TECHNICAL SECTION

EXAMINATION OF RODS OF GLASS-LIKE MATERIAL FROM ARIKAMEDU

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CONTENTS

1. INTRODUCTION

THE excavation of the ancient site of Arikamedu, located on the Coromandal coast near Pondicherry in south India, yielded a large number of rods of glass-like material.[1] Recently, several specimens of similar rods from the same site were sent to the author by the Government Museum, Madras, for investigation into the composition of the raw material, particularly because, though the material seems to have been used for the manufacture of beads, the rods look so much like twigs that an opinion has been expressed that they might be fossil-wood and not glass, this suggestion receiving support from the fact that very near Pondicherry a large number of beds containing fossil-wood are found.[2] The present investigation was, therefore, undertaken with a view to determining the true nature of this material by microscopic examination and chemical analysis.

2. DESCRIPTION OF THE SPECIMENS

Most of the rods range from 2 cm. to 2·4 cm. in length, with a few specimens of larger dimensions, the longest being 4·6 cm., and have fine threading holes, which suggest that they were meant to be used for the preparation of perforated beads. In fact, they

[1] R. E. M. Wheeler, A. Ghosh and Krishna Deva, 'Arikamedu: an Indo-Roman trading-station on the east coast of India', *Ancient India*, no. 2 (1946), pp. 17-124.

[2] Information from Dr. A. Aiyappan, Superintendent, Government Museum, Madras.

have been described as long cylindrical circular glass beads.[1] Some are, however, solid without any holes, and several have been found to possess a core of sand. They are of various colours—olive-green, bottle-green, cobalt-blue, greenish-blue and brick- and liver-red. Most of them are opaque, but a few are transparent. Some show a whitish deposit on the surface, evidently the result of weathering caused by prolonged burial in the soil. Pl. LXII A shows some of the typical specimens.

3. EXPERIMENTS

A. Physical tests

Physical tests, such as refractive index determination, specific gravity measurements and hardness tests, were carried out on a very large number of the specimens. The refractive index (measured by Becke-Method) ranges between 1·4996 and 1·5383. [The refractive index of soda-lime glass is 1·53, that of quartz varies from 1·5442 to 1·5533 and of chalcedony and opal from 1·531 to 1·539 and from 1·40 to 1·46 respectively.]

The above data show that the refractive index of the specimens under examination is much higher than that of opal but is distinctly lower than that of quartz and approaches that of chalcedony; but that they are not chalcedony will be shown later. It is, therefore, obvious that they do not represent fossil-wood, as otherwise they should have conformed to the properties of opal and chalcedony, which produce fossils as a replacement of wood and other organic materials.

Specific gravity determinations have been carried out at a room-temperature of 25°C. on twentyseven specimens. The results are detailed in the Table on p. 141.

From the Table it is seen that with the exception of numbers 1, 2, 4, 18, 19, 23 and 25, which have a specific gravity higher than that of quartz, the specimens have a lower specific gravity ranging between 2·51 and 2·63. [The average specific gravity of soda-lime glass is 2·5.]

It, therefore, follows that although most of the specimens are lighter than quartz, their specific gravity is generally higher than that of soda-lime glass. Density, however, being a function of the molecular weight of the components of glass and varying over a large range, these results indicate that the material of which these rods are made is not quartz but is akin to glass. The higher density caused by the composition of the specimens suggests higher silica, lime and alumina content. The vitreous lustre and conchoidal fracture exhibited by the specimens also indicate their glassy nature.

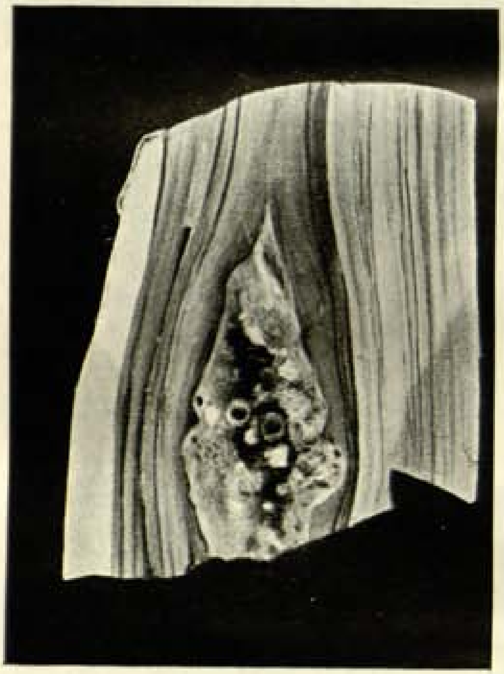
The hardness of the specimens has been determined by using Mohs' scale of hardness. Generally, their hardness varies from 5 to 7; they are thus harder than modern window-glass. The hardness of a very large number is, however, distinctly below 7, the hardness of quartz. The specimens are, therefore, not composed of chalcedony or silica. The wide variation in hardness seen in the specimens is not surprising, as it is determined by their chemical constituents. It may be emphasized that although hardness and resistance to abrasion are important characteristics of glass, they are determined by the composition of individual specimens. The higher the proportion of silica, alumina and lime, the harder is the glass. High alkali content reduces the hardness, and soda-lime glasses are generally harder than potash glasses of the same composition. Moreover, the hardness of glass

[1] Wheeler and others, *op. cit.*, p. 101.

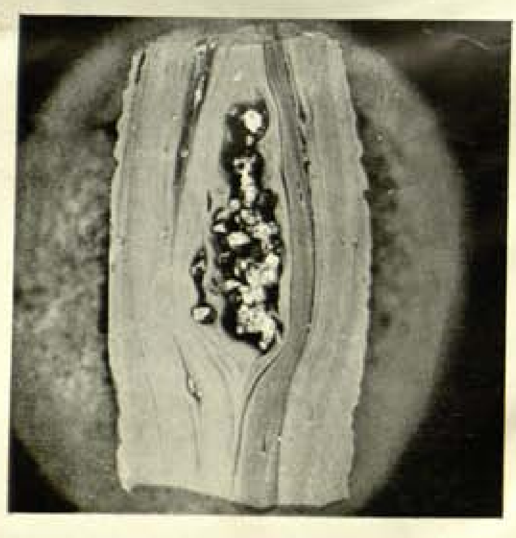
A. *Specimens of rods of glass-like material from Arikamedu* ($\times\frac{3}{2}$). *See page 140*

B. *Thin section of a specimen in ordinary light* ($\times 30$). *See page 142*

C. *Same as* B, *between crossed nicols* ($\times 30$). *See page 142*



A. *Thin section of a specimen in reflected light showing signs of flow* ($\times 6$). *See page 142*



B. *Polished cross-section of a specimen under reflected light showing sand-core and flow of glass* ($\times 6$). *See page 142*

C. *Thin section of a liver-red specimen in ordinary light showing grains of colouring matter* ($\times 70$). *See page 142* also depends on the heat-treatment to which the glass is subjected after working. Poor annealing and uncontrolled cooling at a high rate increase the hardness of glass. The variation in hardness shown by the specimens is, therefore, not unexpected.

TABLE SHOWING THE SPECIFIC GRAVITY OF THE SPECIMENS

Nature of specimens	*Serial no.*	*Specific gravity*
Green opaque specimens	1	2·91
	2	2·77
	3	2·60
Green transparent specimens	4	2·74
	5	2·57
	6	2·52
Red opaque solid specimens	7	2·55
	8	2·64
	9	2·51
	10	2·58
	11	2·54
	12	2·54
	13	2·60
	14	2·54
	15	2·58
Red opaque perforated specimens	16	2·54
	17	2·63
	18	2·65
	19	2·70
	20	2·54
	21	2·59
	22	2·63
	23	2·72
	24	2·61
	25	2·67
	26	2·59
	27	2·57

B. Chemical analysis

The glassy nature of these specimens has been further established by chemical analysis. In a typical analysis, the alkali percentage was found to be 13·22 which agrees with the alkali content of common glass.

C. Microscopic examination

That the specimens are not fossilized wood has also been established by microscopic examination. Thin sections of several specimens were prepared in accordance with the standard method used in petrological examination of rocks. Leitz Panphot universal microscope was used for microscopic examination of the specimens in transmitted and reflected light. Under the microscope, the specimens do not show any trace of plant-structure. A thin section prepared out of a small solid specimen shows in transmitted light a core surrounded by glassy material.

The grains of the core are anisotropic, but the surrounding material is perfectly isotropic between crossed nicols, as seen in photomicrographs (pl. LXII B and C). Had the specimens been composed of fossilized wood, the material would have been anisotropic and cellular structure of wood preserved in opal would have been present, and an aggregate structure would have been seen between crossed nicols (indicating chalcedony). Actually, however, only the core shows some anisotropic grains of quartz and the remaining material is completely isotropic.

A thin section prepared in the above manner was microscopically examined in reflected light. The core of sand is very clearly seen in the photomicrograph (pl. LXIII A), surrounded by compact glassy material having wavy bands of a differently coloured material.

A solid specimen was cut across, and the freshly-cut surface was carefully polished for examination under reflected light. The result is shown on pl. LXIII B. The photomicrograph shows the inner core of grains of sand (light-coloured grains) surrounded by a compact material having wavy bands of a differently-coloured material. Had the specimen been composed of fossilized wood, the cellular structure would have been uniform throughout the surface. The presence of the wavy bands can be accounted for only by the fact that the material had been drawn out in the form of tubes in the molten condition. These wavy bands, therefore, represent flow-lines exhibited by glass.

D. Colouring matter

That the material of the rods is artificial glass and not fossilized wood is further proved by an examination of the colouring matter of the specimens. The specimens show different colours, green, blue and red, and these colours have been found to be due to metallic oxides. Fossilized wood is not likely to show such colours. For example, one brick-red specimen has been found to contain oxide of copper. A thin section of this specimen was examined in transmitted light at a magnification of 70. Pl. LXIII C shows the structure so observed: numerous grains of opaque material (dark specks) are seen disseminated in a glassy matrix. They appear red under reflected light. The colouring material has further been chemically identified to be red oxide of copper (cuprous oxide). That is it not metallic copper has been established by silver sulphate-sulphuric method of Fitzpatric.[1] For this purpose, the specimen was reduced to a fine powder, which was digested with silver sulphate and then filtered. The filtrate was found to be free from copper. This shows that the specimen contained cuprous oxide but was free from metallic copper. It is, therefore, clear that the colouring matter of the specimen is cuprous oxide, which imparts a brick-red to liver-red colour to the specimens.

The green colour of the specimens has been found to be due to copper and iron and the blue to cobalt.

[1] W. W. Scott. *Standard Methods of chemical Analysis*, 5th ed. (Lancaster, 1939) I, p. 394.

4. TECHNIQUE OF MANUFACTURE

In the early stages of the development of the glass-industry and the manufacture of glass objects, sand was used as a core around which molten glass was moulded for the preparation of the desired object. The art of moulding glass has been traced back in India to about fourth to third century B.C.[1] It is probable that this technique was adopted by the glass-workers of Arikamedu for the manufacture of glass beads, etc.

5. CONCLUSION

The rods of glass-like material unearthed at Arikamedu have been found to be composed of glass. Various metallic oxides have been used for producing glasses of different colours. The suggestion that these rods are fossilized twigs has been found to be untenable.

[*Received on the 11th March 1958.—Ed.*]

[1] B. B. Lal, 'Examination of some ancient Indian glass specimens', *Ancient India*, no. 8 (1952), pp. 17-27.

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