Process

For preparing plain bangles, few blocks of crude glass are laid on the floor of the furnace almost in contact with the fire. After being heated for a few minutes, they are thrown into a basin of cold water when they break up into small pieces. These are then transferred into crucibles containing half molten glass along with colouring matter as may be required. When thoroughly fused, the mass is transferred into a second crucible for complete melting. The workman then dips the end of an iron hook (ankuri) into the molten glass and takes out a small ball of glass enough for one bangle. This he winds up on the end of an iron spit (sallukh) into a thick irregular ring. He then takes up a dagger-shaped tool (mālā), and resting the end of the iron spit, around which the glass ring is wound up, on a stone slap (pṛṭī) squeezes the ring with the help of the dagger shaped tool till it is partially cooled. The ring is then detached from the spit by means of an iron wire (barhora) to which it is then removed. From the end of the iron wire, it is transferred to the tip of a tapering clay cone (kalbut). The workman then holds the clay cone towards the opening of the furnace, pressing the thin handle of the iron wire between his open palm and the surface of the stone slab in such a way that the clay cone is slanted upwards towards the furnace. In his other hand, he holds the iron wire which is inserted between the clay cone and the glass ring. Next, by rubbing his open palm against the handle beneath it backwards and forwards over the stone slab he causes the clay on to spin rapidly round, and the glass ring upon its tip becomes gradually enlarged and slips down to the broad base of the cone until it has grown to the size of a bangle. It is then slipped off and thrown to cool in to the pit between the stone slab and the furnace.

Monochrome bangles of this period reveal a marked technical evolution in respect of their decorations, like incised dots and vertical short line, which might have been done by revolving the bangle around some rouletting mechanism.

Perhaps craftsmanship found its zenith in making of bichrome and polychrome bangles, where wires of plastic glasses were possibly placed one over the other and subsequently fused to show vertical bands of various colours, or by wire of various colours or by wire of different coloured plastic glass were possibly twisted to give rise to a spiral pattern. In some other, small
lumps of colourless plastic glass were possibly laid over the surface of a differently coloured bangles to show a design of eye or dots. In some other cases, differently coloured glasses were fixed and fused to the body of a broad bangle surface so as to present an ornamental design.

Perhaps the technique of glazing the upper surface of bangle was not in use during this period.

(III) Process of Making Vessels and Tiles

Moulding

By this time moulding became most common and most popular mode of shaping glass. It was mainly employed for making heavier objects like ear reels, vessels and large objects like tiles.

For preparing vessels, the glass cables were pressed inside a mould probably by coiling and then heated for conjugation into solid mass and sometimes the wares were made in imitation of metal repousse and from the moulds designed for the purpose. The moulding appears in high relief over the flush surface of the glass which generally takes the shape of pillars and hence the glass vessel is often called pillar moulded.

The material for these moulds is not specified but, perhaps sand moulds were used, as they can be destroyed when the objects enclosed in them were extricated. Some of them were made of red sand stone. These moulds were also used by goldsmiths for repousse work in the metals.

Blowing

The most revolutionary development ever made in the history of glass ware was blowing invented towards the end of 1st cent. B.C. The technique began by blowing glass into a mould and then developed into free blowing. The vessels from Taxilā indicate about the use of this newer and highly developed technology. This was made by taking canes made of threads of white and colourless glass, which had been twisted together so as to from a spiral and then winding the
canes, when plastic, round the inside of a mould and fusing them together with heat and pressure. To form the rim a piece of blue and white glass was used. This method was employed extensively by the Romans to produce lac glass wares\textsuperscript{118}.

**Annealing**

Some glass articles require annealing, i.e. removal of strains, which is effected by allowing the highly treated prepared articles to cool slowly to a lower temperature of about 500°C. Though the use of this technique is not recorded in general in India during this period, but the large tiles found from Taxila\textsuperscript{119}, which require a good knowledge of moulding as well as annealing, show that such high order of technical skill was perhaps introduced in India approximately during A.D. 200-300.

Literary evidences show the trade relations between the West and India, as reflected in the writing of foreign writers\textsuperscript{120}. Discoveries have proved beyond doubt that the Indian glass of this period was generally very rich in its silica contents\textsuperscript{121}. Pliny and Warmington record that glass was first produced in Phoenicia and was widely used in Egypt, where the technique was generally highly developed\textsuperscript{122}. Later the industry flourished in Italy during the first cent. A.D. Glass articles from all these places are reported to have been exported to India.

Fragments of pillar moulded bowls found from Arikamedu have a striking similarity with those originated apparently in Italy and spread throughout the Roman world from the end of the first cent. A.D. According to Marshall\textsuperscript{123} the glass vessels and fragments of glass vessels found at Taxila were undoubtedly of foreign origin. Nearly all these specimens date from the 1st cent. A.D. The method by which it seems to have been manufactured was employed extensively by the Romans and many such specimens have been recovered at Pompeii and other sites in Rome. Other glass objects were also produced at various places in the Mediterranean area, and have been also found in India at Taxilā, which suggests the foreign import of these items. Besides the vessels, 'eye beads' from 'Taxilā' are virtually identical with those found around the Mediterranean area, dating from 9th to the 3rd cent. B.C. From their close resemblance it appears that these beads were actually made in the Mediterranean area or at least by men who came from that area, or who
had learnt how to make them from the workmen from the Mediterranean countries. Regarding the ‘gold foiled glass beads’ and Millefiori beads’ found from all-over India, Back\textsuperscript{124} is of the opinion that they have great resemblance with Roman beads. Hence, they are either of foreign make or made by the Indian workmen who learnt the techniques from the Roman experts.

A considerable number of amber coloured beads and a still larger number of minute yellow and orange colour beads from Ṣaka-Parthian settlements also suggest that by the 1st cent. A.D., local glass makers had learnt the technique to produce these colours also. On the other hand several beads of rarer colours, (cobalt, pale blue, peacock blue, cream and violet) appeared for the first time in India, in the Ṣaka-Parthian time, were in all probability imported from the Mediterranean coast along with other glass vessels or produced by Indian glass craftsmen, who perhaps have learnt it by them.

In view of the fact that the colours of glass vessels, discovered from Taxilā, Arikāmedu and Ter, are identical with those used in the beads, it is natural to believe that the beads came from the same sources as the vessels\textsuperscript{125}.

Of-course, in the period between c.200 B.C. - c.200A.D. there was a filtration of foreigners into India through land and sea routs and specimens found from Taxilā, Arikāmedu, Nevāsa, Ter and other sites provide evidences of Indian cultural contacts with the Roman world\textsuperscript{126}. However, it is essential to know here that all glass specimens discovered from these places were not essentially of foreign make. Many glass objects, made locally at these places and other sites of India during this period, are also noticed\textsuperscript{127}. Moreover, findings of Indian glass beads specially wounded and drawn beads of opaque glass in East Africa on the west, as well as in Japan, Sumatra and Malāya Peninsula show that Indian glass industry found its way into many contemporary cultures as a result of ever expanding Roman trade during this time.

Thus, it can be concluded that though Roman glass objects appear in Taxilā but it was about the beginning of the Christian era that the knowledge of glass blowing reached India and attained its peak. The techniques of making ‘eye beads’, millefiori beads’ and prolific use of ‘gold foiled beads’ were introduced in India. The contacts with Rome, in ancient India, might have
introduced new practices in technology. Working in the glass during this period was thus influenced by foreign ideas and practices. In no other period in ancient India did glass making make such progress as it did during this period.

Findings at Taxilā show that city was directly in touch with Rome and the Mediterranean countries through trade contacts but it is wrong to suppose that all the articles of glass made there were the work of foreign artisans as favoured by Marshall. From the other artifacts of glass found from other sites in India (e.g. excavations at Kopia, Ter, Nevāsa etc), it would be seen that glass technology was known to Indians to this period. Literacy references and actual specimens prove this conclusion.
Table 3

Physical properties of glass objects recovered from various important sites

<table>
<thead>
<tr>
<th>Sites</th>
<th>Dates</th>
<th>Objects</th>
<th>Colours</th>
<th>Shapes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Taxila</td>
<td>c. 400 B.C. - c. 100 A.D.</td>
<td>a. Bhir Mound</td>
<td>Beads, Seals and Pendants, Bangles</td>
<td>Blue, Green, Yellow, Red and Turquois, Green and Black Lenticular, tabular, spear shaped and various other shapes with Scorebold shape.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Sirkōp</td>
<td>Beads</td>
<td>Blue, Red, Yellow, Black, Sea-Green, Yellow, blue Spherical, Gadrooned, Oblate, Barrel, Cylindrical, Collared, Hexagonal, Granulated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bangles</td>
<td>Pale &amp; Dark blue</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glass Rings</td>
<td>Green amber &amp; Pale Blue, Blue etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bottles and Flasks</td>
<td>Sea Green and Jade Green</td>
</tr>
<tr>
<td>c. Sirsukh</td>
<td>c. 400 B.C. - c. 500 A.D.</td>
<td></td>
<td>Beads</td>
<td>Blue, Black, Red, opaque, Turquoise</td>
</tr>
<tr>
<td>d. Dharmarajika Stūpa</td>
<td>c. 200 A.D. - c. 500 A.D.</td>
<td></td>
<td>Beads</td>
<td>Blue, Green Black, Yellow, White, Amber, Shellac red etc.</td>
</tr>
<tr>
<td>2. Hastinapur</td>
<td>c. 400 B.C. - c. 500 A.D.</td>
<td></td>
<td>Beads</td>
<td>Black, Deep blue and Blue</td>
</tr>
<tr>
<td>4. Anikāmedu</td>
<td>c. 400 B.C. - c. 500 A.D.</td>
<td></td>
<td>Beads</td>
<td>Blue &amp; Green</td>
</tr>
<tr>
<td></td>
<td>c. 200 A.D. - c. 500 A.D.</td>
<td></td>
<td>Bangles, Bowls</td>
<td>Amber, Blue &amp; Black, White and Yellow</td>
</tr>
<tr>
<td>5. Bṛha</td>
<td>c. 200 B.C. - c. 500 A.D.</td>
<td></td>
<td>Beads &amp; Bangles</td>
<td>Blue, azure, Blue, Black &amp; Green etc.</td>
</tr>
<tr>
<td>8. Brahamapurt</td>
<td>c. 200 B.C. - c. 500 A.D.</td>
<td></td>
<td>Bangles &amp; Beads</td>
<td>Different</td>
</tr>
<tr>
<td>9. Broach</td>
<td>c. 100 A.D. -</td>
<td></td>
<td>Beads</td>
<td>Various colours</td>
</tr>
<tr>
<td>10. Čāḍraketugāth</td>
<td>c. 200 B.C. - c. 500 A.D.</td>
<td></td>
<td>Beads</td>
<td>Various colours</td>
</tr>
<tr>
<td>11. Devnāmonore</td>
<td>c. 200 B.C. - c. 500 A.D.</td>
<td></td>
<td>Beads</td>
<td>Blue</td>
</tr>
<tr>
<td>12. Dhamikotā</td>
<td>c. 200 B.C. - c. 100 A.D.</td>
<td></td>
<td>Various objects</td>
<td>Various colors</td>
</tr>
<tr>
<td>13. Eran</td>
<td>c. 200 A.D. - c. 300 A.D.</td>
<td></td>
<td>Beads &amp; Bangles</td>
<td>-do-</td>
</tr>
<tr>
<td>14. Kauṣāmbī</td>
<td>c. 200 A.D. - c. 300 A.D.</td>
<td></td>
<td>Beads</td>
<td>Opaque, Blue, Bluish, green, Black, Copper red &amp; Violet</td>
</tr>
<tr>
<td>15. Kauṇḍinyaśpur</td>
<td>c. 200 B.C. - c. 300 A.D.</td>
<td></td>
<td>Beads, Earplugs &amp; Bangles</td>
<td>Different</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>----------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>17. Mahēdwār</td>
<td>Beads, Bangles &amp; Seal</td>
<td>Various colours</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>18. Navadvīpoli</td>
<td>Beads &amp; Bangles</td>
<td>Various colours</td>
<td>Flat, Circular &amp; Globular</td>
<td></td>
</tr>
<tr>
<td>19. Nāgar</td>
<td>Beads</td>
<td>Yellow &amp; its shades &amp; various others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Nāsk &amp; Jorwe</td>
<td>Beads</td>
<td>Yellow &amp; its shades, Green &amp; white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Nevasa</td>
<td>Beads</td>
<td>Different colours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Prakṣh</td>
<td>Bangles</td>
<td>Polychrome - Various colours</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>23. Rainh</td>
<td>Beads</td>
<td>Polychrome &amp; Bichrome</td>
<td>Club like, Spherical, Square, pendant barrel like</td>
<td></td>
</tr>
<tr>
<td>24. Rāighāট</td>
<td>Beads</td>
<td>Different Polychrome type</td>
<td>Different</td>
<td></td>
</tr>
<tr>
<td>25. Sulur</td>
<td>Beads</td>
<td>Whitish, Blue with white opaque, Green Black etc.</td>
<td>Barrel &amp; Circular</td>
<td></td>
</tr>
<tr>
<td>26. Ter</td>
<td>Beads</td>
<td>Whits &amp; its shades &amp; various others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. Tīpurī</td>
<td>Beads</td>
<td>Agate glass colour</td>
<td>Conical shape with a slight Omphalos at the base, High cylindrical neck and slightly projecting rim.</td>
<td></td>
</tr>
<tr>
<td>28. Ujjain</td>
<td>Beads</td>
<td>Orange red, Gold trolled, Black &amp; Groove coloured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Vaśāli</td>
<td>Beads</td>
<td>Blue, Green, Dark red, Bluish green, Orange &amp; Opaque</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. Ahichchhatra</td>
<td>Beads</td>
<td>Blue, Green, Dark red, Bluish green, Orange &amp; Opaque</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>31. Paliyampalli</td>
<td>Beads</td>
<td>Different Polychrome</td>
<td>Different</td>
<td></td>
</tr>
<tr>
<td>32. Patnā</td>
<td>Beads, Bangles Five glass seals</td>
<td>Different Blue, Green</td>
<td>Different Square</td>
<td></td>
</tr>
<tr>
<td>33. Rāngmahal</td>
<td>Bangles</td>
<td>Monochrome &amp; Polychrome, Black &amp; Blue</td>
<td>Monotonously circular</td>
<td></td>
</tr>
<tr>
<td>34. Sopara</td>
<td>Beads</td>
<td>Black &amp; Blue</td>
<td>Different</td>
<td></td>
</tr>
<tr>
<td>35. Kopīa</td>
<td>Glass fragments, lumps of unworked glass and sintered glass</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES

1. Śat. Br., XIII, 2. 6. 8. Taitt. Br., 3. 9. 4. 4-5 and Yajurveda, K.K.S.B.9; Mahāvagga V. 8. 3. Ču., V.91.

2. ibid.


4. Mb., iii, 185, 3.

5. Aś., B. II, Ch.II, p.35; B.II, Ch.XIII, p.44; ibid. p.46; B.III, Ch.III, p.8; B.XXV, Ch.II, p.23; B.VII, Ch.XVII, p.57.

6. Č.S., ci. 18. 125, Ś.S., Śū, 8.12.

7. Dv., i, 250, 503; ii, 142, 438.

8. Saddharma Puṇ., II, 84; and Saundānanda, IV, 13.


10. Ā. Śū., 2.1.6.1., Su, 375; SBE, 22, I, 166-67.


14. ibid, XXXVI, 65.


16. ibid, 60-61.

17. ASIAR, 29, 94, (1911-12).

18. ibid.

19. ASIAR, (1908-09) 82.


22. ibid, (1962-63).8

23. ibid, (1963-64)2.

30. ibid, 180.
33. Sankalia, H.D. and others, From History to Pre History at Nevāsa, (1960-61).
34. Thapar, B.K., and others, Prakash, 109. AI, Nos. 20-21.
35. Puri, K.N., Excavation at Rairh, Jaipur, 41.
40. IAR, (1956-57), 27; (1957-58) 36.
45. Dikshit, M.G., History of Indian Glass, p.47.

50. ibid.


52. ibid, Beads No. 201-202.


54. Dikshit, M.G., op.cit, Bead No. 206, 209.


56. ibid.

57. Lal, B.B., 'Examination of some Ancient Indian Glass Specimens' AI, No. 8, 17, p.57-58; Sankalia, H.D., and others; From History to Pre-history at Nevasa, p.355; Sankalia, H.D. & Dikshit, M.G., op.cit, p.101.

58. Dikshit, M.G., some beads from Kondapur, HAS, No. 16. 1952, Beads No. 212; Sankalia, H.D., and Deo, S.B., op.cit, 89.

59. Dikshit, M.G., Beads from Ahichchhatra, 57 & 60.

60. ibid.


62. ibid, p.154.

63. ibid.


68. Dikshit, M.G., op.cit, 55-60.


70. IAR, (1956-57) 27 (1957-58) 36.

72. See for details Sen, S.N., Chaudhary, M., op.cit, Table XXI, p.120-121.
73. ibid, p.160.
74. ibid.
75. Sankalia, H.D., and others, op.cit, p.216.
77. Thapar, B.K., Prakāsh, 109.
81. Sankalia, H.D. and others, op.cit, 447.
82. Thapar, B.K., op.cit, p.109
84. ibid, 688-89.
85. ibid.
86. ibid.
87. IAR, (1964-68), 35.
90. ibid, p.685.
91. ibid.
92. ibid.
93. Dikshit, M.G., History of Indian Glass, pp.31-32.
94. AI, No. 4, pp.73, 80; Nos. 10-11, pp.90, 92-4.
96. ibid, pp.36-44.
97. AI, No. 8, p.17.
99. Caley, R., op.cit,
106. Dikshit, M.G., Some beads from Koṇḍāpur, Beads No. 208.
107. ibid, Beads No. 201-202.
109. ibid, p.207.
110. ibid.
113. Dikshit, M.G., History of Indian Glass, p.57.
117. Many examples of these moulds were found at Ter, Paithan, Koṇḍāpur and Prakāsh (bangle moulds) (See for details Dikshit, M.G., op.cit, p.55).
120. Pliny, N.H., XXXVI 65.67; Schoff, (ed.) op.cit, p.39-49.
121. Sen, S.N. and Chaudhary, M., op.cit, p.112 and Table No. XIX for recording the high percentage of silica in contemporary Indian glass specimens.


